Organic farming, food quality and human health

A review of the evidence

Contents

The birthright of all living things is health. This law is true for soil, plant, animal and man: the health of these four is one connected chain. Any weakness or defect in the health of any earlier link in the chain is carried on to the next and succeeding links, until it reaches the last, namely, man.

The widespread vegetable and animal pests and diseases, which are such a bane to modern agriculture, are evidence of a great failure of health in the second (plant) and third (animal) links of the chain. The impaired health of human populations (the fourth link) in modern civilised countries is a consequence of this failure in the second and third links.

This general failure in the last three links is to be attributed to failure in the first link, the soil: the undernourishment of the soil is at the root of all. The failure to maintain a healthy agriculture has largely cancelled out all the advantages we have gained from improvements in hygiene, in housing, and medical discoveries.

To retrace our steps is not really difficult once we set our minds to the problem. If we are willing to conform to natural law, we shall rapidly reap the reward not only in a flourishing agriculture, but in the immense asset of an abounding health in ourselves and in our children's children.

Sir Albert Howard (1945)

Preface

Record numbers of people are now eating organic, and many of them are doing so because they feel intuitively that they are making a more natural and healthy choice. This report assesses the evidence behind that intuition.

Sir Albert Howard, whose research in the 1930s did much to inform the development of organic farming and inspired the foundation of the Soil Association, believed the health of the soil, plants, animals and people was 'one and indivisible'. But how much evidence is there to validate the hypothesis that farming methods have an important effect on the nutritional quality of the food we eat?

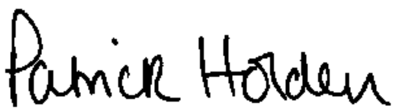
This report examines over 400 published papers considering or comparing organic and non-organic foods in relation to key areas of food quality important to the promotion of good health – food safety, nutritional content and the observed health effects in those consuming food. It points out that organic standards specifically prohibit the use of certain additives and manufacturing processes linked to health concerns such as osteoporosis and heart disease, and argues that there are no grounds for complacency about the long-term effects of pesticides and additives on our health. It asserts that there is indicative evidence suggesting nutritional differences between organic and non-organic food. More research is needed, it emphasises, but if the indications of the available evidence are confirmed there could be major implications for public health.

These conclusions are sure to be controversial. They contradict Sir John Krebs of the Food Standards Agency, who said in August 2000 that "there is not enough information available at present to be able to say that organic foods are significantly different in terms of their safety and nutritional content to those produced by conventional farming". Sir John's comments rather echo those of the critics of the mid-1980s who said there was no evidence to justify the Soil Association's decision to ban animal protein from feed for organic livestock. Within a few years Britain's non-organic herds were being ruined by BSE, and the scientific evidence linking the disease with feed was all too abundant.

It is almost as if consumers have become laboratory animals in the huge experiment that is industrialised agriculture, storing up untold health problems for the future. Chemicals such as DDT and lindane have been banned after the initial dismissal of safety concerns. Research in animal feeding trials has indicated that health effects often only reveal themselves over long time spans, sometimes even over successive generations. So the evidence presented in this report showing nutritional differences between organic and non-organic foods should not be lightly dismissed. Nor should the food safety issues raised. The organic movement has repeatedly advocated the precautionary principle, questioning practices that violate the natural cycle and represent a potential threat to health.

It would be easy to criticise this report, as some surely will, on the grounds that the Soil Association is a partisan organisation. However in the midst of a distinctly ill-informed debate, we have taken responsibility for bringing together the existing evidence and subjecting it to closer scrutiny than ever before. A number of scientists, organisations and experts in the fields of medicine, nutrition and organic research have endorsed our findings and recommendations and I urge you to read the report for yourself and draw your own conclusions.

Organic Farming, Food Quality and Human Health complements the strong environmental arguments for going organic presented in our previous report, *The Biodiversity Benefits of Organic Farming*. It is a compelling and challenging contribution to an important debate, which I hope will help all food producers to deliver healthier food, and enable consumers and governments to make informed choices in this time of crisis for our agriculture.



Patrick Holden
Director, Soil Association

Executive summary

Key findings

A comprehensive review of existing research reveals significant differences between organically and non-organically grown food. These differences relate to food safety, primary nutrients, secondary nutrients and health outcomes demonstrated by feeding trials.

Food safety

- *Pesticides*
  Nearly all pesticides are prohibited in organic farming and residues are rarely found. By contrast, a high incidence of pesticide residues occurs in non-organic foods, and there is growing concern about the 'cocktail effect' of multiple residues on human health.
- *Food poisoning*
  There is no evidence linking organically produced foods with an increased risk of food poisoning. A recent survey gave organic food a clean bill of health and confirmed expectations that organic methods, such as careful composting of manure, minimise pathogenic risks.
- *GMOs*
  Genetically modified organisms (GMOs) and their derivatives are prohibited in organic production. There is currently insufficient published evidence to reach any definitive conclusions regarding the safety of genetically modified foods for humans, although negative health effects have been observed in animal trials.
- *Antibiotics*
  The routine, growth promoting or prophylactic use of antibiotics is prohibited in organic standards for animal husbandry. There is growing concern over the risk to human health from antibiotic resistance developing in micro-organisms partly because of the misuse and overuse of antibiotics in livestock rearing.
- *BSE and vCJD*
  No record has been found of any case of BSE, suspected of being linked to new variant CJD in humans, in any animal born and reared organically.
- *Food additives*
  More than 500 additives are permitted for use in non-organically processed foods, compared with around 30 permitted in organic processing. Organic standards prohibit additives and ingredients which have been linked to allergic reactions, headaches, asthma, growth retardation, hyperactivity in children, heart disease and osteoporosis.
- *Nitrate*
  Non-organic fertilisation practices result in higher levels of potentially harmful nitrate in vegetables. Studies have shown lower levels in organically produced crops.

Primary nutrients

This review differs from previous inconclusive studies as a result of exacting criteria which have been introduced to establish the adequacy of the methodologies of research. Each comparative study has been screened against these clearly stated criteria before being included in this review.

- Vitamin C and dry matter contents are higher, on average, in organically grown crops.
- Mineral contents are also higher, on average, in organically grown crops, although the small number and heterogenous nature of the studies included mean that more research is needed to confirm this finding.
- Research indicates a clear long-term decline in the trace mineral content of fruit and vegetables, and the influence of farming practices requires further investigation.

Secondary nutrients

- Research is beginning to confirm the expectation that organic crops contain an increased range and volume of naturally occurring compounds known variously as secondary plant metabolites or phytonutrients.
- Phytonutrients increase the capacity of plants to withstand external challenges from pests and diseases, and an

increasing number of them are also known to be beneficial to humans.
- Further research is needed in this field.

Observed health effects

- Feeding trials have shown significant improvements in the growth, reproductive health and recovery from illness of animals fed organically produced feed.
- A small body of observational and clinical evidence supports the hypothesis that consumption of organically produced food is beneficial to human health.

Holistic approaches

This report also reviews holistic techniques for assessing qualitative aspects of food, including picture forming methods and storage degradation tests.

- Picture forming methods, including biocrystallisation, reveal consistent differences between food samples in areas such as freshness and method of production.
- While the interpretation of these differences is subjective and their relevance to human health unknown, further development of these qualitative assessments may prove valuable in the search for improved food quality.

Conclusions

- Collectively, the evidence supports the hypothesis that organically grown crops are significantally different in terms of food safety, nutritional content and nutritional value from those produced by non-organic farming.
- Should these indications be substantiated by further research there are clear implications for public health, since the majority of UK agriculture has been based on non-organic production systems for decades.

Recommendations

- Consumers wishing to improve their intake of minerals, vitamin C and antioxidant phytonutrients while reducing their exposure to potentially harmful pesticide residues, nitrate, GMOs and artificial additives used in food processing should, wherever possible, choose organically produced food.
- Farmers wishing to protect their own health – as well as their workers – and improve the quality of their produce should make full use of the available advisory and financial support to convert to organic farming.
- The government should introduce a ‘health of the nation’ initiative involving the department for environment, food and rural affairs (DEFRA) and the department of health, linking farming and food production methods with the environment, food safety and human health.
- Further research is urgently needed to clarify the exact relationships between agricultural management and the nutritional quality of crops. Future research priorities include:

  1. Food safety
  Including human health impact assessments of multiple pesticide residues and genetically modified crops.
  2. Primary nutrients
  The impact of fertilisation, soil management, pest and weed control practices on the vitamin, mineral and dry matter contents of crops.
  3. Secondary nutrients
  The impact of fertilisation, soil management, pest and weed control practices on the phytonutrient contents of crops, plus the beneficial or toxic effects of specific phytonutrients on human health.
  4. Long-term feeding trials
  With both animals and humans to assess the influence of consuming organic food on various health parameters including foetal health and male fertility.
  5. Holistic approaches
  Including biocrystallisation, computer assisted morphological analyses, and an examination of the hypothesised link between the qualities demonstrated by these methods and human or animal health.

1 | Introduction

All truths are easy to understand once they are discovered. The point is to discover them.
Galileo Galilei

Public concern about food quality has intensified in recent years. A series of food scares and the controversy surrounding genetically modified crops have prompted heated debate about the safety and integrity of our food.

Against this background, demand for organically grown food has been growing rapidly. Opinion polls have suggested that a significant proportion of organic consumers believe that organic food is qualitatively better than non-organic, giving 'it tastes better' and 'it's better for you' as the most common reasons for purchasing it.[1]

Until now this perception that organically grown food is 'better for you' appears to have been largely based on intuition rather than conclusive evidence. Influential agencies of the UK government such as the Food Standards Agency (FSA) and the Health Education Authority have asserted that there is no evidence of organic produce being safer or healthier than non-organic food.[2,3] The object of this report is to scrutinise the available scientific evidence, assessing whether there really is something qualitatively different about organic food.

Until now reviews of the relevant scientific literature have painted an inconclusive picture, highlighting the contrasts and contradictions between research results. What these reviews have failed to do, however, is look critically at the methodologies used. This report breaks new ground by subjecting research methodologies to close inspection and revealing fundamental flaws in a significant number of studies. Once these flawed studies are discarded and a wider consideration of food quality is included, the remaining robust and reliable scientific data reveals a clearer picture.

The concept of food quality can be defined in many different ways. The quality of fresh produce is often judged by visual characteristics such as size, shape, colour, and freedom from blemishes which, it could be argued, are enhanced by pesticide and fungicide applications. Researchers within the organic movement have produced a wider definition of food quality which includes six criteria, embracing functional, biological, nutritional, sensual, ethical and 'authentic' considerations.[4] Under this definition, quality factors vary widely, ranging from how food tastes to the working conditions of those producing it. This review takes as its focus those aspects of food quality which are most important to the promotion of good health, specifically examining the available evidence in four areas:

- *Food safety* (see section 3.1)
  To what extent do organic and non-organic foods contain undesirable components such as potentially harmful chemicals, drug residues and pathogens?
- *Primary nutrients* (see section 3.2)
  What contribution do organic and non-organic foods make to a varied and balanced diet, providing nutrients such as essential vitamins and minerals required to achieve and maintain positive health?
- *Secondary nutrients* (see section 3.3)
  Do farming practices influence the concentration and range of secondary plant compounds (antioxidant phytonutrients such as flavonoids and phenolic compounds) and thus the health-promoting and protective properties of food? This represents a new way of regarding these compounds that have previously been classified at best as 'non-essential', and at worst as 'plant toxins' or 'natural pesticides'.[5]
- *Observed health effects* (see section 3.4)
  The ultimate test of nutritional quality is the capacity of a food to support health, growth and reproduction. Relevant, then, are studies that feed organically and non-organically grown food to animals or people and then assess their health.

In addition, this report explores holistic methods of quality determination which are being used by a small number of researchers to distinguish between foods in relation to such characteristics as degree of freshness, degree of processing and method of production (see section 4). These methods show different results for organically and non-organically grown foods, and while the significance of these differences is not yet known, some in the organic movement believe such results may point to qualitative differences in the health of crops which could be passed on through the food chain.[6]

This review has focused mainly on comparisons of organically and non-organically produced fruits, vegetables and cereals, as there is a substantial body of comparative research on these crops and they currently comprise around 60 per cent of the UK organic market.

Livestock products such as meat, dairy and eggs comprise an important group of foods worthy of further investigation. In the area of food safety there exist important differences between the two systems. Organic standards include measures designed to improve animal welfare with the aim of reducing the need for antibiotics and the unpredictable consequences of poor animal husbandry standards such as BSE and E.coli o157 proliferation. These issues are discussed in section 3.1. At present there is an insufficient body of research to allow any reliable conclusions to be drawn on the comparative levels of desirable nutritional contents (such as vitamins, minerals and protein) in livestock products from either organic or non-organic systems. Brief consideration is given in section 3.2.5 to the evidence regarding the fat composition of livestock products, as some comparative research has been conducted in this area.

Processed foods are also an important area worthy of further examination. This is a growing sector of the organic food market and includes such items as organic prepared meals, soups, snacks, desserts, condiments, drinks, baby foods, sauces and spreads. Food processing, often resulting in a reduction of nutrients and / or the addition of various additives, has been a significant development in all areas of food production in recent decades. Additives which are in common use in non-organic food processing are suspected of being linked with numerous health concerns and are discussed further in section 3.1.6.

By combining the wealth of available research into one document, by examining various methods of food quality assessment, and by carefully scrutinising the evidence to hand, the Soil Association hopes that this report will help both consumers and regulators take a fresh look at the scientific evidence behind the intuition that organic food is a healthier choice.

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2 | Background

The development of the organic movement

Health claims for organically grown food can be traced back to the early 20th century, most notably Lady Eve Balfour, a pioneer of the British organic movement who in the 1940s observed relationships which she described simply as "Healthy soil, healthy plants, healthy people".[1]

Since then the organic movement has grown considerably. Standards have been set, legally defined by EU Regulation no. 2092/91, implemented in the United Kingdom by the UK Register of Organic Food Standards (UKROFS), and policed by certifying bodies such as the Soil Association, whose *Standards for Organic Food and Farming* comprise 110 pages of detailed requirements and recommendations, and are under constant review. The UK organic food market is currently growing at around 40 per cent a year and by 2002 is expected to top £1 billion.

Agricultural methods and crop quality

The organic agricultural movement has grown largely through increasing awareness of the importance of good soil husbandry based on early work by Sir Albert Howard, Lady Eve Balfour and others, as well as a rejection of agriculture that is dependent on synthetic inputs and prioritises minimising costs while maximising yields. Advocates of organic agriculture maintain that the intensification of agriculture over the last 50 years has depleted the soil, and resulting crops, of nutrients, especially trace minerals, because the crops removed from the soil contain a wider variety of nutrients than farmers typically add back in the form of chemical fertilisers.

Data from the Department for the Environment, Food and Rural Affairs (DEFRA) shows that between 1940 and 1991, trace minerals in UK fruits and vegetables fell by up to 76 per cent,[2,3] and United States Department of Agriculture (USDA) figures show similar declines.[4] It is not clear whether these changes are due to varietal differences, depletion of nutrients in the soil, yield and dry matter content differences, or diminished soil microbiological activity needed to 'unlock' nutrients from the soil and make

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them available to crops. While the DEFRA data was not originally designed as a time series trial and some crops show increases in some nutrients, the overall trend is clearly downward (despite changes in cooking methods used in the surveys that are more likely to retain nutrients) and suggests that something is going wrong in intensive agriculture.

The method of cultivation (including fertilisation, weed, pest and disease control) is only one influence on the nutritional quality of a crop. Also known to affect the crop's quality are factors such as geographical area, soil type, soil moisture, plant variety, weather and climatic conditions, pollution, length of growing season, and post-harvest handling.[5] As many of these factors are beyond the farmer's control, the method of agricultural practice employed emerges as a significant controllable influence on the quality of a farm's produce, though clearly other controllable factors such as variety and irrigation / soil moisture can also have significant impacts.

Of course, references to 'organic' and 'non-organic' (sometimes referred to as 'conventional') agriculture inevitably fail to adequately describe the very diverse systems within these umbrella terms. For the purpose of this comparative review they are differentiated by fundamental differences in fertilisation and crop protection methods, as described below (see also section 3.2.3).

Organic farming

In organic agriculture, nutrients returned to the soil in manures and composts have to be cycled via the biological life of the soil before they become available to crops.[6] A gram of healthy soil can contain some 600 million micro-organisms and tens of thousands of different species of bacteria and fungi (including mycorrhizae), as well as organic and inorganic matter, air, water and water vapour that undergo complex, far from fully understood, chemical reactions.[7] It is known that mycorrhizae proliferate in soil with a high organic matter content, such as that supplied with manures and composts, and that they form symbiotic associations with plant roots. Root uptake of nutrients is enhanced by mycorrhizae, due to the larger nutrient-absorbing surface provided by the fungi.[8] This area has been calculated to be up to ten times that of roots without mycorrhizal fungi.[8]

In this way and through the actions of other microbiological soil life, plants are naturally supplied with a whole range of nutrients that would otherwise be too distant, insufficiently supplied or physically unavailable for uptake by the plant roots alone. So in the organic system the biological activity within the soil is fundamental to the breakdown of organic matter and the delivery of the range and quantity of nutrients required by the crop.[1]

The recently released results of a 21 year field trial in Switzerland comparing organic and non-organic farming systems show dramatic differences in soil microbiology. The mass of micro-organisms responsible for soil fertility and delivering nutrients to the roots of crops was up to 85 per cent higher in the organically managed field than that non-organically managed.[9] Control of pests, disease and weeds is managed in organic farming with practices such as crop rotation, weeding, mulching, intercropping, maintenance of natural predator populations and biological controls.

Non-organic farming

In non-organic agriculture nutrients are typically supplied to crops by adding synthetic chemical fertilisers containing a few key mineral nutrients necessary for plant growth, commonly known as 'NPK' (nitrogen, phosphorus and potassium), though other minerals such as calcium, magnesium and sulphur are sometimes added depending on the crop or identified deficiencies. Synthetic chemical pesticides are used in an attempt to eliminate insects, weeds and other pests. The use of chemical fertilisers, herbicides and pesticides can inhibit the microbiological life in the soil,[10,11] though this is of limited interest to non-organic farmers as the high concentrations and readily soluble form of the nutrients applied generally allow them to be taken up by the plants by mass flow and simple diffusion.[8]

Regarding the necessity of chemical pest and disease control, numerous studies have shown a link between NPK fertilisation and increased plant susceptibility to pests and disease, necessitating the use of pesticides.[6,12–14] It has been demonstrated that plants provided abundantly with nutrients, especially with nitrogen, are preferentially attacked by aphids, while plants manured organically are less or not at all affected by aphids because of the lower water contents and thicker cell walls of the plants.[15] As agriculture has developed and become more intensified, crop losses due to pests and disease have increased.[16]

It is true that modern agriculture has been able to produce food which is seemingly abundant and cheap (though many of the costs are externalised and paid for elsewhere).[17] Concerns have arisen, however, over the impact this has had on the environment and on the nutritional quality of the foods produced.

The concept of positive health

A major premise of the organic approach to farming is that plant and animal health cannot be defined as simply the absence of disease, but rather a state of health and vitality in which the organism is better able to withstand external challenges within its given environment.[18] In plants this involves natural fecundity with a resilience to pests and disease. In people good health manifests in ways such as consistent and high levels of energy, mental clarity, resistance to stress, good physical strength and stamina, freedom from infections, sound reproductive health, healthy skin, hair and nails … as well as an absence of illness.

While improvements have occurred in disease treatment, there has been a general decline in public health as indicated by increases in allergies, obesity, osteoporosis, diabetes, food intolerances, cancers, cardiovascular disease, infertility, sexual development disorders, respiratory sensitivity and mental health problems.[19–22] Many doctors and nutritionists believe that the cause of this rise in degenerative diseases is two-fold: an increase in the amount of stressors and toxins our bodies are exposed to, and a decrease in the amount of nutrients in people's diet needed to deal with those stresses.[4,21–28] The result is commonly more cellular damage, more degenerative diseases, and a declining quality of life for many.

Linus Pauling, winner of two Nobel prizes, believed "Every sickness, every disease, and every ailment can be traced to a mineral deficiency". Supporting this hypothesis, the United States Department of Agriculture reported, 30 years ago, that the highest death rate areas in the US generally corresponded to those where agriculturists had recognised that the soil was depleted.[29]

Influences on health

There are many influences on people's health – genetic make-up, environmental pollutants, lifestyle factors such as smoking, not exercising enough, alcohol consumption, side effects of medicinal and recreational drugs, emotional well-being and more. But diet is increasingly being viewed as playing a key role. The UK government advises eating more fruit and vegetables and less fat to lower one's risk of cancer and heart disease,[30,31] a view supported by many including the World Cancer Research Fund,[32] the US Surgeon General,[33] and the US National Research Council,[34] acknowledging clear links between dietary choices and good health. However no single dietary habit, including consuming organically grown food, can claim to guarantee good health.

The FSA asserts that the balance of our diet is more important than the nutritional value of the individual foods chosen, yet the nutritional quality of foods is also very important. Even though the typical Western diet is more varied now than ever before, studies consistently show that many people fail to take in the recommended daily allowance (RDA) for many nutrients.[35–37] The protective and health promoting compounds in fruit and vegetables are being increasingly recognised by science, and it is widely agreed that an increased consumption of fruit and vegetables is the simplest way to improve one's nutrient intake and protect one's health. But are there advantages to be gained by consuming organically grown produce?

To answer this, the appropriate question to ask is not "Will organically grown food make you healthy?", but rather "Is organically grown food healthier than non-organically grown food?". In other words, does consuming it make a greater, lesser or equal contribution to one's overall health than consuming non-organically grown foods?

3 | The evidence

3.1 | Food safety

Any comparison of the quality of foods from different agricultural systems must begin with a foundation of food safety, given its prominence in the public perception of organic food.

Consumer perceptions of the term 'organic food' [1]
59% – no chemicals / additives / pesticides
47% – natural
41% – healthy
37% – expensive
35% – good for the environment
35% – GM free

Issues such as BSE and genetic modification have had a dramatic impact on how consumers view food safety, making them wary of assurances and turning many toward unadulterated and natural foods.

3.1.1 | Pesticides

While many in agriculture believe that pesticides are necessary to produce and protect crops, it is universally agreed that consumer exposure to these toxins should be minimised on safety grounds. Over 450 pesticide active ingredients are licensed for use in UK agriculture,[2] and around 25,000 tonnes of pesticides were applied to UK crops in 2000.[3] Due to the persistent nature of many pesticides, air, water and soils are inevitably contaminated by them.

Contrary to public perception, while the use of pesticides is severely restricted in organic farming, a small number can be used. They tend to represent the final option for pest control when other methods (as discussed in section 2) have failed or are known to be ineffective. Soil Association standards allow organic farmers restricted use of seven non-synthetic pesticides that have been approved on the basis of their origin, environmental impact and potential to persist as residues. They are copper ammonium carbonate; copper sulphate; copper oxychloride; sulphur; pyrethrum; soft soap and derris (rotenone). Some plant oils such as neem and microbial agents such as *Bacillus thuringiensis* (Bt) are also

3.1.1

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10 Bitaud C, 2000, 'Study on pesticide residues in organic food products in France', *The World Grows Organic: Proceedings from the 13th IFOAM Scientific Conference*, Basel, Switzerland, 28–31 Aug 2000, p 311
11 MAFF, 2000, *Annual Report of the Working Party on Pesticide Residues 1999*, Health and Safety executive, MAFF Publications, London
12 Buffin D, 1997, 'High insecticide residue levels in food', *Pesticides News* 36
13 HDRA, 2001, *Specific Aspects of the Quality of Organic Food*, (unpublished report)
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15 Boyd CA, Weiler MH and Porter WP, 1990, 'Behavioural and neurochemical changes associated with chronic exposure to low-level concentrations of pesticide mixtures', *J Toxicol. Environ. Health* 30, p 209–221
16 Porter WP, Green SM, Debbink NL and Carlson I, 1993, 'Groundwater pesticides: interactive effects of low concentrations of carbamates aldicarb and methomyl and the triazine metribuzin on thyroxine and somatotrophin levels in white rats', *J Toxicol. Environ. Health* 40, p 15–34

permitted. They are generally simpler substances than those used in non-organic agriculture, tend to degrade quicker, and are typically only used on a non-routine basis following authorisation from the certifying body for a specific reason. For example, permission was granted by the Soil Association for farmers to use derris in only 20 instances in the UK in 2000 after the farmers had justified its use and put forward plans to avoid its use in the future. Copper is being phased out of Europe-wide organic standards because of concerns about possible detrimental effects on earthworms and other soil life.

There are concerns about the safety of these compounds permitted in organic agriculture,[4,5] though, as would be expected given the prohibition of routine pesticide applications, organically grown food is usually found to have no residues. When residues are present, they are usually of lower incidence and lower levels than residues in and on non-organically produced food.[6–8] In two reviews, examining over 35 papers and 9,100 samples respectively, pesticide residues were found much less often in organically produced vegetables than typical non-organic levels, and contamination of organic samples appeared more often than not to have originated from environmental pollution.[9,10]

In contrast, according to the latest available figures, nearly half (48 per cent) of all fruit and vegetables tested in the UK in 1999 contained detectable pesticide residues, as did 28.6 per cent of all foods tested (which includes cereals, meat, dairy, fish and processed foods).[11] The UK government's deputy chief medical officer Dr Jeremy Metters has recommended "Washing fruit before consumption is always a sensible precaution to ensure it is clean; and peeling fruit … is a sensible additional precaution when preparing fruit for small children", though this is likely to reduce the nutritional content of the fruit.[12]

In 1999 the legal limit (MRL – maximum residue level) was exceeded in 1.6 per cent of samples, and while the Working Party on Pesticide Residues (WPPR) reiterated that most of these residues above the MRL posed no threat to human health, they warned that they had found potentially harmful levels in pears and peppers.[11] There have also been examples of illegal use of pesticides. In the late 1980s and early 1990s the WPPR repeatedly identified lettuce containing both residues of banned substances and evidence of use of substances closer to harvest than permitted, and evidence of this was found again in the latest survey (1999).[11,13]

Many samples of fresh produce carry multiple pesticide residues (see table, right)[6,11] and this issue could have profound implications for the question of safety. MRLs and acceptable daily intakes (ADIs) are set – as legal limits and safety levels respectively – for *individual* pesticides. They do not take into account the so-called 'cocktail effect' of combinations of pesticides in and on foods. Regulators are now starting to consider this problem, admitting "little is known about the toxicological interactions between pesticides … It is likely that residues of the same class (for example organophosphates – OPs) will be at least additive

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18 Thiruchelvam M, Richfield EK, Baggs RB, Tank AW and Cory-Slechta DA, 2000, 'The Nigrostriatal Dopaminergic System as a preferential target of repeated exposures to combined paraquat and maneb: implications for Parkinson's Disease', Journal of Neuroscience 20(24), p 9207–9214

19 Walsh LP, McCormick C, Martin C and Stocco DM, 2000, 'Roundup inhibits steroidogenesis by disrupting steroidogenic acute regulatory (StAR) protein expression', *Environmental Health Perspectives* 108(8), p 769–776

20 Nott T, 1997, 'Washing aid for fruit and vegetables', *Pesticides News* 35

21 *Health Which?*, 1998, 'Pesticides in fruit and veg', June 1998, p 8–11

22 MAFF, 1998, 'Orchards and fruit stores in Great Britain 1996', *Pesticide Usage Survey Report 142*, MAFF Publications, London

23 Pesticides Safety Directorate, 1997, *Unit to Unit Variation of Pesticide Residues in Fruit and Vegetables*, MAFF Publications, London

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28 Kiraly Z, 1996, 'Sustainable agriculture and the use of pesticides', *Journal of Environmental Science and Health part B* 31(3), p 283–291

29 Brandt K, 2000, 'Potentially poisonous plant compounds in food plants. Do they affect health positively or negatively?', *Bulletin of the Danish Institute of Agricultural Sciences*, distributed by MAFF

30 Brandt K, PhD, Head of Research at the Danish Institute of Agricultural Science, *personal communication, 23 Dec 2000

31 Williams CM, Pennington TH, Bridges O and Bridges JW, 2000, 'Food quality and health', *Shades of Green – a Review of UK Farming Systems*, Royal Agricultural Society of England, p 73–90

32 Colborn T, Dumanoski D, and Myers J, 1996, *Our Stolen Future*, Abacus Publishers, UK

33 Muir D, Wagemann R, Hargrave B, Thomas D, Peakall D and Norstrom R, 1992, 'Arctic marine ecosystem contamination', *Sci Total Environment* 122, p 75–134

34 Mott L and Broad M, 1984, *Pesticides in Food*, San Francisco: National Resources Defence Council

35 Meacher M, 2000, minister for the environment, UK, quoted in Beaumont P and Harvey J, 2000, 'Pesticide poisoning – we still do not know', *Pesticides News* 50, Dec 2000, p 3–4

36 Peter Beaumont, 2001, development director of Pesticide Action Network UK, *personal communication, 15 May 2001

37 Eaton KK and Anthony HM (moderators), 2000, 'Multiple chemical sensitivity recognition and management', Third Scientific Report of the British Society for Allergy, Environmental and Nutritional Medicine, *Journal of Nutr Environ Med* 10, p 39–84

38 Morgan D and Roan C, 1971, 'Absorption, storage, and metabolic conversion of ingested DDT and DDT metabolites in man', *Archives of Environmental Health* 11, p 301–308

Multiple pesticide residue incidences

Year of MAFF test	*Fruit or vegetable*	*Samples with multiple residues*	*Maximum no. of detected compounds*
1998	apples	29%	three
1999	apples	8%	three
1998	pears	68%	six
1998	carrots	14%	three
1999	carrots	10%	two
1998	lettuce	72%	seven
1999	lettuce	33%	six
1998	oranges	94%	six
1999	oranges	93%	seven
1999	celery	26%	two
1998	infant food	7%	five
1999	strawberries	42%	five

in their effects".[11] American researchers who combined three pesticides at safe levels found that this combination multiplied the toxicity by hundreds of times.[14] While this study involved dermal and not dietary exposures, it clearly demonstrates the interactive potential of multiple pesticides.

Other researchers examining dietary exposures have found that mixtures (such as insecticides, herbicides and nitrate at low concentrations that are legally permitted in groundwater) can have effects on the reproductive, immune and nervous systems that individual chemicals do not have.[15–18] On the other hand, one study has shown that multiple compounds can interact antagonistically and reduce their overall toxicity.[19] The key issue is that very little is known and therefore risk assessments could be very wrong. The Food Standards Agency has recently established the UK Working Group on the Risk Assessment of Mixtures of Pesticides (WiGRAMP) to examine this issue and formulate risk assessment advice. The group intends to report its findings by July 2002.

Washing produce with water has little effect on these residues as many are formulated to resist being washed off easily (for example, by rain). Tests with potatoes, apples and broccoli showed that between 50 and 93 per cent of residues remained on the produce after washing with water.[20,21] While peeling, topping and tailing help, many pesticides are not only found on the surface of produce, but can also be taken up by a plant and contaminate its entire flesh. Peeling or washing is unable to remove very much of any such (systemic) pesticide.[21]

One of the problems in reporting pesticide levels in foods is the issue of residue variability. Cox's apples, for example, can be sprayed 16 times with 36 different pesticide active ingredients before reaching the consumer.[22] However professionally these sprays are applied, apples near the inside of the tree are unlikely to receive as much spray as apples nearer the outside of the tree. The UK government's Pesticides Safety Directorate has found that some apples can contain as much as 13 times the average residue level,[23] while residues on carrots, sprayed with an average of four insecticides, three herbicides and two fungicides,[24] can be up to 29 times the average.[25] Findings such as these led the UK government to recommend the topping and tailing of carrots to reduce exposure to residues,[23] though this advice has subsequently been withdrawn.

Another problem in reporting residue levels is the degradation of unstable chemicals during analysis. Tests run in 1999 by the WPPR showed significant losses of pesticides during laboratory analysis. Apples, lettuce, oranges and tomatoes were spiked with known quantities of over 100 pesticide residues and sent to three laboratories for testing.[11] The reported residue levels were more than a fifth down in between three and 82 per cent of the samples, depending on the food and the laboratory doing the testing. The reason for these losses is not known, though it is suspected that unstable pesticide compounds may degrade during the procedures of the analysis. This raises serious questions about the validity of MAFF's published pesticide residue levels, and suggests that there could be more pesticides in foods than are being reported.[26] The Pesticides Safety Directorate is now examining ways to improve the analyses to reduce these residue losses, and insists that "The potential underestimation of residue levels is not an issue for the pesticide approval process or consumer risk assessment".[11]

It has been argued that the toxicity of pesticides in food is much lower than the toxicity of naturally occurring components in food, so called 'natural pesticides' or 'plant toxins'.[27,28] These compounds, thought to be part of the plant's own immune system, typically occur at very low levels and their label as 'toxins' is misleading. While they have been shown to be toxic in high ('near lethal') dose rodent tests,[27] these same compounds may be innocuous or even beneficial at lower, naturally occurring concentrations[29] and protective effects of many of them have been documented (see section 3.3). In addition, we and many other species possess a full complement of the enzymes needed to degrade or in other ways eliminate the many types of natural compounds found in plant foods. In contrast, there is no guarantee that synthetic compounds will be eliminated by our innate protection systems.[30*] Through bio-accumulation they may then turn out to have deleterious effects even at low concentrations, while most natural compounds are dangerous only at high (usually unrealistic) concentrations. Glycoalkaloids in potatoes are a well known exception, occurring in high and potentially harmful quantities in the green surface of potatoes exposed to light. While it is not argued that 'natural' always means 'safe', it appears erroneous to consider these 'natural' and 'synthetic' pesticides similarly, as previous reviews have done.[31]

Exposure to pesticides does not only occur via the food to which they were initially applied. Many pesticide compounds persist as environmental pollutants and can contaminate soil, air and water and can also bio-accumulate in the food chain.[32,33] Evidence of the potential of these compounds to persist in the environment can be found in an American study in which 17 per cent of carrots analysed contained detectable levels of DDT 20 years after it was banned.[34] Environmental exposures are a direct consequence of pesticide use in agriculture and they must also be considered when comparing the safety of the two agricultural systems. WiGRAMP is expected to consider this issue in its examination of human exposure to multiple pesticide residues.

The UK environment minister, Michael Meacher, recently admitted "Comprehensive information on the number of people who are poisoned by pesticides each year is not available".[35] While this comment referred particularly to acute exposures, uncertainty also surrounds chronic low-level exposure given that:

- There are pesticide residues in and on a large portion of non-organically grown produce.
- They are not washed off easily with water.
- Their toxicities may be different in combination than individually.
- Individual pieces of fruit or vegetable may have residues many times higher than the average.
- Average residue levels may be higher than are being reported.
- Their potential toxicity should not be confused with naturally occurring plant compounds.
- Exposure can also occur environmentally.
- Effects on different individuals can be very different.

Effects of pesticides on health

The public's disbelief of reassurances about pesticide safety stems partly from previous retractions. Following a report conducted by Austria's ministry of agriculture (1998) which concluded that there was no safe limit of exposure for the pesticide Lindane, the EU agreed in July 2000 to withdraw Lindane from use in agriculture by 2002. This is the latest example from a long list of agricultural pesticides (including DDT, other organochlorines and organophosphate sheep-dips) formerly claimed to be safe that had to be withdrawn from use. While newer pesticides tend to be less persistent compounds than those used previously, they are also more powerful at lower doses, so it is difficult to draw any line [between old and new pesticides with regards to safety] with clarity.[36*] All OPs are now under review by the European Commission.

It has been implied that infrequent enquiries to UK poisons centres about pesticide intoxications suggests the problem is relatively unimportant compared to other issues such as food-borne microbial infections,[31] yet it is extremely unlikely that consumers would be able to link long-term, low-level pesticide exposures with negative health effects. Symptoms may be sub-clinical or may not become apparent for many decades. Adverse effects are unlikely to be recognised unless they are acute or cause a rare condition. Except in a population that is completely healthy it is even more difficult, in fact virtually impossible, to prove that chemical exposures do not cause chronic ill-health.[37] High-level pesticide exposures, through acute or accidental poisoning, occupational use, or environmental effects on wildlife and people, can provide valuable indications of the potential health effects of these compounds. Having observed the symptoms that occur from high-level exposures in these groups, it is then possible to examine whether or not similar symptoms occur in individuals or groups only experiencing chronic low-level exposures, such as through pesticide residues in food and the environment.

The risk of adverse health effects from pesticide residues in foods is considered on the basis of Acceptable Daily Intakes (ADIs) – defined as 'the amount of a chemical that can be consumed every day, for an individual's entire lifetime in the practical certainty, on the basis of all known facts, that no harm will result'. But accumulations of combinations of pesticides in the human body could make ADIs for individual pesticides wholly inadequate. While this point is hotly contested by regulators and the pesticides industry, there is a growing body of evidence in the medical literature demonstrating the detrimental health effects of pesticides on human health. As many are fat-soluble, pesticides can accumulate in lipid-rich tissue. Biological half-lives of several years have been reported in human beings for some compounds,[38,39] and there is particular concern regarding possible neurobehavioural and neurotoxic effects, mutagenicity, teratogenicity, carcinogenicity, and allergic and other immuno-regulatory disorders.[40,41]

Neurotoxicity

In 1983 a study of five adult patients in Israel indicated that their chronic gastrointestinal and neurological complaints were linked to organophosphate (OP) residues in fruit and vegetables, and in each case when the patient was taken off fresh fruit and vegetables their health returned to normal.[42] American researchers have linked symptoms such as headaches, tremor, malaise, lack of energy, muscle weakness, depression, anxiety, poor memory, loss of co-ordination, dermatitis, convulsions, nausea, vomiting, indigestion and diarrhoea with pesticide levels in patients' blood streams.[43] Anecdotally, UK farmers occupationally exposed to pesticides sprays without protective clothing have been observed to develop symptoms of paraplegia, "but of slow and insidious onset".[44*] Long term low level exposure to OP sheep dips has been linked to neuro-psychological effects.[45–47] A 1997 review of the medical literature demonstrated the "flaws of scientific concepts… used to identify organophosphates as non-neurotoxic", and presented evidence of effects of OP compounds including chronic fatigue, peripheral neuropathy, neurobehavioral and cognitive abnormalities, and autonomic nervous system disturbances.[48]

Children may be particularly susceptible to pesticide residues as they have a higher intake of food and water per unit of body weight than adults, have immature organ systems, and may have a limited ability to enzymatically detoxify these substances.[49] In 1975 French researchers found that mothers' milk contained two to eight times more chlorinated pesticides than the World Health Organisation (WHO) maximum tolerated level in foodstuffs, and when the mothers under investigation increased their intake of organically grown foods the concentration of residues in their milk declined.[50] According to the US National Academy of Sciences, exposure to neuro-toxic compounds at levels believed to be safe for adults could result in permanent loss of brain function if it occurred during the prenatal and early childhood period of brain development.[51] Developmental effects such as altered learning, memory and motor skills have also been linked with prenatal exposure to pesticides.[52] Children, although more vulnerable, are not alone in this risk; adults are also susceptible in varying degrees, especially those who have compromised immune systems or less than optimal liver function.[53]

Endocrine system disruption

The hormone disrupting effects of pesticides have been well documented in studies on wildlife.[32] Many pesticide compounds have oestrogenic properties, and are classed as xeno(foreign)-oestrogens. The Institute for Optimum Nutrition advises that women with symptoms of hormonal imbalance such as PMT and menstrual irregularities should avoid non-organically grown food to reduce their exposure to xeno-oestrogenic pesticide residues as part of a 'hormone-friendly' diet.[54] The European Commission has produced a draft list of 34 pesticides for which there is either clear evidence of endocrine disrupting effects or which are recognised as potential endocrine disrupters.[55] Nineteen of these are approved for agricultural use in the UK.

The herbicide glyphosate (Roundup) has been shown to be capable of disrupting hormone synthesis in male mice.[19] In humans, research has supported the hypothesis that exposure in pregnancy to environmental xeno-oestrogens can affect the human male offspring's reproductive system.[56–58] There has been an increase of genital abnormalities such as undescended testes, which it is thought could be due to an environmental effect on the developing male foetus.[59] Evidence of effects on the male reproductive system in adult life was reviewed by a Danish review of 61 papers examining a total of nearly 15,000 men that concluded "there has been a genuine decline in semen quality in the last 50 years … probably due to environmental rather than genetic factors".[60] Since then, at least three studies have compared the semen quality of men with differing levels of dietary exposures to pesticides. Shortcomings of these studies necessitate caution in drawing any conclusions and more research is needed. The most recent study found that men consuming

39 Brown J, Lawton R, Ross M, *et al*, 1989, 'Persistence of PCB congeners in capacitor workers and Yusho patients', *Chemosphere* 19, p 829–834
40 BMA, 1992, *The BMA Guide to Pesticides, Chemicals and Health*, Report of the Board of Science and Education, British Medical Association
41 Robbins C, 1991, *Poisoned Harvest: A Consumers Guide to Pesticide Use and Abuse*, Victor Gollancz Ltd, p 300–313
42 Ratner D, Oren B and Vidger K, 1983, 'Chronic dietary anticholinesterase poisoning', *Israel Journal of Medical Science* 19, p 810–814
43 Laseter J and Rea W, 1983, 'Chlorinated hydrocarbon pesticides in environmentally sensitive patients', *Clinical Ecology* 2 (1)
44 Harrison HL, 2001, Registered Naturopath, UK, *personal communication, 12 April 2001
45 Stephens R, Spurgeon A, Calvert IA *et al*, 1995, 'Neuropsychological effects of long term exposure to organophosphates in sheep dip', *Lancet* 345, p 1135–1139
46 Davies DR, 1995, 'Organophosphates, affective disorders and suicide', *J Nut Environ Med* 5, p 367–74
47 Forbat IN and Shekan JD, 1992, letter, *BMJ* 305, p 1503
48 Jamal G, 1997, 'Neurological syndromes of organophosphorus compounds', *Adverse Drug Reactions Toxicology Review* 16 (3), p 133–170
49 Eskenazi B, Bradman A and Castorina R, 'Exposures of children to organophosphate pesticides and their potential adverse health effects', *Environmental Health Perspectives* 107 (supp 3), p 409–418
50 Aubert C, 1975, 'Die Muttermilch, ein erschreckender Stand der Toxiditaet', *Leb Erde*, Heft 1
51 National Research Council, 1993, *Pesticides in the Diets of Infants and Children*, National Academy of Sciences, National Academy Press, Washington, DC
52 Guillette EA, Meze MM, Aquilar MG, Soto AD and Garcia IE, 1998, 'An anthropological approach to the evaluation of preschool children exposed to pesticides in Mexico', *Environmental Health Perspectives* 106, p 347–353
53 Arnold S, Vonier P, Collins B, Klotz D, Guillette L, and McLachlan J, 1997, 'In vitro synergistic interaction of alligator and human oestrogen receptors with combinations of environmental chemicals', *Environmental Health Perspectives* 105, p 615–618
54 Savona N, 1998, 'Female health problems and their nutritional solutions', *Optimum Nutrition*, Journal of the Institute for Optimum Nutrition 11 (3), p 46–51
55 European Commission DG Env, June 2000, *Towards the Establishment of a Priority List of Substances for Further Evaluation of their Role in Endocrine Disruption – Draft List*, BKH Engineers, Delft, the Netherlands. See also: Schmitt H, 2000, 'PAN Europe calls for pesticide reduction', *Pesticides News* 50, Dec 2000, p 5, citing data from The UK Environment Agency, UK Department of Environment, Transport and the Regions, German Federal Environment Agency, European Union, Oslo and Paris Commission and the World Wide Fund for Nature
56 North K and Golding J, 2000, 'A maternal vegetarian diet in pregnancy is associated with hypospadias', *BJU International* 85, p 107–113
57 Jensen TK, Toppari J, Keiding N and Skakkebaek NE, 1995, 'Do environmental oestrogens contribute to the decline in male reproductive health?', *Clin Chem* 45, p 1896–1901
58 Sharpe RM and Skakkebaek NE, 1993, 'Are oestrogens involved in falling sperm counts and disorders of the male reproductive tract?', *The Lancet* 341, p 1392–1395

no organically grown food had significantly lower concentrations of morphologically normal sperm.[61] Overall though it found no significant differences in 14 of 15 sperm quality parameters investigated and concluded that dietary intake of pesticides did not entail a risk of impaired overall semen quality. However sampling was generally conducted in cooler months (February to April) for non-organic food eating respondents and warmer months (May to June) for those with high organic food intakes, and as testicular temperature is known to influence sperm production these seasonal differences may have influenced the outcomes.

Two previous studies found correlations between organic food consumption and sperm health. Men belonging to organic farming associations and eating organic food had higher sperm concentrations than control groups (airline workers, printers, electricians and metal workers) who did not eat organic food, though these differences could have been due to other lifestyle and / or geographical factors, such as country versus city dwelling or occupational exposure to other chemicals.[62,63] Providing clearer evidence, occupational exposures to pesticides are known to influence sperm health: the success rates for couples in IVF programmes were observed to significantly decrease for couples with paternal occupational pesticide exposure;[64] and another study noted an inverse relationship between semen quality and the level of occupational exposure to pesticides experienced by greenhouse workers.[65]

Epidemiological evidence has been collated that suggests combinations of pesticides cause increased incidence of birth defects in the offspring of pesticide applicators and in the local residents of areas of heavy pesticide use.[66] The Royal Society recently recommended that exposure of pregnant women to hormone disrupting chemicals, including pesticides, should be minimised in order to protect unborn children.[67]

Carcinogenicity

The US Environmental Protection Agency (EPA) ranks pesticide residues among the top three environmental cancer risks.[68] Many pesticides are known animal and suspected human carcinogens.[69–72] When asked why pesticides which are suspected carcinogens are allowed, professor David Coggon, chairman of the Advisory Committee on Pesticides, the body which registers pesticides in the UK, explained “Our concern is not just whether a pesticide is carcinogenic, but if so, whether use of the pesticide carries an unacceptable risk of cancer in people. There may, for example, be good evidence that a carcinogenic effect observed in animals would not occur in humans, or that it would only occur at much higher exposures than result from the proposed use”.[73*] Others remain unconvinced. In its report on diet and cancer, the US National Academy of Science concluded that “there is no epidemiological evidence to suggest that [environmental contaminants] individually make a greater contribution to

59 Schettler T *et al*, 1999, *Generations at Risk: Reproductive Health and the Environment*, MIT Press, Cambridge, MA
60 Carlsen E, Giwercman A, Keiding N and Skakkebaek NE, 1992, ‘Evidence for decreasing sperm quality of semen during past 50 years’, *BMJ* 305, p 609–613
61 Juhler RK, Larsen SB, Meyer O, Jensen ND, Spanò M, Giwercman A and Bonde JP, 1999, ‘Human semen quality in relation to dietary pesticide exposure and organic diet’, *Archives of Environmental Contamination and Toxicology* 37, p 415–423
62 Abell A, Ernst E and Bonde JP, 1994, ‘High sperm density among members of organic farmers’ association’, *The Lancet* 343, June 11, p 1498
63 Jensen TK, Giwercman A, Carlsen E, Scheike T and Skakkebæk NE, 1996, ‘Semen quality among members of organic food associations in Zealand, Denmark’, *The Lancet* 347, June 29, p 1844
64 Tielemans E, van Kooij R, Velde E, Burdorf A and Heederik D, 1999, ‘ Pesticide exposure and decreased fertilisation rates in vitro’, *The Lancet* 254, p 484
65 Abell A, Ernst E and Bonde JP, 2000, ‘Semen quality and sexual hormones in greenhouse workers’, *Scandinavian Journal of Work and Environmental Health* 26(6), p 492–500
66 Garry VF, Schreinemachers D, Harkers ME and Griffith J, 1996, ‘Pesticide applicators, biocides and birth defects in rural Minnesota’, *Environmental Health Perspectives* 104, p 394–399
67 The Royal Society, 2000, *Endocrine Disrupting Chemicals*
68 Balch JF and Balch PA, 1997, Prescription for Nutritional Healing, 2nd edition, Avery publishers, USA, p 176–183
69 Ames B, 1987, ‘Ranking possible carcinogenic hazards’, *Science* 236, p 272
70 Watts MA, 1994, ‘Pesticide residues in food’, *Proceedings of the Nutrition Society of New Zealand* 19, p 58–63
71 Buffin D, 2001, ‘Licensed to cause cancer’, *Pesticides News* 51, March 2001, p 18–19, citing data from the International Agency for Research on Cancer, US Environmental Protection Agency and the EU
72 Council on Scientific Affairs, 1988, ‘Cancer risk of pesticides in agricultural workers’, *JAMA* 260, p 959–966
73 Coggon D (Prof), Chairman of the UK Advisory Committee on Pesticides, *personal communication with Craig A, Pesticide Action Network UK, May 2001
74 National Research Council, 1982, *Diet, Nutrition, and Cancer*, National Academy Press, Washington DC
75 Wigle DT, Semenciw RM, Wilkins K, *et al*, 1990, ‘Mortality study of Canadian male farm operators: non-Hodgkin’s Lymphoma mortality and agricultural practices in Saskatchewan’, *J Nat Cancer Inst* 82, p 575–582
76 Fan AM and Jackson RJ, 1989, ‘Pesticides and food safety’, *Regul Toxicol Pharmacol* 9, p 158–174
77 Sterling T and Arundel AV, 1986, ‘Health effects of Phenoxy herbicides’, *Scandinavian Journal of Work and Environmental Health* 12, p 161–173
78 Lander F, Knudsen LE, *et al*, 2000, ‘Chromosomal aberrations in pesticide-exposed greenhouse workers’, *Scandinavian Journal of Work and Environmental Health* 26(5), p 436–442
79 Schreinemachers DM, 2000, ‘Cancer mortality in four northern wheat-producing states’, *Environmental Health Perspectives* 108(9), p 873–881
80 Allen R, Gottlieb M, Clute E, Pongfiri M, Sherman J and Obrams G, 1997,‘Breast cancer and pesticides in Hawaii: the need for further study’, *Environmental Health Perspectives* 105 (supp 3), p 679–683
81 Høyer A, Grandjean P, Jørgensen T, Brock J and Helle B, 1998, ‘Organochlorine exposure and risk of breast cancer’, *The Lancet* 352, p 1816–1820

the risk of human cancer. However, the possibility that they may act synergistically and thereby create a greater carcinogenic risk cannot be excluded".[74]

Those with high exposures to pesticides such as Canadian farmers have been found to have higher incidences of cancer, including stomach, prostate, brain and skin.[75–77] An increase in genetic damage has been observed in Danish greenhouse workers who did not wear gloves when handling plants that had been treated with any of 50 different compounds,[78] while American researchers suggested a link between higher cancer mortality rates in four northern states and a herbicide used on wheat.[79] Women in Hawaii with high exposures to xeno-oestrogenic chemicals through groundwater have very high rates of breast cancer,[80] a connection confirmed by a Danish study following 717 women over 20 years which "supported the hypothesis that exposure to xeno-oestrogens may increase the risk of breast cancer".[81]

Immunotoxicity

The well documented contamination of the arctic aquatic food chain with organochlorines in recent decades[33] led researchers to investigate a possible link with the high incidences of infectious diseases among Inuit children in arctic Canada. Inuit in this area report hearing loss (a common consequence of recurring middle ear infection) as their most common chronic health problem. Finding several pesticide compounds in the 213 women tested, plus abnormally high incidences of meningitis and broncho-pulmonary and middle ear infections in their children, it was shown that the relative risk of recurrent middle ear infections (more than three in the first year of life) increased with prenatal exposure to organochlorine compounds.[82] Other researchers have also suggested that pesticides may be implicated in immune system suppression,[83–87] and animal studies have shown that some pesticides can affect white blood cell maturation, leading to a reduced ability to fight bacteria and viruses.[13,88,89]

Effects of dietary exposure to pesticides

As can be seen above, the vast majority of evidence of the harmful effects of pesticides on human health comes from environmental and occupational exposures. The question remains, can the levels of pesticide residues to which UK consumers are exposed through diet result in similar symptoms in the long run? There is only a small amount of evidence linking dietary pesticide exposures to human health problems, such as gastrointestinal and neurological complaints,[42] breast milk contamination,[50] and some sperm quality parameters.[61–63] While considerable evidence exists demonstrating the reproductive effects and neurotoxicity of chronic exposures to pesticides in animal

82 Dewailly E, Ayotte P, Bruneau S, Gingras S, Belles-Isles and Roy R, 2000, 'Susceptibility to infections and immune status in Inuit infants exposed to organochlorines', *Environmental Health Perspectives* 108(3), p 205–211

83 Repetto R and Baliga SS, 1996, *Pesticides and the Immune System*, World Resources Institute, Washington DC

84 Snell P and Nicol K, 1986, *Pesticide Residues and Food: The Case for Real Control*, The London Food Commission, UK

85 BSAEM/BSNM, 1995, 'Evidence of adverse effects of pesticides', *Journal of Nutritional and Environmental Medicine* 5, p 341–352

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5 Diez-Gonzales F, Callaway TR, Kizoulis MJ and Russel JB, 1998, 'Grain feeding and the dissemination of acid-resistant Escherichia coli from cattle', *Science* 281(5383), p 1666–1668

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10 Tschape H, Prager R, Streckel W, Fruth A, Tietze E and Bohme G, 1995, 'Verotoxinogenic Citrobacter freundii associated with severe gastroenteritis and cases of haemolytic ureamic syndrome in a nursery school: green butter as the infection source', *Epidemiol. Infect* 114, p 441–450

trials,[90] that dietary exposure to pesticide residues at levels typically found in and on foods is harmful to the majority of consumers is more difficult to prove. As previously discussed, it is extremely difficult to link negative health effects with chronic low-level dietary pesticide residue exposures, and controlled tests with humans are not possible for obvious ethical reasons.

Given the current evidence, the continuing doubts over the levels of pesticides in and on non-organically grown food and the potential synergistic effects of multiple residues, the British Medical Association urges a precautionary approach. “Until we have a more complete understanding of pesticide toxicity, the benefit of the doubt should be awarded to protecting the environment, the worker and the consumer … this precautionary approach is necessary because the data on risk to human health from exposure to pesticides are incomplete”.[40]

This evidence should not deter consumers from eating fresh fruit and vegetables. The risk to health from eliminating fruit and vegetables from the diet would far outweigh the risks posed by possible exposure to pesticide residues. However purchasing organically grown food is advocated as a way of minimising exposure to residues on foods and reducing support for farming systems that continue to contaminate the environment with these toxins.[91]

3.1.2 | Food poisoning

It has been asserted that organically grown food is toxicologically unsafe, particularly in respect of E.coli and aflatoxins.

E.coli

E.coli is a natural commensal in humans and animals but only some strains are virulent. The original assertion that organically grown food is more likely than non-organically grown food to cause food poisoning because of the use of manures as fertilisers came from Dennis Avery of the Hudson Institute. His article ‘The hidden dangers of organic food’ began “According to recent data compiled by the US Centres for Disease Control (CDC), people who eat organic and ‘natural’ foods are eight times as likely as the rest of the population to be attacked by a deadly new strain of E.coli bacteria (o157:h7)”.[1] His interpretation of the data is fundamentally flawed and misleading, given the sole use of data from the only year (1996) since testing began in 1984 that any organically grown foods were involved in E.coli poisoning, and the grouping of organic with ‘natural’ foods (in this case, non-organic unpasteurised apple juice). A subsequent *New York Times* investigation of the organic lettuces involved established that the E.coli came from water to a packing plant contaminated by run-off from a

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19 Mislevic PB, Bruce VR and Andrews WH, 1979, ‘Mycological survey of selected health foods’, *Appl Environ Microbiol* 37(3), p 567–571
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23 Kuhn F, 1999, ‘Bestimmung von trichothecenen im weizen aus verschiedenen anbausystemen mittels HPLC-MS’, in *Organische Analytische Chemie*, University of Basel, Basel, Switzerland, p 60
24 Tamm L and Thurig B, 2001, ‘Chapter 3: mycotoxins’, internal review paper, FiBL (the Research Institute of Organic Agriculture), Switzerland, (yet to be submitted)
25 Gilbert J and Shepherd M, 1985, ‘A survey of aflatoxins in peanut butters, nuts and nut confectionery products by HPLC with fluorescence detection’, *Food Add Contam* 2, p 171–183
26 Sams C, 2000, founder and president of Whole Earth Foods, speaking on the *Food Programme*, BBC Radio 4, UK 17 Sept 2000
27 Clancy K, 1986, ‘The role of sustainable agriculture in improving the safety and quality of the food supply’, *American Journal of Alternative Agriculture* 1, p 11–18
28 Vogtmann H, 1984, ‘Socio-economic aspects of biological agriculture’, in *Alterations in Food Production*, Knorr D and Watkins T (eds.), p 11–40, Van Nostrand Reinhold publishers, New York

nearby non-organic dairy farm, and had nothing to do with the way the lettuces were grown.[2]

E.coli in manure

The first issue with E.coli is its presence in manure. The CDC identifies the main source for human infection with E.coli o157 as meat contaminated by cattle faeces during slaughter, which can cause acute renal failure in children and around 200 and 40 deaths each year in the US and UK respectively.[3,4]

A key difference between organic and non-organic cattle is their diet. Organic standards require that cattle are fed diets with a high proportion (minimum 60 per cent by Soil Association standards) of grass, silage and hay, while non-organic animals are often fed a predominantly grain-based diet.

Different findings have been reported regarding the influence of diet on the presence of E.coli in the digestive tracts of cattle. On the one hand, it has been reported that cows fed mainly with hay have much lower levels of generic E.coli in their digestive tracts than grain-fed animals.[5] On the other hand, researchers who infected grain-fed and hay-fed cattle with E.coli o157:h7 found that it lived for longer in the digestive tracts of hay-fed cattle (average 42 days, compared with four days in grain-fed cattle).[6] Other researchers have found no epidemiological correlation between diet and incidence,[7] and one explanation put forward to explain the different findings is that "perhaps grain-fed animals are kept in more heavily contaminated environments or in environments that promote transmission of infection" that masks differences in incidence brought about by diet.[6]

E.coli contamination of crops

The second issue with E.coli is the use of manure as fertiliser. Concerns persist that the use of manures in organic agriculture raise the risk of E.coli poisoning from organic vegetables. It is clear that the bacterium is present in manure, though when comparing the hazards this poses in organic and non-organic systems it should be remembered that organic farming in the UK accounts for only a small fraction of manure applied to the land. Also, organic standards include clear recommendations as to how it should be composted before use with the specfic intention of killing potential pathogens. Research at the Louis Bolk Institute in the Netherlands has shown that during composting, temperatures of 60 degrees can be attained, killing most pathogens.[8] Appropriate management of manure plays a critical role in preventing the persistence of pathogens including E.coli on all farms, and careless application of manure has led to cases of food poisoning.[9,10]

According to the FSA "Soil Association recommendations for manure storage and treatment on organic farms are likely to lead to enhanced reductions in the levels of pathogens in stored manures which are destined to be spread to land".[11] In a frequently cited case of E.coli poisoning from a manured garden in which a two year old girl died,[12] no record was made of the method of cultivation other than 'manured', so it is not possible to make a comparison of organic and non-organic methods from this case.

The Soil Association is not aware of any case of E.coli poisoning arising from certified organic production methods, and both the FSA and the Royal Agricultural Society of England have concluded that there is no evidence at present to support the assertion that organically grown produce is more or less microbiologically safe than non-organically farmed produce.[11,13] This was recently confirmed by a survey of 3,200 samples of uncooked, ready to eat organic vegetables which detected no Lysteria m., Salmonella, Campylobactor or E.coli o157 in any sample.[14]

Aflatoxins

Aflatoxins and other mycotoxins are potentially carcinogenic by-products of fungal growth,[15] and are found in foods after fungal attack. Many foods are affected but cereals and peanuts are particularly susceptible. It has been suggested that organically produced food has higher aflatoxin levels than non-organically produced food, based on the assumption that because organic farming prohibits the use of fungicides, organically grown crops and foods will therefore be more susceptible to fungal attack. However there is no evidence that this is so – indeed organic farmers contend that their crops are far less prone to fungal diseases than those grown with artificial fertilisers, as high doses of nitrogen speed up the growth of non-organic crops and result in the thinning of the plant cell walls[16] which are then more prone to fungal attack, both before and after harvest.

Concerning mycotoxin contamination of cereals, many studies have found no significant differences between organically and non-organically produced cereals.[17–21] Conversely, both higher and lower levels have been reported in organically grown cereals.[22,23] An extensive review of this subject found that the use of fungicides can actually increase mycotoxin production on cereals, that organically grown cereals are less prone to mycotoxin contamination prior to harvest than non-organically grown grains, and that inadequate storage is the most likely cause of increased contamination levels in either organically or non-organically produced grain.[24]

There is no evidence that organically grown peanuts are more prone to mycotoxin contamination than those non-organically grown. A study sometimes cited as evidence of this was not actually a comparison of organically and non-organically grown products.[25] Organically certified peanuts have only been commercially available since 1988, and annual tests since that time by a UK organic peanut butter manufacturer have consistently found aflatoxin levels lower than industry standards.[26]

It appears likely that storage, not farming conditions, is responsible for most aflatoxin production,[27] and some researchers have suggested that the fungicides used to control moulds could be more toxic than the aflatoxins themselves.[28]

The FSA confirmed that "there is no evidence to indicate that organically grown food is more prone to mycotoxin contamination than conventionally grown food".[11]

3.1.3 | Genetic modification

"Any conclusion upon the safety of introducing genetically modified materials into the UK is premature as there is insufficient evidence to inform the decision making process at present."
British Medical Association[1]

The Soil Association has numerous environmental, social, ethical, economic, and political concerns about the use of biotechnology in agriculture, though only concerns pertaining to food safety are discussed here. Genetic engineering (GE) involves the artificial insertion of a gene from one organism into the genetic material of another. There are many differences from traditional breeding methods and some scientists have suggested that there could be serious potential risks to health, related to the fact that the effects of the interactions of different genes and the process of gene transfer are not fully understood nor the procedures for controlling them.[2] Problems could arise from:

- *Potential absence of controlling factors*
  In nature, genes are regulated by a huge number of transcriptional factors and by many other events (post-transcriptional and post-translational) that control, for example, when or where in the plant the functional gene should operate. Many factors regulate many different genes, and they map at many different positions in the genome. While some of the genes for regulatory factors have been identified, the effects of single gene transplants – perhaps without their regulatory factors, many of which have not yet even been identified – cannot be known. This raises doubts over the claim that it is preferable to have a single known change (for example the insertion of a transgene) than a lot of unknown ones such as in traditional breeding and hybridisation.
- *Unpredictable effects*
  Genes interact with those around them. As a result of the random location of the inserted gene and absence of regulating factors, unknown interactions can take place between the inserted gene and the rest of the plant genes, causing unexpected outcomes that can impact on any characteristic of the plant, and could even disrupt beneficial processes. Unexpected changes that could affect the nutritional quality or allergic potential of the resulting crops have been identified in genetically modified (GM) rice and soya.[3,4] It is hard to see how all the unintended and unexpected consequences could be identified and excluded from GM seeds. Indeed, in the US some side effects have been identified in GM crops only once they were being commercially grown.[5]
- *Gene transfer to other organisms*
  During the genetic engineering process, to ensure a high take up of the foreign gene and to identify if the transfer has been successful, most current GM crops are produced using gene promoters and markers of viral or bacterial origin. In its recent report on the safety aspects of GM foods the World Health Organisation stated "There is no evidence that the markers currently in use pose a health risk to humans. Nevertheless, with the variable gene transfer frequencies noted in current literature, the transfer and expression of a functional antibiotic resistance gene to recipient cells, while remote, cannot be ignored". Further, "Bacteria that are susceptible neither to culture nor identification represent a significant proportion of the existing microflora. Therefore, without available knowledge of these bacteria, it is not possible to assess the possibility, probability or consequences of their acquisition of genes or gene fragments".[3] Horizontal gene transfer from genetically modified organisms (GMOs) to other organisms has been observed.[6]
- *Very little safety testing*
  Biotechnology companies have persuaded the authorities that GE is not significantly different from traditional breeding methods, so there has been very little research into establishing the health and safety consequences. Despite the importance of this subject, in the decades of GE development there have been very few published studies on the health effects of GMOs, though at least three have shown negative effects.[7–9]

The Royal Society has recently set up a working party (announced 12 March 2001) to investigate the human health consequences of consuming GM foods.

The British Society for Allergy, Environmental and Nutritional Medicine, a society of doctors who look for the causes of disease, especially nutrient deficiencies, allergies and toxic overload, have stated "We have particular concerns about the effects of GM foods on patients. Namely:

- GM foods may cause difficulty for people who are allergic because antigens may appear unexpectedly in totally unrelated foods.
- GM foods may contain levels of micronutrients different from the originals and this seems to have been less than adequately researched.
- Those GM crops which are modified for pesticide resistance permit farmers to apply more pesticides to a crop without damage. (Recent investigations have found, despite repeated claims by the biotechnology industry that this would not happen, that up to 30 per cent more herbicides are used on Round-up Ready soya grown in the US).[10]
- Those GM crops which are modified for pest resistance may contain high levels of natural insecticides, such as lectins, which may well have a deleterious effect on the health of the animal or human consuming that food".[11]

In a February 1999 statement from the UK's chief scientific advisor, Sir Robert May, he concludes "there can be questions of health and safety associated with some GM foods, particularly if we introduce genes coding for production of toxins against certain kinds of pests".[12] Together with the chief medical officer, Liam Donaldson, Sir Robert wrote that "although there is no current evidence to suggest that the GM technologies used to produce food are inherently harmful … nothing can be absolute in a field of rapid scientific and technological development".[13]

Despite these concerns, several GM crops have been declared substantially equivalent to regular crops and are being marketed. The Soil Association believes the technology is under-developed, the risks to human health and the environment are unknown, and that the precautionary principle should be upheld. These issues are discussed further in section 5.

Genetic engineering is prohibited in organic farming and food production.

3.1.4 | **Antibiotics**

Antibiotics are used in animal husbandry for two purposes – to treat or prevent disease and to promote growth. Intensive animal husbandry typically involves crowding animals into confined and enclosed spaces, and animals kept in such conditions must be treated prophylactically or therapeutically with antibiotics in order to prevent the spread of bacterial infections which could otherwise ruin the flock or herd.[1–3] A by-product of prophylactic sub-therapeutic antibiotic use is the improvement of the animals' growth rate through more efficient feed conversion.

The growth promoting, prophylactic and routine use of antibiotics in agriculture is of mounting concern to governments and the medical profession, and there is growing evidence that it is contributing to increasing antibiotic resistance in pathogenic bacteria. Antibiotics in animal feed are currently under review in the EU and several of those used as growth promoters are already banned, contributing to a 21 per cent reduction in UK sales of farm antibiotics to 448 tonnes in 1999.[4] A WHO meeting of 70 health experts concluded in 1997 that "Resistant strains of four bacteria that cause disease in humans have been transmitted from animals to humans and shown to have consequences for human health. They are Salmonella, Campylobacter, Enterococci, and E.coli".[5]

There is also concern that antibiotic residues in meat and dairy products could result in the development of antibiotic resistance in bacteria that are prevalent in humans, thereby reducing the effectiveness of antibiotics used to treat human disease.[6] While this hypothesis is contested by some,[3] recent research has shown that bacteria passing through human intestines exchange genes with the resident bacteria, and 80 per cent of a major bacterial species found in the colons of people in the late 1990s carried tetracycline resistance genes, compared with 30 per cent before 1970.[7] The

3.1.3

1 BMA, 1999, *The Impact of Genetic Modification on Agriculture, Food and Health*, an interim statement, Board of Science and Education

2 Brown P, 2000, *The Promise of Plant Biotechnology – The Threat of Genetically Modified Organisms*, College of Agriculture and Environmental Science, University of California

3 World Health Organisation, 2000, 'Safety aspects of genetically modified foods of plant origin', Report of a joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology, Geneva, Switzerland, 29 May–2 June 2000

4 Nordlee JA, Taylor SL, Townsend JA, Thomas LA and Bush RK, 1996, 'Identification of a Brazil Nut allergen in transgenic soyabeans', *New England Journal of Medicine* 334(11), p 688–692

5 More lignin was found in GM soya causing stunted, weak stems, *New Scientist*, 20/11/99, 'Deformed buds in GM cotton', *Ecology and Farming*, Jan 1999

6 In 1976, virologists at the National Institute of Health in the US found that tumour causing genes inserted into a bacteria transferred to mice. Cited in *Genewatch* 13(3), July 2000, the bulletin of the Council for Responsible Genetics. While it is not suggested that these genes known to cause tumors would be used in GM food, this study demonstrates how the expression of inserted genes can be transferred from one organism to another, and the effects of foreign genes in all possible locations of another genome are not known

7 Ewen SWB and Pusztai A, 1999, 'Effect of diets containing genetically modified potatoes expressing Galanthus nivalis lectin on rat small intestine' *The Lancet* 354, p 1353–1354

8 See *www.biointegrity.org*

9 *Chardon LL Hearing: Transcript of Proceedings Day 14, Tuesday 24 Oct 2000, Novotel Conference Centre, London*, published at www.maff.gov.uk/planth/pvs/chardon/001024.pdf

10 Greenpeace, 2001, 'New study finds Monsanto soya means more pesticides in the environment', using 1998 USDA data, available at www.greenpeace.org/monsanto_may4.htm

11 Dr K Eaton and Dr S Myhill, BSAENM, 2001, Letter to the Editor, *The Independent*, 20 January 2001

12 May R, 1999, *Genetically Modified Foods: Facts, Worries, Policies and Public Confidence*, Office of Science and Technology, London

13 Donaldson L and May R, 1999, *Health Implications of Genetically Modified Foods*, Department of Health, UK

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1 Body R, 1991, *Our Food, Our Land – Why Contemporary Farming Practices Must Change*, Rider, Random Century Group, London

2 Conway GR and Pretty JN, 1991, *Unwelcome Harvest – Agriculture and Pollution*, Earthscan Publications, London

3 Sundlof S, 1997, *Antibiotics in Animals – an Interview with Stephen Sundlof, DVM, PhD*, International Food Information Council, Washington DC

4 MAFF, 2001, 'Farmers cut back on use of antibiotics', Press Release 56/01, 19 February. See also: 'Sales of antimicrobial products used as veterinary medicines or growth promoters in the UK in 1999', Veterinary Medicines Directorate website www.vmd.gov.uk

5 World Health Organisation, 'Antibiotic use in food-producing animals must be curtailed to prevent increased resistance in humans', press release WHO/73, 20 October 1997

[6] Food Ethics Council, 1999, *Drug use in Farm Animals*, Food Ethics Council Report, UK
[7] Salyers A *et al*, 2001, *Applied and Environmental Microbiology* 67, p 1494
[8] VMD, 1997, *Annual Report on Surveillance for Veterinary Residues in 1996*, Veterinary Medicines Directorate, Surrey, UK
[9] Young R and Craig A, 2001, *Too Hard to Swallow: the Truth About Drugs and Poultry*, Soil Association, UK
[10] BMA, 1999, 'The impact of genetic modification on agriculture', *Food and Health, a Report from the BMA*

3.1.5

[1] SEAC: Summary of public meeting,17 July 2000, UK
[2] Peter Jones, 2001, CJD Policy Team, Department of Health, UK, *personal communication, 21 May 2001
[3] Roy Smith, 2001, Executive Officer in the BSE Division of MAFF UK, *personal communication, 11 May 2001

3.1.6

[1] Clayton P, 2001, *Health Defence*, Accelerated Learning Systems, Bucks, UK, p 246
[2] Clancy K, 1986, 'The role of sustainable agriculture in improving the safety and quality of the food supply', *American Journal of Alternative Agriculture* 1, p 11–18
[3] Hanssen M and Marsden J, 1987, *E for Additives*, 2nd Edition, Harper Collins, UK
[4] Holford P, 1998, *100% Health*, Piatkus, London, p 128–132
[5] Ward NI, Soulsbury KA, Zettel VH, Colquhoun ID, Bunday S and Barnes B, 1990, 'The influence of the chemical additive tartrazine on the zinc status of hyperkinetic children. Double blind placebo-controlled study', *Journal of Nutritional Medicine* 1, p 51–57
[6] Booth J, 1993, 'Food intolerance in a child with urticaria', *Journal of Human Nutrition and Dietietics* 6, p 377–379
[7] Fuglsang G, Madsen C, Saval P *et al*, 1993, 'Prevalence of intolerance to food additives among Danish schoolchildren', *Pediatr Allergy Immunol* 4(3), p 123–129
[8] EC Multicentre Study on Antioxidants, 1997
[9] Willet W *et al*, 1993, 'Intake of trans fatty acids and risk of coronary heart disease among women', *The Lancet* 341(8845), p 581–585
[10] Triosi R *et al*, 1992, *Am J Clin Nut* 56, p 1010–1024
[11] Erasmus U, 1999, *Fats That Heal, Fats That Kill*, 2nd Edition, Alive Books, Canada
[12] Mensink RM *et al*, 1990, *New Eng J Med* 323, p 439–445
[13] Reported in *The Times*, 5 September 1997
[14] Wyshak G, 2000, 'Teenage girls, carbonated beverage consumption and bone fractures', *Archives of Paediatric and Adolescent Medicine* 154(6), p 610–613
[15] Balch JF and Balch PA, 1997, *Pres for Natural Healing*, 2nd Edition, Avery, USA
[16] Roberts HJ, 1990, *Aspartame (Nutrasweet) – is it safe?*, The Charles Press, USA
[17] Koehler GM, 1988, 'The effect of aspartame on migraine headache', *Headache* 28(1), p 10–14
[18] Lipton RB, 1989, 'Aspartame as a dietary trigger of headache', *Headache* 29(2), p 90–92
[19] HDRA, 2001, *Specific Aspects of the Quality of Organic Food*, (unpublished report)

excessive and often inappropriate use of antibiotics in medical practice is also recognised as a major contributor to the problem, though it is thought that agricultural use has played a significant role. While many of the antibiotics used routinely in agriculture are not the same ones used to treat disease in humans, there are overlaps. The agricultural use of the fluoroquinolone family of antibiotics is under review as they are also used to treat many serious infections in humans.

The UK Veterinary Medicines Directorate (VMD) monitors residues of veterinary medicines in animal products and typically finds very few samples with antibiotic residues above the action level, the level at which the VMD investigates and acts to prevent a recurrence.[8] Concerns have been raised, however, about how the VMD reports its findings. A recent Soil Association investigation has discovered that incidences of detectable antimicrobial and antiparasitic drug residues in chicken meat and eggs may be up to 20 times higher than are being reported by the VMD.[9]

The House of Lords select committee on science and technology concluded in a 1999 report that "There is a continuing threat to human health from imprudent use of antibiotics in animals", and that the "misuse and overuse of antibiotics are now threatening to undo all their early promise and success in curing disease". The WHO has called for a reduction in the use of antibiotics in agriculture because of the risk to human health, adding that healthy animal husbandry would lessen the need for drugs which, it said, should never be used to prop up inadequate hygiene.[5] The British Medical Association (BMA) has warned "The risk to human health from antibiotic resistance developing in micro-organisms is one of the major public health threats that will be faced in the 21st century".[10]

Despite these concerns, antibiotics are still used widely by non-organic livestock farmers as growth promoters or for disease suppression by routinely adding them to feed and water.

The routine use of antibiotics to curb disease outbreaks or promote growth is prohibited in organic standards. Instead, disease outbreaks are minimised by the avoidance of dense stocking levels or intensive housing and the promotion of positive animal health through good husbandry and free-range conditions. The veterinary use of antibiotics is minimised and strictly controlled, and withdrawal periods after administration of a veterinary drug are stricter than those recommended in order to prevent detectable residues in meat or milk.

3.1.5 | BSE

In 1996, the UK government announced the suspected link between cases of new-variant-Creutzfeldt-Jakob Disease (vCJD) in humans and exposure to Bovine Spongiform Encephalopathy (BSE). Since then there have been around 100 confirmed deaths from vCJD, and the Spongiform Encephalopathy Advisory Committee (SEAC) has identified a rising trend of 20–30 per cent more new cases each year.[1] Because of the many unknowns about vCJD (for example the incubation period, the role of genetic susceptibility, infectious dose), accurate predictions of the total number of people who will be affected by the disease are difficult. Models have produced estimates ranging from about 100 cases to over 100,000.[2*]

The Soil Association banned the feeding of animal proteins to ruminants in 1983, five years before the ministry of agriculture began to take similar action to combat BSE in cattle, first identified in 1986. Soil Association standards prohibit any animal not born and reared on an organic farm from ever being sold as organic beef. Breeding replacements can be brought in, and dairy cattle can become organic milk producers after a minimum three, and maximum nine, month conversion period (depending on the situation). But no cattle can be brought into an organic herd if they are the cohorts or progeny of a confirmed BSE case.

"Cases of BSE have fallen considerably in conventional herds since MAFF, having first introduced feed controls for ruminants in 1988, further banned the feeding of mammalian meat and bonemeal to all farmed livestock in 1996, to prevent cross-contamination of ruminant feed. In May 2001 some 20 new suspect cases are still being reported each week (down from a thousand per week at the peak in winter 1992–93). These are considered to be the tail-end of the epidemic caused by exposure via feed. It is projected that the current rate of reported suspects will fall to less than 650 annual cases by the end of 2001, and by 2004 to be on track for fewer than 30 annual cases in 2006".[3*]

After exhaustive searches of both its own records and those of other certifying bodies of organic cattle in the UK, the Soil Association has found no recorded cases of BSE in any animal born and reared organically. Cases of BSE *have* been recorded in registered organic herds, however these animals have always been cattle brought in from a non-organic source.

3.1.6 | Food additives and ingredients

Because of the restrictions on additive use required by organic food processing standards, a wide range and large quantity of potentially allergenic or harmful additives are avoided on a diet high in organically grown foods. It is estimated that the average American consumes over two kilograms of additives each year.[1]

Artificial food additives are widely used in the modern food processing industry. Many of them are relied on to put back the taste that processing often removes, to prevent spoilage or to improve the texture, colour or flavour of foods. They are present in extraordinary abundance in the food supply, and several have been found to be unsafe after long use. Many are untested, and their widespread use

20 Rumsaeng V and Metcalf DD, 1999, *Nutritional Reviews*, 56(1), 5153–5160
21 Scoppal, 1991, 'MSG and hydrolyzed vegetable protein induced headache: review and case studies', *Headache* 31(2), p 107–110
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3.1.7

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continues despite questions about their safety.[2]

More than 500 food additives are permitted for use in non-organic processed foods.[3] Food colourings such as tartrazine and other additives have been linked with symptoms such as allergic reactions, urticaria, headaches, asthma, growth retardation and hyperactivity in children.[3–6] Danish researchers using double-blind placebo controlled challenges have calculated that one to two per cent of school-age children have an intolerance to food additives such as preservatives, colourings and flavourings.[7] In contrast, organic standards permit only a limited list of around 30 additives which are allowed in organic food products only if the authenticity of the product is respected and the product cannot be produced or preserved without them. Specific ingredients and additives not allowed in organic food products include:

- *Hydrogenated fats*
  No hydrogenated fats are used in organic food. Also known as 'trans-fats', they are created artificially by the hydrogenation process and are included in many processed foods to make the product more solid (for example, in biscuits and margarines). They are rare in nature, and consumption of hydrogenated fats has been directly linked to substantially increased rates of heart disease, cancer and skin disease.[8–11] Higher intakes of trans-fats have been shown to increase levels of LDL cholesterol (the 'bad' cholesterol), and decrease HDL cholesterol (the 'good').[12] In 1994 the Committee on Medical Aspects of Food Policy recommended reducing the amount of hydrogenated fats in the British diet,[13] but they are still widely used and are present in many processed foods.
- *Phosphoric acid*
  No phosphoric acid is used in organic food or drinks. Phosphoric acid is a highly acidic ingredient in cola drinks. The way the kidneys excrete it is by buffering it with calcium taken from bone reserves which can leave the bones porous and brittle and increase the risk of osteoporosis.[1] Athletic teenage girls who consume cola drinks have been found to have five times the risk of bone fractures of those athletic girls who do not consume cola drinks.[14]
- *Aspartame*
  Aspartame is banned from organic food and drinks. Aspartame (marketed as Nutrasweet, Equal and Spoonful) is the most widely used artificial sweetener in the world. It is found in a wide range of products including diet foods, chewing gum, fizzy drinks, sweets, breakfast cereals, frozen desserts and yoghurt. Despite assurances from the US Food and Drug Administration that it is safe, a significant number of people have reported suffering from ill-effects as a result of aspartame consumption.[15] Reported reactions include headaches, mood swings, changes in vision, nausea and diarrhoea, sleep disorders, memory loss and confusion, convulsions and seizures.[16–18]
- *MSG*
  The flavour enhancer monosodium glutamate is banned from all organic food. It is thought to be responsible

for 'Chinese restaurant syndrome' which can involve dizziness, headaches and perspiration, and may also cause asthma attacks.[19–21] Australian researchers concluded that "MSG can provoke asthma … the higher the dose, the more likely the attack … and is not safe for some individuals."[22] It is not permitted in baby foods and is prohibited from all organic food.

- *Sulphur dioxide*
  Sulphur dioxide often causes problems in individuals who have asthma.[3] Foods that may contain sulphur dioxide include fruit juices, soft drinks such as squashes, dried fruit, wine, beer, sauces and pickles. Organic regulations prohibit sulphur dioxide in these foods with the exception of wine, where the permitted level is one third the EU maximum for non-organic wine. Organic producers are developing ways of creating sulphur free wines.

3.1.7 | **Nitrate**

Nitrate is a natural constituent in plants and is present in all vegetables, with high levels commonly found in green vegetables such as spinach, lettuce and celery, and root vegetables such as beetroot and radish. Other sources include fruits, dairy products, grains/bread and cured meats, though these represent only a fraction of those ingested in vegetables.[1] Nitrate concentrations in ground water are also increasing through leaching of nitrogenous fertilisers.[2] Several factors influence the accumulation of nitrate in plants including lack of sunlight or water, variety, maturity and high levels of fertilisation.[3] Numerous researchers have confirmed that the nitrate levels in vegetable crops are higher when nitrogen is supplied in high-dose inorganic form than when supplied from compost or other organic manures.[4,5] Even when fertilised with excessive amounts of composted farmyard manure the risk of high nitrate concentrations in organically grown vegetables appears to be very low.[6]

A review of 16 valid studies comparing the nitrate contents of organically and non-organically grown fruit and vegetables (see section 3.2.3 and appendix) revealed the following: 14 studies demonstrated a trend toward significantly lower nitrate contents in organically grown crops,[6–19] averaging around 50 per cent lower, and two studies found inconsistent or not significant differences.[20–21]

Overall trend demonstrated within studies comparing the nitrate content of organically and non-organically grown fruit and vegetables on a fresh-weight basis

Studies showing:

Lower nitrate content in organically grown crops
■■■■■■■■■■■■■■ 14

Inconsistent or non-significant difference
■■ 2

Lower nitrate content in non-organically grown crops
None

Until recently nitrate was perceived to be a purely harmful dietary component, linked to gastric cancer and infantile methaemoglobinaemia (blue baby syndrome). Some researchers have concluded that the "health risks from the ingestion of nitrate have been widely discussed and though the evidence is by no means conclusive, it would appear to be sufficient to encourage a cautious approach".[22] Others explain further – "In the quantities normally occurring in food, nitrate becomes toxic only under conditions in which it is reduced to nitrite and nitrosamine. At reasonable concentrations nitrate is rapidly excreted in the urine".[3] It has also been shown that nitrate itself, at typical dietary levels, may have beneficial effects.[23]

High intakes of nitrate may then constitute a hazard only under conditions that are favourable for its reduction to nitrite. This can occur in people of all ages but is a particular risk in infants whose lower stomach acidity may permit the growth of micro-organisms that can reduce nitrate to nitrite. Numerous deaths from this source have been reported,[3] and also a number of cases of toxicity in infants from (nitrate rich) spinach stored under conditions that permit the growth of micro-organisms which can reduce nitrate to nitrite (for example, left at room temperature for some time after cooking or after a jar of baby food was opened).[3,24] A direct source of nitrite in the diet is cured meats (including organic), but they typically only contribute around half of the levels formed in the saliva from nitrate.[1]

Ascorbic acid (vitamin C) can afford protection from this conversion of nitrate to nitrite to nitrosamines,[23,25] so it is of some interest that the higher levels of nitrate in non-organic crops have often been linked with lower ascorbic acid levels,[7–9,12,15–17] as confirmed by previous reviews.[4,5]

Nitrosamines are known carcinogens in animals[26,27] including primates,[28] and although no cancer in humans has yet been traced to nitrosamines as causative agents, the experimental results in animals suggest that these compounds would also be carcinogenic in humans.[3] Nitrosamines can result when nitrite, formed in the saliva from nitrate, is swallowed into the stomach and combines with amines from digested foods.[29] It has been argued that the falling rates of stomach cancer in recent decades are evidence that nitrosamines are not carcinogenic in humans. However in animal toxicity trials that established nitrosamine carcinogenicity, local sarcomas were rarely observed at the site of the injection. It seems, therefore, that the nitrosamines themselves are not carcinogens but may behave as carcinogen precursors,[3] and although they are formed in the stomach, they could cause cancer elsewhere.

Researchers from the US Department of Agriculture concluded "Nitrate is not toxic per se, but may under some circumstances be the starting point for a chain of reactions that result in the conversion to toxic substances. Hence, prudence dictates that we monitor the nitrate content of our foods and water supply … and be aware of actions that can lead to decreasing the amount of nitrate in foods".[3]

3.2 Primary nutrients

It is often stated that insufficient research has been carried out comparing the nutritional quality of organically and non-organically grown foods, but literature reviews conducted in the late 1990s identified hundreds of papers examining this question. Superficially, it is difficult to explain the inconclusive, conflicting and confusing results reported, though a closer examination of the methodologies of these studies exposes many common flaws. By taking these into consideration the picture may become considerably clearer.

3.2.1 Previous reviews

There have been at least five major literature reviews comparing the nutritional quality of organically and non-organically grown crops in the last five years. Their outcomes are summarised here:

- *Woese, Germany (1997)*[1]
  Review of "the results of 150 papers". Reveals "some differences": organic produce had lower nitrate, lower pesticide residues, higher dry matter, trend toward higher vitamin C, clear animal preference shown. Inconsistent or no difference in mineral contents.
- *Worthington, USA (1998)*[2]
  Sixty or so papers comparing nutrient contents and animal health. Examined 1,230 individual nutrient comparisons. 56 per cent showed better nutrient levels in organically grown crops, 37 per cent favoured non-organically grown crops. Data averaged 10 to 20 per cent in favour of organic; concluded there was a "pattern of better nutrient composition and better health in animals consuming organic food."
- *Diver, USA (2000 – revised)*[3]
  Discusses declining food quality in the industrialised food production system; points out that there are many factors influencing food quality other than method of agriculture; concludes "the data on nutritional quality of organic produce in comparison to conventional produce are inconclusive"; discusses holistic methods of food quality determination.

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2 Worthington V, 1998, 'Effect of agricultural methods on nutritional quality: a comparison of organic with conventional crops', *Alternative Therapies Health Med* 4(1), p 58–69

3 Diver S, 2000, *Nutritional Quality of Organically Grown Food*, ATTRA (Appropriate Technology Transfer for Rural Areas), Arkansas, US

4 Brandt K and Mølgaard JP, 2001, 'Organic agriculture: does it enhance or reduce the nutritional value of plant foods?', *Journal of the Science of Food and Agriculture* 81, p 924–931

5 Williams CM, Pennington TH, Bridges O and Bridges JW, 2000, 'Food quality and health', *Shades of Green, a Review of UK Farming Systems*, Royal Agricultural Society of England, p 73–90

6 Saffron L, 1997, 'Agriculture, food and cancer risk', Bristol Cancer Help Centre

7 Soil Association, *Standards for Organic Food and Farming*

8 Abele U, 1987, 'Product fertilisation and quality – mineral, organic, biodynamic', *Angewandte Wissenschaft* 345

9 Ahrens E, Elsaidy S, Samaras I, Samaras F and Wistinghausen E, 1983, 'Significance of fertilisation for the post-harvest condition of vegetables, especially spinach', in *Environmentally Sound Agriculture*, 4th IFOAM Conference, Cambridge MA, Selected Papers, Lockeretz W (ed.), Praeger, New York, p 339–346

10 Alenson C, 2000, 'Nutritional study of vegetables grown on revitalised soil in Australia', *Elm Farm Research Bulletin* No. 49, May 2000

11 Alfoldi Th, Mader P, Niggli U, Spiess E, Dubois D and Besson J-M, 1996, 'Quality investigations in the long-term DOC-trial', *Quality of Plant Products Grown with Manure Fertilization: Proceedings of the Fourth Meeting* (Juva, Finland, July 6–9 1996). Darmstadt; Germany: Institute for Biodynamic Research, p 34–43

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13 Appledorf H, Wheeler WB, Koburger JA, 1973, 'Health foods versus traditional foods: a comparison', *Journal of Milk and Food Technology* 36(4), p 242–244

14 Assano J, 1984, 'Effect of organic manures on quality of vegetables', *Japan Agricultural Research Quarterly* 18(1), p 31–36

[15] Barker A, 1975, 'Organic vs inorganic nutrition and horticultural crop quality', *HortScience* 10, p 50–53
[16] Basker D, 1992, 'Comparison of taste quality between organically and conventionally grown fruits and vegetables', *American Journal of Alternative Agriculture* 7(3), p 129–136
[17] Bear FE, Toth SJ and Prince AL, 1948, 'Variation in mineral composition of vegetables', *Proceedings of the Soil Science Society of America 1948*, p 380–384
[18] Blanc D, Gilly G, Leclerc J, Causeret J, 1984, 'Long term effects of organic or mineral fertiliser treatment on the composition of lettuce and potatoes', *Sciences des Aliments* 4 (special issue), p 267–272
[19] Borghi B, Giordani G, Corbellini M, Vaccino P, Guermandi M and Tolderi G, 1995, 'Influence of crop rotation, manure and fertilisers on the bread making quality of wheat (Triticum aestivum L)', *European Journal of Agronomy* 4(1), p 37–45
[20] Brandt CS and Beeson KC, 1951, 'Influence of organic fertilisation on certain nutritive constituents of crops', *Soil Science* 71(6), p 449–454
[21] Chang P and Salomon M, 1978, 'Metals in grains sold under various labels - organic, natural and conventional', *Journal of Food Quality* 1, p 373–377
[22] Clarke RP and Merrow SB, 1979, 'Nutrient composition of tomatoes home grown under different cultural procedures', *Ecology of Food and Nutrition* 8, p 37–46
[23] DeEll JR and Prange RK, 1993, 'Postharvest physiological disorders, diseases and mineral concentrations of organically and conventionally grown McIntosh and Cortland Apples', *Canadian Journal of Plant Science* 73(1), p 223–230
[24] Dlouhy J, 1977, 'The quality of plant products under conventional and biodynamic management', *Biodynamics* 124, p 28–32
[25] Dlouhy J, 1981, 'Product quality in alternative agriculture', *Food Quality – Concepts and Methodology*, Elm Farm Research Centre Colloquium, 1990, p 30–35
[26] Eggert FP, 1983, 'Effect of soil management practices on yield and foliar nutrient concentration of dry beans, carrots and tomatoes', in *Environmentally Sound Agriculture*, 4th IFOAM Conference, Cambridge MA, Selected Papers, Lockeretz W (ed.), Praeger, NY, p 247–259
[27] Eggert FP and Kahrmann CL, 1984, 'Response of three vegetable crops to organic and inorganic nutrient sources', in Kral DM and Hawkins SL (eds.) *Organic Farming: Current Technology and its Role in a Sustainable Agriculture*. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison WI, p 97–111
[28] Ehrenbergerova J, Vaculova K and Zimolka J, 1997, 'Grain quality of hull-less spring barley from different cropping systems', *Rostlinna Vyroba* 43(12), p 585–592
[29] El Sheikh EAE and El Zidany AA, 1997, 'Effect of rhizobium inoculation, organic and chemical fertilisers on yield and physical properties of faba bean seeds', *Plant Foods for Human Nutrition* 51(2), p 137–144
[30] Eltun R, 1996a, 'The Apelsvoll cropping system experiment iii. Yield and grain quality of cereals', *Norwegian Journal of Agricultural Sciences* 10(1), p 7–22
[31] Eltun R, 1996b, 'The Apelsvoll cropping system experiment iv. Yield and quality of potatoes, forage crops and entire cropping systems', *Norwegian Journal of Agricultural Sciences* 10(1), p 23–41
[32] Evers AM, 1988, 'Effects of different fertilisation practices on the growth, yield and dm content of carrot', *Journal of Agricultural Science in Finland* 60, p 135–152

- *Brandt & Molgaard, Denmark (2000)*[4]
  Examines potential health effects of consuming organic or non-organic produce. Nutrient content differences inconsistent and not dietarily important enough to alter nutritional value; secondary metabolites more important determinant of nutritional value, organic expected to be more health promoting but insufficient data available to assess significance of difference.
- *Williams et al, UK (2000)*[5]
  Looked at nutrient content, nutritional value, microbial toxicity, and pesticide residues. No new review of nutrient content (relied on Woese and Worthington); "moderately strong evidence" that organic feed has a beneficial effect on animal health; "no reliable data" to compare beneficial secondary nutrients; considered natural plant defence compounds and synthetic pesticide residues as being of equal risk; "limited evidence" supporting higher toxicological contamination of organic produce; concluded that the "widely held public view that organic foods are safer and healthier is incorrect for the great majority of consumers."

3.2.2 | **Re-examining the evidence**

In an effort to address a key issue often raised in previous reviews, that the quality of the studies is unsatisfactory and therefore firm conclusions cannot be drawn, this review has applied a set of strict criteria to ensure study validity. The Bristol Cancer Help Centre, in its 1997 report *Agriculture, Food and Cancer Risk*, called for just this approach, suggesting that "using strict inclusion criteria, it may be possible to reach a less ambiguous conclusion".[6]

For the purposes of this review then, in addition to current literature searches, as many as possible of the studies referred to in previous reviews have been collected, excluding the many small reviews, articles, opinions, dissertations, theses, unpublished papers and a small number of papers that were beyond the extensive resources of the British Library reference service. Relevant German studies referenced in Woese *et al's* review that compared the mineral contents of fruit and vegetables were specially sought and translated, adding two valid studies to this comparison.

Ultimately 99 papers claiming or claimed to make a direct comparison of the nutritional quality of organically and non-organically grown crops have been reviewed here. Flaws are evident in the methodologies of many of these studies, and as previous reviews have not assessed each paper for its validity or otherwise they have often been able to come to few, if any, conclusions. Industry, governments and critics of organic agriculture have seen this as evidence that agricultural practices have little or no influence on the nutritional content of crops.

3.2.3 | Criteria to ensure study validity

Comparative studies fall into three categories:

- *Field trials*
  Organically and non-organically cultivated crops grown in close proximity under controlled conditions.
- *Farm surveys*
  Crops are obtained from organic and non-organic farms, paired for location, climate, crop variety and soil type.
- *Market or 'shopping basket' surveys*
  Organically and non-organically produced samples are obtained from retailers, as they are available to consumers.

To allow a meaningful examination of how agricultural practices affect the nutrients in crops it is important to ensure that any comparative studies properly reflect the agricultural systems in question. The available studies were therefore assessed for validity in terms of agricultural practice and scientific analysis. Specifically:

- *Only data from certified organic produce, certified organic farms, or crops grown in soil in its third year (or more) of organic management can be considered a valid representation of organic agriculture for comparison with non-organic produce, farms and crops.*
  For a farm to receive full organic certification, which is legally required before labelling any produce as organic, it must undergo a two year conversion period, then is deemed fully organic from the third year on (by Soil Association standards).[7] This is to allow the development of soil fertility and a reduction in residual pesticides.
  Market or farm surveys where organic certification details are not given are judged valid or otherwise on a case by case basis. In the case of farm surveys this depends on whether details were given about the history of the soil and the specific cultural practices employed. In the case of market surveys, consideration has been given to the market conditions in the given time and place of the survey including the legal requirements for organic labelling in the state or country at the time of the study. For example, since January 1993 it has been illegal in the EU to label any item as organic that is not certified as such by a recognised certifying body, and thus one can be reasonably sure that any produce labelled as organic actually is. Judgements have been made on all available information and full explanations given in the appendix.

- *Agricultural practices in experimental trials must reflect typical practices within the respective methods of agriculture.*
  The practices employed with the comparative crops should ideally be described in the study, as interpretations and practices can vary widely from researcher to researcher, as indeed from farmer to farmer. Non-organic farming practices typically involve the use of chemical fertilisers, insecticides and herbicides, all of which can impact on the nutritional quality of the crop, so none of these practices should be purposely avoided in experimental trials. It is true that non-organic farming can incorporate many practices that protect and encourage biodiversity and soil fertility, usually referred to as 'integrated' farming. However the term 'integrated farming' can be used to describe a very wide range of approaches, from almost complete dependence on artificial inputs plus occasional or infrequent manure applications to a system very similar to the organic ideal plus very small amounts of chemical pesticides, herbicides or fertilisers. For the purposes of this review then, 'non-organic' farming is defined as a system involving a significant and ongoing dependence on artificial inputs for plant nutrition, weed and pest control.
  There are many differences among organic farmers also, though a clear distinction between organic and other systems of agriculture is that there exists a minimum set of standards and practices to which organic producers must comply in order to maintain their organic certification. Of course many organic farmers go beyond these minimum requirements, and biodynamic farming, which incorporates certain astrological and spiritual principles and practices is an example of this. For the purposes of this review, 'organic' farming includes 'biodynamic' and 'ecological' systems, and is defined by compliance with the International Federation of Organic Agricultural Movements (IFOAM) standards or those of the authorised local organic certifier (for example the Soil Association). Such standards are generally characterised by an avoidance of chemical fertilisers, herbicides and pesticides and use of specific measures such as composting, mulching and crop rotation to improve soil fertility and control pests.
  Care should be taken in field trials and farm surveys to control other influential factors such as soil type, geographical location, crop variety, and growing season. Use of unauthorised pesticides or fertilisers renders the study invalid. In market surveys, variety and source should be matched as closely as possible, and while these and other factors such as soil type, date of sowing and date of harvest cannot always be determined and controlled in these studies, their consumer relevance is often sufficient to supersede these uncertainties and render them worthwhile comparisons.
  Studies that compare fertilisation but not crop protection methods are accepted as valid comparisons of the two systems (so long as other practices do not invalidate the study), as the method of fertilisation plays such a significant role in the nutrient availability to and growth of crops.

- *Only comparisons of nutrients on a fresh-weight basis are considered.*
  Because organically grown produce often has a higher dry matter content than non-organically grown produce (see section 3.2.5), comparing nutrient contents on a dry-weight basis (where samples are completely dehydrated for analysis then the minerals are reported as a percentage of the weight of this dry component instead of the fresh-weight of the fruit or vegetable) eliminates the dilution

effect of the higher water contents of some non-organically grown produce, and could therefore skew the results. Comparisons on a fresh-weight basis are far more relevant to the consumer, who purchases and consumes them in this way.

- *Studies must include quality comparisons relevant to this review.* In other words, studies must focus on known essential nutritional components that arable and horticultural crops can provide a significant portion of in the typical human diet, and can therefore have an impact on health. This includes vitamin and mineral contents, and additionally for cereals, protein content and quality. In mineral comparisons, studies that compare the crop contents of only N, P and K which are applied to non-organically grown crops in relatively high doses and in a readily soluble form through the use of chemical fertilisers are unlikely to reflect the overall mineral composition of crops and are therefore not considered a valid comparison. However when a range of minerals are compared, including P and K, these essential minerals are included in the comparison. This is discussed further in section 3.2.5.

  Dry matter content is worthy of comparison also, representing the portion of crops that includes their nutritional contents. The many studies that examine levels of nitrate and its potential implications for health make this a component worthy of comparison, with results presented in section 3.1.

  Fat and carbohydrate contents of arable and horticultural crops are not included in this review. They are not generally compared in the available literature, and may not be significantly influenced by agricultural methods anyway. A brief section is included regarding the fat composition of livestock products, as some comparative research has been conducted in this area.

  All references to statistical significance correspond to a 95 per cent confidence level ($p<0.05$). Where statistical analysis has not been conducted, differences of ten per cent or less are not considered significant.

These criteria have been applied to each study fairly and without bias, using all available information. Where insufficient information was given in the paper itself, efforts have been made to contact the author and people with an expert knowledge of the market conditions in the relevant time and place. Rejected studies have included a wide range of outcomes, including some strongly in favour of organic produce. Two notable studies that have been used extensively by the organic movement in the past as 'proof' that organically grown produce is qualitatively better than non-organically grown produce (Bear 1948 and Smith 1993) are shown here to be invalid. A summary of all 99 studies with validity explanations can be found in the appendix.

Valid studies have been tabled in comparisons of nitrate contents (section 3.1.7), primary nutrients (3.2.5), secondary nutrients (3.3), taste (3.4.3), picture forming qualities (4.2) and storage degradation tests (4.3). It was not possible to assess the validity or otherwise of many animal feeding trials so all available studies (since 1975) have been presented in section 3.4.2 – organically grown food and animal health.

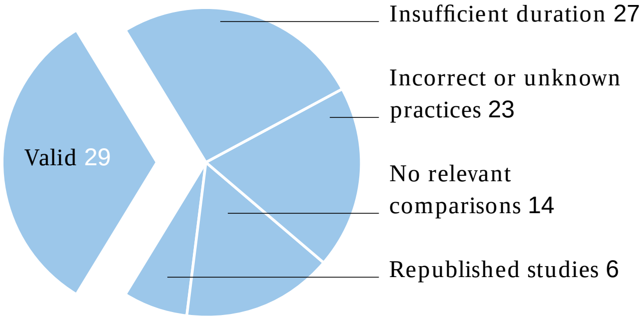
3.2.4 | Validity assessment outcome

Of the 99 studies reviewed, 70 were rejected for the following reasons:

- The study was not a fair and accurate comparison of organically and non-organically grown crops because of:
  1. Insufficient field trial duration on soil with no organic history, as is required for organic certification [27 studies].
  2. Incorrect or unknown practices employed in a field trial, or sampling was not of organically and non-organically grown produce (such as inclusions of 'natural', 'traditional' or uncertified organic produce for which confidence in the accuracy of the labelling could not be established) [23 studies].

- The study was a fair and accurate comparison of organically and non-organically grown crops but could not be included because of:
  1. A lack of quality comparisons relevant to this review (for example some studies make comparisons of yields, dry-weight basis mineral concentrations, technical processing characteristics, sugar content, fruit gradings, or soil properties), or data presentation that did not allow separation of valid and invalid data (such as a three year field trial in which only the third year would be valid to allow for a theoretical two year conversion period, but the data is presented as an average of all three years, so the valid third year data cannot be extracted) [14 studies].
  2. The paper was a republished version or portion of a previous study that did not add significantly to the results already reported (the same study is sometimes published in more than one scientific journal or presented at more than one conference) [6 studies].

Valid and invalid papers



Note: a summary of all 99 studies with complete validity explanations can be found in the appendix.

This is a significant defining point of this review: more than two-thirds of the published studies that claim or are claimed to compare the nutritional quality of organically and non-organically grown crops are rejected on the basis that they do not satisfactorily compare the two agricultural systems or do not make relevant comparisons. They often compare nutrient contents inappropriately on a dry weight basis, do not actually compare crops produced using recognised organic and non-organic farming practices, or compare the correct farming methods but for too short a period to properly represent certified organic farming which must go through at least a two year conversion period to improve the soil. Many of these invalid studies show little or no difference in nutritional quality between organically and non-organically grown crops and serve only to skew or obfuscate the overall result.

3.2.5 | Comparisons of primary nutrient contents in organically and non-organically grown crops

Of 29 valid studies, 27 compare the primary nutritional components of organically and non-organically grown crops, the other two comparing only nitrate contents[97] or secondary nutrients.[105] Altogether 22 studies included comparisons of dry matter, vitamin or mineral contents of fruits and vegetables, while eight studies included comparisons of vitamins, minerals, protein content and protein quality in cereals.

Fruit and vegetables

Twenty-two valid studies compared the primary nutrient contents of organically and non-organically grown fruit and vegetables:

- *Abele (1987)*[8]
  Field trial. Minerals P, K, Ca and Mg and dry matter in carrots, beetroot and potatoes, plus vitamin C in carrots and potatoes and vitamin A (carotene) in carrots.
- *Alfoldi et al (1996)*[11]
  Field trial. Minerals P, K, Ca, Mg, Cu, Mn, and Zn and dry matter content in potatoes.
- *Basker (1992)*[16]
  Farm survey. Dry matter content in tomatoes and bananas.
- *Blanc et al (1984)*[18]
  Field trial. Vitamins A, B and C content in lettuce.
- *DeEll & Prange (1993)*[23]
  Farm survey. Minerals P, K, Ca and Mg and dry matter content in apples.
- *Dlouhy (1981)*[25]
  Field trial. Vitamin C and dry matter content in potatoes.
- *Fischer & Richter (1986)*[35]
  Farm survey. Vitamin C content in potatoes.

33 Evers AM, 1989a, 'Effects of different fertilisation practices on the carotene content of carrot', *Journal of Agricultural Science in Finland* 61(1), p 7–14

34 Evers AM, 1989b, 'Effects of different fertilisation practices on the Ca, Mg, NO^3-N, N, P, K, ash and dietary fibre content of carrot', *Journal of Agricultural Science in Finland* 61, p 99–111

35 Fischer A and Richter C, 1986, 'Influence of organic and mineral fertilisers on yield and quality of potatoes', in Vogtmann H, Boehncke E, Fricke I (eds.), *The Importance of Biological Agriculture in a World of Diminishing Resources – Proceedings of the 5th IFOAM International Scientific Conference* (University of Kassel Germany, Aug 27–30, 1984) Verlagsgruppe Witzenhausen, p 236–248

36 Goh KM and Vityakon P, 1986, 'Effects of fertilisers on vegetable production. 2. Effects of nitrogen fertilisers on nitrogen content and nitrate accumulation of spinach and beetroot', *New Zealand Journal of Agricultural Research* 29, p 485–494

37 Granstedt AG and Kjellenberg L, 1997, 'Long-term field experiment in Sweden: effects of organic and inorganic fertilisers on soil fertility and crop quality', in Lockeretz W (ed.) *Agricultural Production and Nutrition, Proceedings of an International Conference (Boston, Ma, March 19–21 1997)*, Medford, MA: School of Nutrition Science and Policy, Tufts University, p 79–90

38 Gundersen V, Bechmann IE, Behrens A and Sturup S, 2000, 'Comparative investigation of concentrations of major and trace elements in organic and conventional Danish agricultural crops. 1. Onions (*Allium cepa* Hysam) and Peas (*Pisum sativum* Ping Pong), *Journal of Agricultural and Food Chemistry* 48, p 6094–6102

39 Hamouz K, Cepl J, Vokal B and Lachman J, 1999, 'Influence of locality and way of cultivation on the nitrate and glycoalkaloid content in potato tubers', *Rostlinna Vyroba* 45(11), p 495–501

40 Hamouz K, Lachman J, Vokal B and Pivec V, 1999, 'Influence of environmental conditions and way of cultivation on the polyphenol and ascorbic acid content in potato tubers', *Rostlinna Vyroba* 45(7), p 293–298

41 Hansen H, 1981, 'Comparison of chemical composition and taste of biodynamically and conventionally grown vegetables', *Qualitas Plantarum – Plant Foods for Human Nutrition* 30(3/4), p 203–211

42 Harwood RR, 1984, 'Organic farming research at the Rodale Research Center', in Kral DM and Hawkins SL (eds.) *Organic Farming: Current Technology and its Role in Sustainable Agriculture*, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison WI, p 1-17

43 Hogstad S, Risvik E and Steinsholt K, 1997, 'Sensory quality and chemical composition in carrots: a multivariate study', *Acta Agricultuarae Scandanavica Section B, Soil and Plant Science* 47(4), p 253–264

44 Honeycutt CW, 1998, 'Crop rotation impacts on potato protein', *Plant Foods for Human Nutrition* 52(4), p 279–291

45 Hornick SB and Parr JF, 1990, 'Effect of fertiliser practices on the nutritional quality of crops', *Agricultural Alternatives and Nutritional Self-sufficiency for a Sustainable Agricultural System that Respects Man and his Environment – Proceedings of the 7th IFOAM International Scientific Conference* (Ouagadougou, 2–5 Jan 1989), Witzenhausen, Ekopan, p 244–254

46 Kansal BD, Singh B, Bajaj KL and Kaur G, 1981, 'Effect of different levels of nitrogen and farm yard manure on yield and quality of spinach', *Qualitas Plantarum – Plant Foods for Human Nutrition* 31, p 163–170

47 Kolbe H, Meineke S, and Zhang WL, 1995, 'Differences in organic and mineral fertilisation on potato tuber yield and chemical composition compared to model calculations', *Agribiol. Res.* 48(1), p 63–73

48 Kopp HJ, 1992, 'Research on organically versus conventionally grown vegetables', in Kopke U and Schultz DG (eds.) *Organic Agriculture, a Key to a Sound Development and a Sustainable Environment – Proceedings of the 9th IFOAM Conference* (Sao Paulo, Brazil, 16 Nov 1992), Tholey-Theley, Germany, p 324–330

49 Lairon D, Ribaud P, Leonardi J, Lafont H, Gaudin G, and Reynier M, 1981, 'Analysis of vegetables produced by orthodox and biological methods; some preliminary results', in Stonehouse B (ed.) *Biological Husbandry – A Scientific Approach to Organic Farming*, Butterworths Publishers, p 327–328. See also: Lairon *et al*, 1983, 'Studies of yield and food quality of vegetables grown under organic and mineral fertilisation', in *Environmentally Sound Agriculture, 4th IFOAM Conference*, Cambridge MA, Selected Papers, Lockeretz W (ed.), Praeger, New York, p 408–409

50 Lairon D, Spitz N, Termine E, Ribaud P, Lafont H, and Hauton J, 1984, 'Effect of organic and mineral nitrogen fertilisation on the yield and nutritive value of butterhead lettuce', *Qualitas Plantarum – Plant Foods for Human Nutrition* 34, p 97–108

51 Lairon D, Termine E, Gautier S, Trouilloud M, Lafont H and Hauton J, 1986, 'Effects of organic and mineral fertilisations on the contents of vegetables in minerals, vitamin C and nitrates', in Vogtmann H, Boehncke E, Fricke I (eds.), *The Importance of Biological Agriculture in a World of Diminishing Resources – Proceedings of the 5th IFOAM International Scientific Conference* (University of Kassel Germany, 27–30 Aug 1984) Verlagsgruppe Witzenhausen, p 249–260

52 Leclerc J, Miller ML, Joliet E and Rocquelin G, 1991, 'Vitamin and mineral contents of carrot and celeriac grown under mineral or organic fertilisation', *Biological Agriculture and Horticulture* 7, p 339–348

53 Lockeretz W, Shearer G, Sweeney S, Kuepper G, Wanner D and Kohl DH, 1980, 'Maize yields and soil nutrient levels with and without pesticides and standard commercial fertilisers', *Agronomy Journal* 72, p 65–72

54 Mader P, Pfiffner L, Niggli U, Plochberger K, Velimirov A, Balzer U, Balzer F and Besson J-M, 1993, 'Effect of three farming systems (biodynamic, bio-organic, conventional) on yield and quality of beetroot in a seven year crop rotation', *Acta Horticulturae* 339, p 10–31

55 Maga JA, Moore FD and Oshima N, 1976, 'Yield, nitrate and sensory properties of spinach as influenced by organic and mineral nitrogen fertiliser levels', *Journal Sci. Food Agriculture* 27, p 109–114

56 McCarrison R, 1926, 'The effect of manurial conditions on the nutritive and vitamin values of millet and wheat', *Indian Journal of Medical Research* 14, p 351–378

57 Meier-Ploeger A, Duden R and Voghtmann H, 1989, 'Quality of plants grown with compost from biogenic waste', *Agriculture, Ecosystems and Environment* 27, p 483–491

58 Mercadante AZ, Rodriguez-Amaya DB, 1991, 'Carotenoid composition of a leafy vegetable in relation to some agricultural variables', *Journal of Agric. Food Chem.* 39, p 1094–1097

59 Miller DS and Dema IS, 1958, 'Nutritive value of wheat from the Rothamstaed Broadbalk field', *Proceedings of the Nutrition Society* 17, p 94–95

60 Montagu KD and Goh KM, 1990, 'Effects of forms and rates of organic and inorganic nitrogen

- *Granstedt & Kjellenberg (1997)*[37]
  Field trial. Dry matter content in potatoes.
- *Gundersen et al (2000)*[38]
  Farm survey. Minerals P, K, Ca, Mg, Fe, S, B, Cr, Co, Cu, Mn, Mo, Se, Sn, Sr, Va and Zn in onions and peas (plus 38 other elements not known to be essential).
- *Hogstad et al (1997)*[43]
  Farm survey. Vitamin A (as beta-carotene) and dry matter content in carrots.
- *Kolbe (1995)*[47]
  Field trial. Mineral Mg, vitamin C and dry matter content in potatoes.
- *Lairon (1981)*[49]
  Market survey. Minerals P, K, Ca, Mg, Fe, Cu and Mn and dry matter content in potatoes, leeks, kale, lettuce and turnips.
- *Lairon et al (1986)*[51]
  Farm survey. Minerals P, K, Ca, Mg, Fe, Cu and Mn content in carrots, leeks, lettuce and potatoes; vitamin C and dry matter content in lettuce and potatoes.
- *Leclerc et al (1991)*[52]
  Farm survey. Minerals P, K, Ca, Mg, Fe, Cu, Mn and Zn, vitamins A, B and C and dry matter content in carrots and celeriac.
- *Mader et al (1993)*[54]
  Field trial. Minerals P, K, Ca and Mg, vitamin C and dry matter content in beetroot.
- *Pimpini et al (1992)*[67]
  Field trial. Dry matter content in onions, tomatoes and spinach.
- *Pither & Hall (1990)*[68]
  Market survey. Minerals K and Fe, vitamin C and dry matter contents of apples, carrots, green cabbage, potatoes and tomatoes, minerals Ca and Zn contents in potatoes and vitamin A (as beta-carotene) in carrots and tomatoes.
- *Pommer & Lepschy (1985)*[69]
  Market survey. Minerals K, Ca, Mg, Cu and Zn, vitamin A (a and b carotene) and dry matter in carrots.
- *Rembialkowska (2000)*[78]
  Farm survey. Minerals K, Ca and Mg in carrots and white cabbage; plus vitamin A (as beta-carotene) in carrots and vitamin C and dry matter contents in white cabbage.
- *Schuphan (1974)*[86]
  Field trial. Minerals P, K, Ca, Mg and Fe, vitamin C and dry matter contents in spinach, savoy, potatoes and carrots; plus vitamin A (as beta-carotene) in spinach and carrots.
- *Vogtmann (1993)*[96]
  Field trial. Vitamin C and dry matter contents in cabbage and potatoes, plus dry matter content in carrots.
- *Weibel (2000)*[102]
  Farm survey. Minerals P, K, Ca, Mg, vitamins C and E and dry matter contents in apples.

Note: These studies are not all of equal scope and weight, differing as they do in study type, years run, crops analysed, nutrients compared and data presentation (some present individual crop / nutrient / farm / year data, others combined averages). Due to their heterogenous nature it would be inappropriate to combine their data on individual crop / nutrient comparisons. Also, this approach would inappropriately weight studies that present their data separately for individual years, crops or pairs of samples or farms more heavily than studies that present their data as averages of multiple years, crops, samples or farms. Therefore the results reported here represent the overall trend demonstrated in each study, taking all available data within that study into account. There are flaws in this approach also, for clearly not all studies deserve equal weighting. However the total number of crop / nutrient combinations in studies that show differences (for example in mineral contents of organically and non-organically grown fruits and vegetables) is comparable to the total number of crop / nutrient combinations in those that do not, therefore no strong bias is introduced one way or the other. Until more standardised comparative research is available, we consider this to be the most appropriate way of assessing and presenting the evidence to hand, cataloguing as it does the overall outcomes or trends demonstrated in the available valid studies.

Of these 22 studies, 13 were published in peer-reviewed journals,[16,18,23,38,43,47,51,52,54,67,86,96,102] six were presented at scientific conferences[11,25,35,37,49,78] and three were published reports.[8,68,69] Due to their heterogenous nature, specifically differences in study types, crops and nutrients compared and data presentation, the following analyses represent trends demonstrated by the available valid studies only.

Minerals

Which minerals?
Relevant essential minerals required in the human diet from fruit and vegetables include phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), sulphur (S), boron (B), chromium (Cr), cobalt (Co), copper (Cu), iodine (I), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), tin (Sn), strontium (Sr), vanadium (V), and zinc (Zn).[106] In non-organic farming, the minerals P and K – as well as nitrogen (N) – are usually applied in relatively high doses in a readily soluble form by the use of chemical fertilisers, and are thus less likely to reveal differences from organically grown crops than other minerals. However as consumers are more interested in the nutrient content of foods than the nutrient source, available data on all of the essential nutrients listed above is considered in this review, except when a study compares only P and K, as discussed in section 3.2.3.

Findings
Fourteen valid studies compared the fresh-weight essential mineral contents of organically and non-organically grown fruit and vegetables. This included five long-term field trials,[8,11,47,54,86] six paired-farm comparisons,[23,38,51,52,78,102] and three shopping basket surveys.[49,68,69] Due to the small number and heterogenous nature of the available valid comparisons

fertilisers on the yield and some quality indices of tomatoes', *New Zealand Journal of Crop and Horticultural Science* 18(1), p 31–37
61 Nilsson T, 1979, 'Yield, storage ability, quality and chemical composition of carrot, cabbage and leek at conventional and organic fertilising', *Acta Horticulturae* 93, p 209–223
62 Ogbadu GH and Easmon JP, 1989, 'Influence of organic and inorganic fertilisers on the chemical composition of three eggplant cultivars', *Tropical Science* 29(4), p 237–246
63 Pain AK, 1962, 'Effect of compost on nutrient quality of food', *Compost Science* 3(1), p 40–41
64 Peavy WS and Grieg JK, 1972, 'Organic and mineral fertilisers compared by yields, quality and composition of spinach', *Journal of American Horticultural Science* 97, p 718–723
65 Pettersson BD, 1978, 'A comparison between the conventional and biodynamic farming systems as indicated by yields and quality', in *Toward a Sustainable Agriculture – Proceedings of the IFOAM conference* (Sissach, Switzerland), p 87–94
66 Pfeilsticker K, 1992, 'Quality of organic-grown food – an experimental, multifactorial approach on vegetables for example', in Kopke U and Schultz DG (eds.), *Organic Agriculture, a Key to a Sound Development and a Sustainable Environment – Proceedings of the 9th IFOAM Conference* (Sao Paulo, Brazil, 16 Nov, 1992), Tholey-Theley, Germany, p 331–337
67 Pimpini F, Giardini L, Borin M and Gianquinto G, 1992, 'Effects of poultry manure and mineral fertilisers on the quality of crops', *Journal of Agricultural Science* 118(2), p 215–221
68 Pither R and Hall MN, 1990, 'Analytical survey of the nutritional composition of organically grown fruit and vegetables', *Technical Memorandum 597, MAFF Project 4350*, Campden Food and Drink Research Association, UK
69 Pommer G and Lepschy J, 1985, 'Investigation of the contents of winter wheat and carrots from different sources of production and marketing', *Bayerisches Landwirtschaftliches Jarbuch* 62, p 549–563
70 Poretta S, 1994, 'Qualitative comparison between commercial 'traditional' and 'organic' tomato products using multivariate statistical analysis', *Acta Horticulturae* 376, p 259–270
71 Ginger MW, 1988, 'Characteristics of organically and conventionally grown potatoes', *Annual Review 1988*, Potato Marketing Board, Sutton Bridge Experimental Station
72 Raupp J, 1996, 'Quality investigations with products of the long-term fertilisation trial in Darmstadt – Second Period: Fertilisation with total nitrogen equivalents', *Quality of Plant Products Grown with Manure Fertilization – Proceedings of the Fourth Meeting* (Juva, Finland, 6–9 July 1996). Darmstadt; Germany: Institute for Biodynamic Research, p 13–33
73 Raupp J, 1997, 'Yield, product quality and soil life after long-term organic or mineral fertilisation', *Agricultural Production and Nutrition – Proceedings of an International Conference* (Boston, MA, 19–21 Mar 1997), Lockeretz W (ed.), Medford, MA: School of Nutrition Science and Policy, Tufts University, p 91–101
74 Raupp J, 1998, 'Examination of some microbiological and biochemical parameters and tests of product quality used in a long-term fertilisation trial', *American Journal of Alternative Agriculture* 13(3), p 138–144
75 Rauter W and Wolkerstorfer W, 1982, 'Nitrat in Gemuse', *Z Lebensmittel Untersuchung und Forschung* 175, p 122–124
76 Reganold JP, Glover JB, Andrews PK and Hilman HR, 2001, 'Sustainability of three apple production systems', *Nature* 410, p 926–930

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[78] Rembialkowska E, 2000, 'The nutritive and sensory quality of carrots and white cabbage from organic and conventional farms', *The World Grows Organic – Proceedings from the 13th IFOAM Scientific Conference, Basel, Switzerland, 28–31 Aug 2000*, p 297

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[82] Saleha A, 1992, 'Studies on the effects of organic vs inorganic form of nitrogen on the quality of okra', *Journal of Maharashtra Agricultural Universities* 17(1), p 133–134

[83] Schudel P, Eichenberger M, Augstburger F, Kläy R and Vogtmann H, 1979, 'The influence of compost or NPK fertilisation on yield, vit C and nitrate content of spinach and spinach beet', *Schweizerische Landwirtschaftliche Forschung* 18, p 337–349

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[85] Schultz DG, Zedow E and Kopke U, 1992, 'Determining the quality of organic produce: extended quality parameters and quality index', in Kopke U and Schultz DG (eds.), *Organic Agriculture, a Key to a Sound Development and a Sustainable Environment – Proceedings of the 9th IFOAM Conference* (Sao Paulo, Brazil, 16 Nov, 1992), Tholey-Theley, Germany, p 338–348

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[88] Smith B, 1993, 'Organic foods vs. supermarket foods: element levels', *Journal of Applied Nutrition* 45(1), p 35–39

[89] Srikumar TS and Ockerman PA, 1990, 'The effects of fertilisation and manuring on the contents of some nutrients in potato', *Food Chemistry* 37(1), p 47–60

[90] Srikumar TS and Ockerman PA, 1991, 'The effects of organic and inorganic fertilisation on the content of trace elements in cereal grains', *Food Chemistry* 42(2), p 225–230

of individual minerals, conclusions cannot be drawn on this basis. Overall however, seven studies demonstrated a trend toward higher mineral contents in organically grown crops,[8,23,47,49,54,69,86] and one demonstrated a trend toward higher mineral contents in non-organically grown crops that also used crop rotations and manure applications ('integrated farming').[11] Six studies showed inconsistent or not significant differences.[38,51,52,68,78,102]

Overall trend demonstrated within studies comparing the essential mineral contents of organically and non-organically grown fruit and vegetables on a fresh-weight basis

Studies showing:
Higher mineral contents in organically grown crops
■■■■■■■ 7
Inconsistent or non-significant differences
■■■■■■ 6
Higher mineral contents in non-organically grown crops
■ 1

This can be selectively interpreted in different ways:

- Organically grown produce must be better because seven times as many studies show higher mineral contents in organically grown (seven) than non-organically grown crops (one). OR:
- There is no difference between organically and non-organically grown produce as demonstrated by the same number of studies showing no difference or higher mineral contents in non-organically grown crops (seven) as studies showing higher mineral contents in organically grown crops (seven).

Avoiding these selective interpretations, two points are clear:

- While there are many factors that can influence the nutrient contents of crops, the method of farming is also shown to be a strong influence, with the valid scientific studies demonstrating a trend toward significantly higher mineral contents in organically grown than non-organically grown fruit and vegetables.
- More research is needed, further investigating this trend to confirm or refute the presence of differences. The resources required to do this are well justified by the existing data.

The possible reasons for, significance of and implications of differences in the mineral content of organically and non-organically grown produce are discussed in section 5.

Vitamins

Influences
In contrast to minerals which must be in the soil and bio-available for the plant to acquire them, vitamins are synthesised by the plant itself, and the levels in produce are known to be dependent on factors other than the method of husbandry, namely:

- *Crop size*
  Schuphan demonstrated that the larger a red cabbage (of the same age), the lower the vitamin C concentration.[107]
- *Ripeness of the fruit*
  Kader showed that apples and apricots picked green contained no vitamin C, however
  if picked either half or fully ripe the vitamin C content increased to approximately 18 and 60mg per 100g fresh weight respectively.[108]
- *Variety*
  Contents of vitamin C differed considerably in 134 apple cultivars investigated, ranging from 0–31mg per 100g fresh weight.[109]
- *Time since harvest spent in transportation and storage*
  Many vitamins, especially vitamin C and folic acid, are sensitive to oxidation, heat and light and can be rapidly degraded during transportation and storage.[110] For example potatoes, even under optimum storage conditions, can lose up to 70 per cent of their vitamin C content in storage, and kale stored at 21°c has been found to contain 60–89 per cent less vitamin C than when frozen.[108]

Nevertheless, numerous studies have examined whether the method of husbandry does significantly influence vitamin content.

Results
Fifteen valid studies compared the vitamin contents of organically and non-organically grown fruit and vegetables. Of the 13 studies comparing vitamin C contents, seven demonstrated a trend toward significantly higher vitamin C in organically grown crops,[25,35,47,52,68,78,86] with as little as six per cent[25] and as much as 100 per cent more.[35] Six found inconsistent or non-significant differences,[8,18,51,53,96,102] while no studies found significantly higher levels in non-organically grown crops.

Overall trend demonstrated within studies comparing the vitamin C content of organically and non-organically grown fruit and vegetables on a fresh-weight basis

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Studies showing:
Higher vitamin C content in organically grown crops
■■■■■■■ 7
Inconsistent or non-significant differences
■■■■■■ 6
Higher vitamin C content in non-organically grown crops
None

There was insufficient data on other vitamins to allow any firm conclusions: organically grown crops had significantly higher vitamin A levels in four studies,[43,52,68,69] lower levels in one,[86] and inconsistent or non-significant differences were found in three.[8,18,78] B vitamins were significantly higher in organically grown crops in one study[52] but no difference was found in another.[18] Just one study compared vitamin E levels (in apples), finding no significant difference.[102]

91 Stopes C, Woodward L, Forde G and Vogtmann H, 1988, 'The nitrate content of vegetable and salad crops offered to the consumer as from organic or conventional production systems', *Biological Agriculture and Horticulture* 5, p 215–221
92 Svec L, Thoroughgood C and Mok HCS, 1976, 'Chemical evaluation of vegetables grown with conventional or organic soil amendments', *Communications in Soil Science and Plant Analysis* 7(2), p 213–228
93 Syltie PW and Dahnke WC, 1983, 'Minerals and protein content, test weight and yield variations of hard red spring wheat grain as influenced by fertilisation and cultivar', *Qualitas Plantarum – Plant Foods for Human Nutrition* 32, p 37–49
94 Termine E, Lairon D, Taupier-Letage B, Gauthier S and Hauton JC, 1984, 'Influence des techniques de fertilisation organique et min'rale sur la valeur nutritionelle de l'gumes', *Sciences des Aliments* 4, p 273–277
95 Termine E, Lairon D, Taupier-Letage B, Gauthier S, Lafont R and Lafont H, 1987, 'Yield and content in nitrates, minerals and ascorbic acid of leeks and turnips grown under mineral or organic nitrogen fertilisations', *Plant Foods for Human Nutrition* 37, p 321–332
96 Vogtmann H, Matthies K, Kehres B and Meier-Ploeger A, 1993, 'Enhanced food quality: effects of composts on the quality of plant foods', *Compost Science and Utilisation* 1, p 82–100
97 Vogtmann H, Eichenberger M, Ott P, Temperli A and Künsch U, 1984, 'Accumulation of nitrates in leafy vegetables grown under contrasting agricultural systems', *Biological Agriculture and Horticulture* 2, p 51–68
98 Warman P, 1998, 'Results of the long-term vegetable crop production trials: conventional vs. compost amended soils', *Acta Horticulturi* 469, p 333–341
99 Warman P and Havard K, 1996a, 'Yield, vitamin and mineral content of four vegetables grown with either composted manure or conventional fertiliser', *Journal of Vegetable Crop Production* 2(1), p 13–25
100 Warman P and Havard K, 1996b, 'Yield, vitamin and mineral content of organically and conventionally grown carrots and cabbage', *Agriculture, Ecosystems and Environment* 61, p 155–162
101 Warman P and Havard K, 1998, 'Yield, vitamin and mineral content of organically and conventionally grown potatoes and sweetcorn', *Agriculture, Ecosystems and Environment* 68(3), p 207–216
102 Weibel FP, Bickel R, Leuthold S andAlfoldi T, 2000, 'Are organically grown apples tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality', *Acta Horticulturae* 517, p 417–426
103 Wilberg E, 1972, 'Concerning the quality of spinach from biological cultivation', *Landwirtschaftliche Forschung* 25, p 167–169
104 Wolfson JL and Shearer G, 1981, 'Amino acid composition of grain protein of maize grown with and without pesticides and standard commercial fertilisers', *Agronomy Journal* 73, p 611–613
105 Levite D, Adrian M and Tamm L, 2000, 'Preliminary results of resveratrol in wine of organic and conventional vineyards', *Proceedings of the 6th International Congress on Organic Viticulture 25–26 Aug 2000*, Basel, Switzerland, p 256–257
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Overall trend demonstrated within studies comparing the vitamin A, B and E contents of organically and non-organically grown fruit and vegetables on a fresh-weight basis

Vitamin	*A*	*B*	*E*
Studies favouring organic fruit & veg.	4	1	–
Inconsistent or non-significant difference	3	1	1
Studies favouring non-organic fruit & veg.	1	–	–

An extensive review of around 150 non-English language papers assessing the influence of high levels of nitrogen fertilisation on the vitamin contents of crops conducted by the Swiss Institute of Plant Science reported similar findings.[111] While many of the studies were of limited use and experimental conditions varied considerably, the authors reported that the majority of studies were "surprisingly consistent with respect to the effect of nitrogen fertilisers on some vitamins". Namely, high nitrogen fertilisation decreased the concentration of vitamin C in many different fruits and vegetables, among them potatoes, tomatoes and citrus fruits - major sources of this vitamin in many societies. Nitrogen fertilisation was also observed to increase the concentrations of carotene (vitamin A) and vitamin B1 in plants.

Despite this, a subsequent review by the same author found that vitamin B1 contents were usually still higher in organically grown than non-organically grown crops (validity of the studies reviewed has not been assessed), and also that fertilisation with cow dung could significantly increase vitamin B12 levels in crops to levels that could potentially benefit strict vegetarians who are at risk of being deficient in this vitamin.[112]

Dry matter

What is it?

Dry matter represents the non-water component of a food – a lower dry matter content indicating a higher water content, which is undesirable for consumers who typically pay for fresh produce by weight. The data shows that consumers may be paying for more water in non-organically grown than organically grown produce. This issue is also of interest as a higher water content will tend to dilute the nutrient content in produce.

Results

Nineteen valid studies compared the dry matter contents of organically and non-organically grown fruit and vegetables. Ten studies demonstrated a trend toward higher dry matter contents in organically grown crops,[25,37,43,49,52,54,69,78,86,96] averaging around 20 per cent higher. One study showed slightly higher dry matter content in a non-organic crop (bananas),[16] and eight studies found inconsistent or non-significant differences.[8,11,23,47,51,67,68,102] This supports the view that excessive fertilisation (possible with manure but more common with artificial fertilisers) stimulates rapid growth that increases the yield of crops partly by simply swelling them with a higher water content.

Overall trend demonstrated within studies comparing the dry matter content of organically and non-organically grown fruit and vegetables

Studies showing:
Higher dry matter content in organically grown crops
■■■■■■■■■■ 10
Inconsistent or non-significant differences
■■■■■■■■ 8
Higher dry matter content in non-organically grown crops
■ 1

Cereals

Eight valid studies compared the primary nutrient contents of organically and non-organically grown cereals:

- *Alfoldi et al (1996)*[11]
  Field trial. Minerals P, K, Ca, Mg, Cu, Mn and Zn content of barley and wheat.
- *Dlouhy (1981)*[25]
  Field trial. Protein content and protein quality (EAA index) of wheat.
- *Granstedt & Kjellenberg (1997)*[37]
  Field trial. Protein content and quality (EAA index) of wheat.
- *Lockeretz et al (1980)*[53]
  Farm survey. Protein content of maize.
- *Raupp (1996)*[72]
  Field trial. Protein content of wheat.
- *Rutkoveine et al (2000)*[80]
  Field trial. Protein content of wheat and barley.
- *Shier (1984)*[87]
  Farm survey. Protein content and dry matter content of wheat.
- *Wolfson & Shearer (1981)*[104]
  Farm survey. Protein content of maize.

The limited number and heterogenous nature of these studies prevent any general conclusions regarding the comparative primary nutritional contents of organically and non-organically grown cereals.

Only one paper compared the mineral contents of organically and non-organically grown cereals, and reported inconsistent or not significant differences.[11]

Seven studies compared the protein contents of organically and non-organically grown cereals, generally showing a higher crude protein concentration in non-organically grown cereals,[25,53,72,80,104] which combined with other technical characteristics (including rising number, gluten content, maltose percentage), indicated a better baking quality of non-organically grown wheat.[72,80] A more relevant nutritional comparison is that of protein quality (EAA index), reported as significantly higher in organically grown wheat.[25,37]

A small number of studies reviewed by Woese *et al* (1997) could not determine significant differences between non-organically and 'alternatively' produced bread, though the authors observed that "differences in nutritional and sensory quality may be due not only to the different source of the bread grain but above all to the differences in recipe and baking method".[1]

The most significant influence on the nutritional quality of bread and other cereal products is refining. When, for example, wheat is refined to make white flour, bread or pasta, some 50–96 per cent of the fibre, vitamin and mineral contents are removed.[113]

Animal products

The over consumption of saturated fats is recognised as a contributory factor in cardiovascular disease.[114] There is evidence that the ratios of different fat types to one another in meat and diary products are influenced by the rearing methods of animals, and in particular the method of feeding.[115] A study comparing beef cattle reared organically and fed on grass with cattle reared indoors and fed on concentrates indicated that the organically reared cattle had a more favourable fat profile in their meat – that is, a lower ratio of saturated to unsaturated fat. The fat profile of these organic cattle was also more favourable than typical levels reported in the literature for non-organic cattle.[116] Other studies have found similar differences.[117,118] This could be significant, as the ratio of saturated fats to omega-3 and omega-6 polyunsaturated fats in the diet has implications for circulatory and perhaps other diseases.[114,116,119,120]

Interest is growing in conjugated linoleic acid (CLA), a natural fat found in beef, poultry and eggs. Studies have shown that it can help prevent cancer, reduce heart disease and help weight control.[121–125] CLA levels increase in meat and milk if there is a higher content of grass, hay or silage in the cows' diet.[126,127] Organic standards require a minimum of 60 per cent of these foods in the diets of organically reared cattle, improving the levels of this beneficial fat in organic produce.

3.3 Secondary nutrients

What are they?

Other than primary essential nutrients such as water, fibre, proteins, fats, carbohydrates, vitamins and minerals, there are some 5,000–10,000 secondary compounds in plants, also referred to as 'secondary metabolites' or 'phytonutrients'.[1]

There are four general categories of secondary compounds:[2]

- *Phenolics*
  Aromatic compounds that include the flavonoids, the largest group of phenolics. Flavonoids can be sub-classified into different groups that include potentially important phytonutrients including isoflavonoids, flavones, flavonols, anthocyanins, tannins, and lignin.
- *Terpenes*
  Includes the carotenoids (lutein, lycopene), steroids, and limonoids.
- *Alkaloids*
  A diverse group of nitrogen containing secondary compounds, synthesised primarily from amino acids which include toxic and psychoactive plant compounds such as nicotine, caffeine, cocaine, morphine, strychnine and atropine; as well as the glycoalkaloids – solanin and chaconine.
- *Sulphur containing compounds*
  Includes the glucosinolates (found in brassicas such as cabbage, kale, broccoli); allicin and other compounds from garlic and onions.

None are known to be essential for health as by definition, whenever such compounds have been identified as essential they have been reclassified as vitamins. Many are known to be harmful in very high doses, and a few, such as linamarin in cassava and solanin in potatoes, are potentially harmful in regularly occurring concentrations. Conversely, there are other secondary compounds that have been shown to be useful in the prevention or treatment of human diseases. The question of whether these compounds are, on the whole, toxic or beneficial has been the subject of much debate and requires further consideration.

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Toxicity

The toxicity of different substances is commonly tested by isolating them and then feeding them in very high doses to animals, often rats. If a harmful effect is found, the substance will be reported as being toxic. A high proportion of both natural and synthetic chemicals have been identified as carcinogens in this way.[3] Some have argued therefore that exposure to an abundance of naturally occurring toxic compounds is a far greater risk than any potential exposure to synthetic toxins such as pesticide residues,[3] and that the overall exposure to various chemicals, both natural and synthetic, occurring in foods would be similar for people on comparable diets regardless of source (either organic or non-organic).[4]

Others have argued that while some naturally occurring compounds in plants may be toxic, this cannot be made to support a view that any additional and avoidable risk from pesticide residues is acceptable.[5*] Further, epidemiological evidence firmly contradicts the concern that naturally occurring plant compounds, 'phytonutrients', pose a health hazard due to their potential toxicity. It is well established that the greater the daily intake of vegetables and fruit, the lower the risk of the main causes of death in Western society, including cancer, cardiovascular disease and diabetes.[6–8] This might also be interpreted as evidence of the non-toxicity of synthetic pesticide residues, but for the emerging epidemiological evidence demonstrating the negative health implications of dietary pesticide exposures discussed in section 3.1.1.

The issue with secondary compounds raises doubts about methods of establishing toxicity and suggests that results from testing chemicals at the highest tolerated dose do not necessarily correlate with real risks at real doses.[9*] The toxicity of these (and very likely all)[10] substances appears to be dose related. Therefore phytonutrients that are toxic at high concentrations may be innocuous or even beneficial at lower (naturally occurring) concentrations.[11]

This could also be true for synthetic compounds,[12] though there is no evidence to support this in the case of pesticide residues. In contrast, the benefits of phytonutrients and their metabolites are being increasingly documented, and many are now known to be antioxidant or anticarcinogenic.[13–31]

Benefits

In the treatment of cancer, phytonutrients have been identified in the literature as having beneficial effects through various mechanisms, including quenching free radicals, acting as anti-proliferative agents, inducing detoxifying enzymes, inducing differentiation of cancer cells, inhibiting metastasis, stimulating the anti-tumour activities of the immune system, and inhibiting tumour blood vessel formation.[13]

Examples of specific benefits include:

- *Glucosinolates*
  Found in cabbage, broccoli, cauliflower and Brussel sprouts. They are goitrogenic (interfere with thyroid function), but are also the best proven cancer preventing component in vegetables.[14]
- *Glycoalkaloids*
  Found in potatoes. They have been known to cause deaths in humans, but were recently demonstrated to possess protective properties – concentrations corresponding to those regularly found in the average human diet significantly reduced mortality from lethal doses of salmonella infection in mice.[15]
- *Flavonoids*
  Found in high concentrations in brightly coloured fruits and vegetables, soya, green tea and red wine. They have been shown to be powerful antioxidants, are anti-inflammatory, anti-allergenic, anti-atherosclerotic, anti-mutagenic, collagen stabilising, capillary protective, and can discourage the growth of established tumors.[16–22] Highly coloured fruits such as blueberries and strawberries, which are rich in anthocyanins (flavonoids) have been identified as having the highest antioxidant activity of any plant foods.[23]
- *Carotenoids*
  Found in high concentrations in dark green leafy and red or yellow vegetables; have been shown to be antioxidant, antimutagenic and beneficial in the treatment of breast and prostate cancers.[24–28]
- *Sulphur compounds*
  Including allicin in garlic, and its by-product metabolites such as ajoenes and vinyl dithiins. They are known antioxidants and have been shown to aid detoxification, heavy metal removal, general connective tissue repair and cardiovascular protection.[29] Regular consumption of garlic and onion has been shown to significantly reduce the risk of heart disease[30] and the spread of cancer.[31]
- *Tomatine*
  The glycoalkaloid tomatine is usually regarded as a plant toxin,[32,33] but has also been reported to prevent the absorption of cholesterol from the gut, lowering serum levels of low-density lipoproteins.[33,34]

In long term feeding trials with rats, supplementation of diets with extracts from antioxidant-rich fruits and vegetables appeared to retard age-related declines in the central nervous systems as well as cognitive behavioural deficits.[35]

The benefits or toxicities of many other secondary metabolites remain unknown and it is also not clear if it is possible to have too much of these compounds. Some polyphenols, for example, can bind to proteins and make them indigestible, some are mutagenic or slightly pro-oxidant,[36–38] and while others are powerful antioxidants they can also inhibit the uptake of iron and zinc from the gut.[39]

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Organic versus non-organic crops

Phytonutrient compounds are synthesised by plants and do not appear to play a direct role in their growth and development,[40] but rather in a diverse range of other plant processes including defence against herbivore and pathogen attack, protection against environmental stresses such as UV damage, and as attractants for pollinators.[41] For example polyphenols are known to contribute to the defensive mechanism of plants in the case of attack by disease or pests,[42] as confirmed by researchers who induced a fungal disease on leaves of plantain and measured how the plants responded immediately by increasing the concentration of caffeic acid (a phenolic compound) in the leaves, with the highest concentrations just around the zone of the attack.[43]

There are three main hypotheses suggesting that organically grown crops will tend to have higher concentrations of phytonutrients than non-organically grown crops:

- *Different plant protection methods*
  Because many of these compounds are produced by plants to protect themselves against attack, disease and damage, if a plant is subjected to higher levels of stress it will accumulate higher levels of secondary compounds.[3] Thus, if exogenous chemicals such as insecticides and fungicides are reduced or avoided, a greater reliance on the plants' own natural protection systems will result in the accumulation of higher levels of these plant defence related compounds (secondary nutrients).[30]
- *Different fertilisation methods and growth rates*
  Organic farming is generally characterised by a lower level of nitrogen supply compared to non-organic farming.[44] This can lead to an earlier completion of vegetative growth in organic plants and an earlier onset of maturity processes than in non-organically produced plant products.[45] As phytonutrient metabolites are often synthesised primarily during the maturation of plant products, this may result in higher concentrations of these compounds in organically grown foods.[45] This has been supported by observations that an increase in nitrogen application generally reduces the quantity and diversity of secondary metabolites in the resulting crops.[43] Numerous studies of natural ecosystems have also shown that increased availability of plant nutrients causes a reduction in the concentrations of many defence-related secondary metabolites.[46,47]
- *Varietal differences*
  One consequence of crop plant domestication is the deliberate or inadvertent selection for reduced levels of secondary compounds that are distasteful or toxic. Insofar as many of these compounds are involved in the defence of plants against their enemies, the reduction in these defences (due to artificial selection) could account at least in part for the increased susceptibility of crop plants to herbivores, insects and pathogens.[48] Cultivated plant foods commonly contain fewer natural toxins (including phytonutrients) than their wild counterparts.[49,50]

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57 Weibel FP, Bickel R, Leuthold S andAlfoldi T, 2000, 'Are organically grown apples tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality', *Acta Horticulturae* 517, p 417–426

Because of restrictions on pesticide and fungicide usage, organic farmers are more likely to select varieties with greater resistance to pests or disease, and could thus be choosing varieties that have higher levels of secondary compounds.[51] It may be the case that these varietal differences are greater than the differences brought about by the methods of fertilisation or pest control.[1,45,52,53]

A small number of valid and relevant studies were found which made direct comparisons of the secondary nutrient contents of organically and non-organically grown crops, and yielded the following results:

- *Pither & Hall (1990)*[54]
  Significantly higher levels of lycopene (a carotenoid) were found in store-bought organic tomatoes than in non-organic tomatoes.
- *Hamouz, Cepl, Vokal & Lachman (1999)*[55]
  Potatoes grown without pesticides had an average of 27 per cent higher glycoalkaloid concentrations than non-organically cultivated potatoes, though this difference was not statistically significant.
- *Hamouz, Lachman, Vokal & Pivec (1999)*[56]
  Potatoes grown without pesticides had a statistically significant average of 10 per cent higher polyphenol concentrations than non-organically cultivated potatoes.
- *Weibel (2000)*[57]
  Organic apples were found to have an average of 18.6 per cent more phenolic compounds (mainly flavonols) than fruit from non-organic / integrated orchards.
- *Levite, Adrian & Tamm (2000)*[53]
  In a preliminary study of wine, resveratrol content (an antioxidant phenolic compound in the skin of red grapes) was, on average, 26 per cent higher in organically than in non-organically produced wines in paired comparisons of the same grape variety (within a range of minus 10 to plus 50 per cent).

Brandt & Molgaard's recent review of this issue observed that these studies are insufficient to draw any final conclusions, yet tentatively estimated, "on the basis of the currently available evidence, that organically grown vegetables will tend to have 10–50 per cent more secondary or 'plant defence related' compounds than conventionally cultivated vegetables", and concluded that "if these secondary metabolites are an important determinant of the nutritional value of fruits and vegetables in the diet of developed countries, then vegetable and fruit products grown in organic agriculture would be expected to be more health promoting than non-organic ones".[1]

3.4 | Observed health effects

While some insights can be gained by investigating the nutritional components of food, the ultimate test of the nutritional value of food is its ability to support health, growth and reproduction over successive generations of animals or humans.[1] The nutritional value of food is a product of many factors, potentially including:

- The sum of all macro, trace, primary, secondary, residual and currently unknown substances which are present in foods and exert either a positive or negative action on biological health.
- Interactions between nutrients and other substances in foods, which can be neutral, synergistic or antagonistic in nature.[2]
- Interactions between foods and the organism which ingests them that can influence nutrient bioavailability, such as the preparation of a food (cooking or processing) and the consuming organism's capacity to digest, absorb and utilise the nutrients in a food.[3]
- The hypothesised 'vital quality' of food.[4]
- Aroma and taste to stimulate appetite and digestion.[5]

3.4.1 | Organically grown food and human health

Positive health effects

There are reports of positive health effects in humans resulting from the consumption of organically grown foods. A report published in 1940 tells of the improved health of students at a New Zealand boarding school that began serving almost exclusively organically grown produce. After three years a report was submitted that made the following observations of the pupils: a period of detoxification upon arriving at the school, lower incidences of catarrhal conditions, a "very marked decline" in colds and influenza, more rapid convalescence, excellent health generally, fewer sports injuries, a greater resilience to fractures and sprains, clear and healthy skin, and improved dental health.[6]

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18 Hoppe H, 2000, 'Measuring food quality', *New European Quality Forum presentation at the 11th National Conference on Organic Food and Farming, Royal Agricultural College*, Cirencester, Jan 2000
19 Lampkin N, 1990, *Organic Farming*, Farming Press, Ipswich, UK, p 557–573
20 Woese K, Lange D, Boess C, and Werner Böel K, 1997, 'A comparison of organically and conventionally grown foods - results of a review of the relevant literature', *Journal of Science of Food and Agriculture* 74, p 281–293
21 Meier-Ploeger A, 'Quality of organic foods – perception and criteria', *University of Applied Science, Fulda, Germany, presentation at the 10th National Conference on Organic Food and Farming, Royal Agricultural College, Cirencester*, Jan 1999
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24 Plochberger K, 1989, 'Feeding experiments. A criterion for quality estimation of biologically and conventionally produced foods', *Agriculture, Ecosystems and Environment* 27, p 419–428
25 Plochberger K and Velimirov A, 1992, 'Are food preference tests with laboratory rats a proper method for evaluating nutritional quality?', *Biol Agric Hortic* 8, p 221–233
26 Mader P, Pfiffner L, Niggli U, Plochberger K, Velimirov A, Balzer U, Balzer F and Besson J-M, 1993, 'Effect of three farming systems (biodynamic, bio-organic, conventional) on yield and quality of beetroot in a seven year crop rotation', *Acta Horticulturae* 339, p 10–31
27 Weibel FP, Bickel R, Leuthold S and Alfoldi T, 2000, 'Are organically grown apples tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality', *Acta Horticulturae* 517, p 417–426
28 Linder MC, 1973, 'A review of the evidence for food quality differences in relation to fertilisation of the soil with organic and mineral fertilisers', Biodynamics 107, p 1–12
29 Howard Sir A, 1947, *The Soil and Health – A Study of Organic Agriculture*, Schoken, New York
30 Weiss CL and Horvath DJ, 1970, 'Effects of nitrogen fertilisation on the thyroid function of rats fed 40% orchard grass diets', *Journal of Nutrition* 100, p 1121–1126
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Nutritional cancer therapies

More recent clinical evidence comes from doctors and nutritionists administering 'alternative' cancer treatments who have observed that a completely organic diet is essential for a successful outcome.[7–10] Nutritional cancer therapies involve avoidance of pollutants and toxins as much as possible, the exclusive consumption of organically grown foods and increases in nutrient intakes, and have yielded good results.[11] The Nutritional Cancer Therapy Trust reports "The overwhelming number of patients following alternative cancer therapies are those who have been declared terminal, with minimal life expectancies, following initial allopathic treatment. The ability of these patients to gain remission from all clinical evidence of cancer is therefore very significant".[12*]

Semen quality

While the evidence is not yet clear, studies have indicated that exposures to pesticides either dietarily or occupationally may influence sperm quality.[13–15] This is of particular interest given that average sperm concentrations around the world, in the 50 years until 1990, fell by half from around 113 million / ml to around 66 million / ml[16] and are still falling by around 2 per cent a year.[17] The World Health Organisation estimates the minimum level needed for men to reproduce as around 20 million / ml.[18] In contrast, two recent studies found that groups of men who consumed organically grown food had average concentrations of 99 and 127 million sperm / ml respectively,[13,14] the latter having the higher intake of organic food: >25 versus >50 per cent of their diet. The control groups who did not eat organically grown food had average concentrations of 69 and 55 million sperm / ml respectively, though these differences may have been due to other lifestyle or geographical factors such as country versus city dwelling or occupational exposure to other chemicals, as discussed in section 3.1.1.

Research needed

An ideal study would be to compare groups of people fed on identical diets using either organically or non-organically produced food, preferably over multiple generations.[19] However the problems of setting up such an experiment to yield meaningful results are considerable. Differences between individuals, their lifestyles and exposure to other environmental factors would all serve to confuse the picture. Researchers who did conduct human nutritional studies in the 1930s and 1940s with infants, children, adolescents and adults achieved little and could draw no conclusions.[20]

Clearly it is very difficult to illustrate the influences of foods produced by contrasting agricultural systems on humans because there are always numerous other factors involved. However controlled studies with animals have given some strong indications of the superiority of foods from organic farming…

3.4.2 Organically grown food and animal health

It has been asserted that animal feed preference tests can reflect the quality of foods.[21] These tests typically involve the provision of two identical feed containers to animals who have free choice of which they wish to eat. While it is not possible to confirm the authenticity (according to the criteria in section 3.2.3) of the organic and non-organic samples compared in many of these tests, interesting results have been reported:

- *Edelmuller (1984)*[22]
  Two groups of rabbits were raised on either organically (group 1) or non-organically (group 2) grown food before being given free choice. Preference tests with barley, potatoes and beetroots showed a highly significant preference for organically cultivated food in group 2. In group 1 a significant preference could only be demonstrated for barley, though the test series with beetroot and potatoes showed a tendency to higher consumption of organically cultivated food also.
- *Neudecker (1987)*[23]
  Feed selection tests with rats in which "it was clearly recognisable that the test animals preferred organically produced products to conventionally produced products".[20]
- *Plochberger (1989)*[24]
  Tests with beetroot "proved that all hens (whether previously fed on organically or conventionally grown beetroots) preferred the organically produced food to the conventionally produced food at a highly significant level".
- *Plochberger & Velimirov (1992)*[25]
  In two preference tests conducted with rats, organically produced beetroots were significantly preferred to those grown non-organically.
- *Mader et al (1993)*[26]
  Food preference tests with rats showed that organically cultivated beetroot was significantly preferred to the non-organically grown beetroot.
- *Weibel et al (2000)*[27]
  Feed preference tests with rats found no significant preference for apples from either organic or non-organic (integrated) orchards.

Linder asserts "These kinds of experiments (animal preference tests) clearly indicate that there are differences in the quality of food grown with organic as compared with mineral fertiliser. They leave no doubt that the content of these quality differences should be fully established and the implications of such differences on human and animal nutrition assessed".[28] Woese *et al's* more recent review of this issue concluded that "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".[20]

Even more interesting are tests assessing the health of animals fed on either organically or non-organically grown feed. There are many anecdotal reports of increased disease resistance, productivity and fertility of farm animals fed on organically grown fodder.[1,29–33] The relationship between agricultural practices and animal health demonstrated by these observations is supported by the body of more formal investigations.

There have been numerous studies published comparing the health of animals on organically or non-organically grown feed, though not all are valid (as discussed where necessary) and it is not possible to confirm the authenticity (according to the criteria in section 3.2.3) of the organically and non-organically grown feeds compared in many tests. Therefore all available studies since 1975 are presented here (studies prior to this are of questionable relevance to current conditions or practices).

- *Gottschewski (1975)*[34]
  Perinatal mortality of rabbits was 27 per cent for animals fed organically grown feed versus 51 per cent for those fed non-organically grown feed and 50 per cent for those fed commercial pellets.[31]
- *McSheehy (1977)*[35]
  No difference in weaning weight for mice fed either manure fertilised or chemically fertilised wheat plus supplements of vitamin A and other nutrients. Because vitamin A is known to affect growth and reproduction, supplementation of this vitamin alone could account for the lack of difference found.[31]
- *Aehnelt & Hahn (1978)*[36]
  Experiment 1: reduced sperm motility in bulls transferred from organically to non-organically grown fodder. Motility was restored when organic fodder was resumed.
  Experiment 2: greater number of eggs (nine versus three and six) and higher fertilisation rate (100 per cent versus 29 and 26 per cent) in rabbits fed organically versus non-organically fertilised feed.[31]
- Edelmuller *(1984)*[22]
  Almost all fertility and growth criteria tested, including total number of perinatal young, number of living perinatal young, live weight at birth, and number and weight of young at day 90, showed significantly better results for the organically fed rabbits than the non-organically fed rabbits.
- *Neudecker (1987)*[23]
  No clear differences could be detected in respect of gestation rate and litter weight of rats at the time of birth and weaning or the litter size and the birth and weaning weights for individual young. In some cases, however, in litters of animals fed on non-organically produced feed the percentages of stillborn young animals and of animals who died shortly after birth were significantly higher.[20]

- *Staiger (1988)* [3]
  The use of organically grown feeds led to higher pregnancy rates, more embryos, larger litters and better health of rabbits over three generations, in spite of the fact that the feed pellets for the two groups were shown to be identical in terms of known essential and harmful ingredients. The author admitted "any attempt to explain this improvement would be speculative, given that in a strict scientific sense, it has not yet been possible to record or measure special effective components". The fertility rate of rabbits declined over three generations in rabbits fed non-organically grown feed.
- *Plochberger (1989)* [24]
  Better weight gain after coccidial illness and fewer incidents of illness in chickens fed organically grown feed; significantly higher egg weight, yolk weight and body weight at 32 weeks in organically fed chickens compared with birds fed chemically fertilised feed.[31]
- *Brandenburger et al (1992)* [37]
  No reproducible significant differences were observed in various reproductive and growth parameters between two groups of rabbits fed on organically or non-organically produced alfalfa, wheat, carrots, beets and potatoes.
- *Velimirov et al (1992)* [38]
  Fewer stillbirths and perinatal deaths in first litters and better weight maintenance in lactating female rats fed organically grown feed versus non-organically grown feed.[31]

Worthington recently reviewed this issue extensively and concluded "These results support the notion that organically produced crops may be more conducive to good health. The positive health effects are most striking in sick or otherwise vulnerable animals such as newborns and in sensitive areas of reproduction such as sperm motility. It is particularly interesting to see that the fertility of animals fed fodder grown with chemical fertilisers and pesticides declined over several generations. This recalls the progressive decline in health that Dr Pottenger saw in each succeeding generation of cats fed on a less than optimal diet".[39]

3.4.3 | Taste

Taste, while not a direct influence on nutritional quality, can indirectly affect the nutritional value of a food through the stimulation of appetite and digestive processes.[5]

It is also an important quality distinction for consumers, and anecdotally many organic consumers feel that food grown organically tastes better. Indeed, 43 per cent of organic consumers give this as a major reason for purchasing it.[40]

Although differences in taste are difficult to confirm in controlled studies, of the six agriculturally valid studies reviewed here, five reported better taste qualities in organic produce:

- *Basker (1992)* [41]
  Inconsistent and non-significant differences in the taste of nine different fruit and vegetables.
- *Dlouhy (1981)* [42]
  Better taste in organically grown peeled potatoes after four months storage.
- *Hogstad et al (1993)* [43]
  Better total flavour strength, sweet taste and sugar content in organically grown carrots.
- *Reganold et al (2001)* [44]
  Organically grown apples were sweeter and less tart.
- *Rembialkowska (2000)* [45]
  Taste and smell better in organically grown raw carrots and sauerkraut (cabbage).
- *Weibel et al (2000)* [27]
  15 per cent better taste in organic apples.

There are a number of difficulties with research on taste, including:

- *Cooking*
  Taste differences in one study were found in raw carrots but not when they were cooked.[45]
- *Ripeness*
  The study that reported inconsistent or not significant differences found that taste was more dependent on the level of ripeness or maturity of the samples (which had not been fully controlled).[41]
- *Subjectivity*
  Taste is a personal thing and individual preferences can vary.
- *Preconceptions*
  Consumers may have preconceived opinions about the superior taste of organic produce.[46]

Possible reasons for a difference in taste between organically and non-organically grown produce include:

- *Water content*
  The higher water content in non-organically grown produce could dilute its flavour.
- *Variety*
  Differences in choices of cultivars between the two systems might explain differences in taste.
- *Sugar content*
  Organic produce has sometimes been shown to have a higher natural sugar content,[2,43,47] which may be perceived as a better or worse taste, depending on the product.
- *Secondary nutrient content*
  Levels of some aromatic compounds may be higher in organically grown produce.[27]

[36] Aehnelt E and Hahn J, 1978, 'Animal fertility: a possibility for biological quality assay of fodder and feeds', *Biodynamics* 25, p 36–47

[37] Brandenburger H, Sundrum A and Kopke U, 1992, 'The influence of differently cultivated foodstuffs (organic / mineralic manuring) on animal health', in Kopke Uand Schultz DG (eds.), *Organic Agriculture, a Key to a Sound Development and a Sustainable Environment – Proceedings of the 9th IFOAM Conference* (Sao Paulo, Brazil, 16 Nov 1992), Tholey-Theley, Germany, p 424–425

[38] Velimirov A, Plochberger K, Huspeka U and Schott W, 1992, 'The influence of biologically and conventionally cultivated food on the fertility of rats', *Biol Agric Hort* 6, p 325–337

[39] Worthington V, 1998, 'A fresh look at an old debate – is organic food more nutritious?', *Acres USA*, June 1998, p 17

[40] MORI poll, 2001, *Organics and the Political Agenda*, 15–20 Feb

[41] Basker D, 1992, 'Comparison of taste quality between organically and conventionally grown fruits and vegetables', *American Journal of Alternative Agriculture* 7(3), p 129–136

[42] Dlouhy J, 1981, 'Product quality in alternative agriculture', Food Quality – Concepts and Methodology, Elm Farm Research Centre Colloquium, 1990, p 30–35

[43] Hogstad S, Risvik E and Steinsholt K, 1997, 'Sensory quality and chemical composition in carrots: a multivariate study', *Acta Agricultuarae Scandanavica Section B, Soil and Plant Science* 47(4), p 253–264

[44] Reganold JP, Glover JB, Andrews PK and Hilman HR, 2001, 'Sustainability of three apple production systems', *Nature* 410, p 926–930

[45] Rembialkowska E, 2000, 'The nutritive and sensory quality of carrots and white cabbage from organic and conventional farms', *The World Grows Organic: Proceedings from the 13th IFOAM Scientific Conference*, Basel, Switzerland, 28–31 Aug 2000, p 297

[46] Hansen H, 1981, 'Comparison of chemical composition and taste of biodynamically and conventionally grown vegetables', *Qualitas Plantarum – Plant Foods for Human Nutrition* 30(3/4), p 203–211

[47] Rutkoveine V, Baltramaityte D and Stancevius A, 2000, 'Integrated research on production systems and product quality', *The World Grows Organic: Proceedings from the 13th IFOAM Scientific Conference*, Basel, Switzerland, 28–31 Aug 2000, p 301

4 | Holistic approaches

Health – origin: Old English hǣlth, of Germanic origin; relating to whole.
Oxford English Dictionary

In addition to standard methods of analysis involving measurements of mineral, vitamin and phytonutrient contents, some researchers have examined food by using methods that claim to assess food quality holistically, such as storage degradation tests and assessments of the picture forming properties of plant extracts through crystallisation techniques and chromatography. Past experience shows that as analytical and nutritional sciences evolve, more elements and aspects are found to be vital for health, though they may not even be measured at present.[1] Some researchers have therefore developed methods that attempt to assess food as a whole, rather than its constituent parts, and claim, for example, to make visible the organising, architectural level in living organisms.

Dr Ursula Balzer-Graf of the Swiss Institute of Vital Quality, who has worked in this field for decades explains: "Quality research in the field of living substances needs research methods appropriate to the phenomena of life. Not only the substance of foods but also the organising activity thereof has to be included in proper scientific work. This is where these methods pick up as holistic quality research methods. The duality of substance and organising activity are taken into account together and at the same time".[2]

Alan Gear of the Henry Doubleday Research Association (HDRA) observes "This may sound pretty esoteric but we don't have to go back very far to discover a time when vitamins were not known to exist. Those who suggested such factors were present in food invited ridicule. Can we really rule out as absurd those who claim the presence of a life force in food which can have an important bearing on whether or not such food can sustain us, helping to keep us healthy? Is food more than merely an agglomeration of chemical nutrients? Time will tell".[3]

Can this 'organising activity' or 'life force' be measured?
Western science does not cope well with these concepts, and tends therefore to marginalise them and concentrate instead on physical matter analyses.[4] However within the organic and bio-dynamic movements several methods have been developed and used in comparative studies of organically and non-organically grown produce, including picture forming methods and storage degradation tests, which are both examined here. Other methods which are not evaluated or discussed here include Kirlian photography, biophoton emissions, delayed luminescence tests, P-values, and the Goethean archetype method.

4.1 | Picture forming methods

Of the various picture forming methods researched, biocrystallisation – also known as copper chloride crystallisation – has gained most recognition.[5] This method is not novel. It was originally introduced by Ehrenfried Pfeiffer 70 years ago,[6] and is based on the crystallographic phenomenon that when adding biological substances, such as plant extracts, to aqueous solutions of dihydrate copper chloride, biocrystallograms with reproducible dendritic crystal structures are formed during crystallisation.[7] The morphological features found in these pictures are then interpreted visually in terms of the number of centres, the structure and distribution of the needles, the number and kind of branches and the formation of hollow structures.[8] Each species of plant, say a carrot, forms an easily identifiable signature pattern. Yet the intricacy of the pattern varies according to how the plant has been grown, how fresh it is and how it has been processed. According to many repeated observations and measurements, the more artificial inputs used to grow the plant, the more time since harvest, and the more processing it has undergone, the more coarse, broken and disrupted the crystal patterns formed by the extracts.[9]

That plant extracts exert some organising force on the crystallisation of metal salts is clear. In water alone, crystallisation of copper chloride occurs according to the inorganic laws of metal salts and is generally poor in form and structure (figure 1, see over). In contrast, the crystallographic pictures formed by copper chloride in

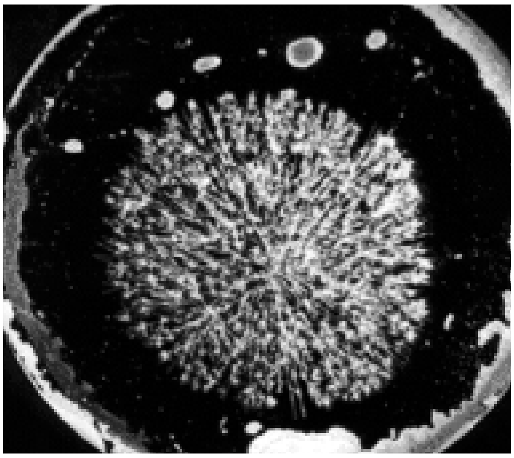


Figure 1

Water and copper chloride ($CuCl_2$) only

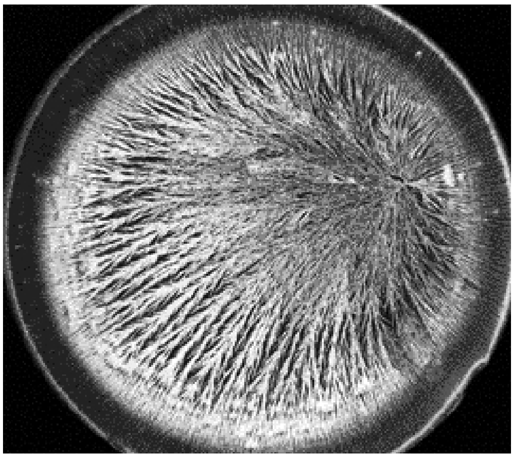


Figure 2

Non-organically grown beetroot extract and $CuCl_2$ – from Mader *et al* (1993)

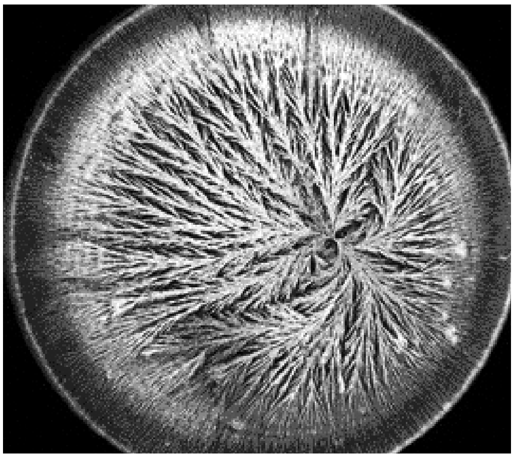


Figure 3

Organically grown beetroot extract and $CuCl_2$ – from Mader *et al* (1993)

beetroot extracts can be seen to be more structured and intricate (figures 2 and 3, see left).[2] It has also been observed that differences exist in the picture forming properties of different extracts, such as those from non-organically (figure 2) or organically grown produce (figure 3).

Consistently in these analyses, over two decades and many thousands of pictures, and in blind and double blind tests, Balzer-Graf has observed high reproducibility of pictures and claims the method can distinguish between various samples because they differ in their characteristic organising and form developing qualities, and that the picture forming methods make those qualities visible.[2] The greater picture forming quality of fresher extracts compared to older,[7] traditional varieties compared to modern,[8] and whole foods compared to processed[9] have led some within the organic movement to speculate that this organising ability reflects some inherent quality in crops or foods, usually referred to as 'vitality'.[10] However:

- The mechanisms are not fully understood, and others have suggested that the co-ordination of the crystals could be related to proteins or other nitrogenous compounds in the extracts.[11–13]
- The lack of standardised and objective methods of quantifying and classifying the resulting pictures has prevented a wider application of biocrystallisation and other picture forming methods. Computerised image analysis techniques could meet the demand for more standardised methods, and a team of Danish researchers have recently developed the appropriate software.[7,14,15] Using this image analysis software they have been able to correctly classify 21 biocrystallograms into seven groups, representing each of seven days over which a carrot extract was allowed to degrade.[7]
- The significance of the differences shown by these methods remains unclear. Although these techniques can sometimes show quite dramatic differences, there has been no way of determining whether they represent improvements in quality. This problem has been addressed by German researchers who have used both holistic and standard methods of quality analysis and compared the results. They concluded "The very often high and significant correlations between physico-chemical parameters (dry matter, mineral and nitrate contents) and features determined by picture forming methods are striking, and … clearly confirm picture forming methods as a suitable tool for quality assessments which provide reliable results".[16] Swiss research has also found picture forming methods to reveal traits closely in line with technical quality.[17] These are significant developments and suggest that this field of science may eventually be able to demonstrate its value in indicating food quality.
- There remains, however, no scientific proof that a higher integral organising ability in a crop reflects its vitality, or indeed is more favourable for the consumer's well-being. Also the impact of storage and cooking by consumers or processors on any potential 'life force' in foods remains

unknown. In an effort to examine the hypothesised link between the qualities shown by holistic methods and the wholesomeness of foods, a three generation rat feeding trial is now underway in Denmark.[18*]

Other picture forming methods that are used in food quality determinations include circular chromatography and ascending chromatography, which both involve using plant extracts to form images on chromatographic paper impregnated with silver nitrate.[13,19]

Several independent comparative studies have utilised picture forming methods to compare organically and non-organically grown crops, and valid studies have yielded the following results:

- *Mader et al (1993)*[20]
  In blind tests, samples of beetroots grown under organic or non-organic (integrated) management had to be grouped and identified according to their farming system using various picture forming methods, including biocrystallisation. Though not perfect, a high degree of differentiation and identification was possible in all three years investigated.
- *Alfoldi et al (1996)*[21]
  In blind tests, samples of wheat and potatoes grown under organic or non-organic (integrated) management had to be grouped and identified according to their farming system using various picture forming methods, including biocrystallisation. Successful identifications of all samples were reported.
- *Schultz et al (1997)*[22]
  While compositional comparisons from this experiment are not included in this review (see appendix), an assessment of the applicability of picture forming methods to distinguish crops from differing fertilisation types and levels is still possible. Tubers from plants that received biodynamic preparations were unambiguously distinguished from those that didn't in one year but not the other. Different levels of fertilisation were correctly grouped and identified. The authors concluded that these results "confirmed the applicability of this assay for additional quality determinations".
- *Granstedt & Kjellenberg (1997)*[23]
  A 32 year field trial comparing the effects of non-organic and organic fertiliser treatments applied to a four year crop rotation. Using the biocrystallisation method with potatoes and wheat it was observed that "the organisational traits were consistently better in the organically grown samples than the non-organic ones".
- *Weibel et al (2000)*[17]
  A survey of apples from organic and non-organic (integrated) orchards, comparing many parameters including mineral content, secondary nutrients, taste and a 'vital quality' index determined by Balzer-Graf using picture forming methods including biocrystallisation. The farming system was found to significantly influence the overall 'vital quality' of the fruit, with organic apples scoring 65.7 per cent higher than the non-organic

1 HDRA, 2001, *Specific Aspects of the Quality of Organic Food*, (unpublished report)
2 Balzer-Graf U, 2000, 'Vital Quality – quality research with picture forming methods', report by Forschungsinstitut fur Vitalqualitat, Ackerstrasse 5070 -Frick
3 Gear A, 1986, *What is Organic Farming?*, Henry Doubleday Research Association, UK
4 Anderson J-O, 2001, The Royal Veterinary and Agricultural University, Denmark, 'Food quality and health – the need for new concepts and methods', presentation at the Triodos Bank Annual General Meeting, 7 April 2001, London
5 Diver S, 2000, *Nutritional Quality of Organically Grown Food*, Report from the ATTRA (Appropriate Technology Transfer for Rural Areas), Fayetteville, Arkansas, US
6 Pfeiffer E, 1931, *Studium von Formkraften an Kristallizationen*, Naturweissenschaftliche Sektion am Goetheanum, Dornach
7 Andersen JO, Henriksen CB, Laursen J and Nielsen AA, 1999, 'Computerised image analysis of biocrystallograms originating from agricultural products', *Computers and Electronics in Agriculture* 22, p 51–69
8 Balzer-Graf U and Balzer FM, 1988, 'Aspekte zum Nachernteverhalten und zur Lagerungseignung', *Lenensmittelqualitat: Ganzheitliche Methoden und Konzepte*, Meier-Ploeger A and Vogtmann H (eds.), p 163–210, Verlag CF Muller, Karlsfhue
9 Balzer-Graf U, 2000, 'Quality research with picture forming methods', IFOAM-Trade Conference, Florence, cited in *Living Earth* 206 Apr–Jun 2000
10 Woese K, Lange D, Boess C, and Werner Böel K, 1997, 'A comparison of organically and conventionally grown foods – results of a review of the relevant literature', *Journal of Science of Food and Agriculture* 74, p 281–293
11 Labouriau R, Andersen J-O and Neilsen M, 1999, 'Statistical analysis of biocrystallisation patterns of carrot extracts', Danish Institute of Agricultural Science, Internal Report 11, August 1999
12 Neuhaus A, 1957, in Andersen JO, Henriksen CB, Laursen J and Nielsen AA, 1999, 'Computerised image analysis of biocrystallograms originating from agricultural products', *Computers and Electronics in Agriculture* 22, p 51–69
13 Knorr D, 1982, 'The use of circular chromatographic method for the distinction of collard plants grown under different fertiliser conditions', *Biological Agriculture and Horticulture* 1, p 29–38
14 Le Gai V, Teisseron G, Michel MC and Cauffet G, 1996, 'Application of texture analysis for the crystallisation image characterisation', in Grossmann H *et al* (eds.), *Proceedings from the Third European Research Symposium: Image Analysis for Pulp and Paper Research and Production*, Stockholm
15 Henriksen CB, 1998, 'ACTA 1.0 users manual', Internal report, Department of Agricultural Science, The Royal Veterinary and Agricultural University, Copenhagen
16 Hagel I, Bauer D, Haneklaus S and Schnug E, 2000, 'Quality assessment of summer and autumn carrots from a biodynamic breeding project and correlations of physico-chemical parameters and features determined by picture forming methods', in Alfoldi T, Lockeretz W and Niggli U (eds.), *The World Grows Organic: Proceedings from the 13th IFOAM Scientific Conference*, Basel, Switzerland, 28–31 Aug 2000, p 284–287
17 Weibel FP, Bickel R, Leuthold S andAlfoldi T, 2000, 'Are organically grown apples tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality', *Acta Horticulturae* 517, p 417–426

(integrated) apples. The authors concluded "The picture forming method distinguished 100 per cent correctly the organic and non-organic (integrated) samples and was closely in line with technical quality", though they questioned the current value of these "expensive and time demanding" methods.

Woese *et al* reviewed several other comparative studies using picture forming methods with vegetables (spinach, radish, beetroot, potatoes, white cabbage, carrots and tomatoes), wheat, herbs, beer, milk and eggs. The authors observed "altogether it was mostly concluded that the crystallisation images made with extracts from organically produced foods had a higher form-shaping ability and thus more 'vital' activity than the corresponding non-organically produced foods".[10]

4.2 Storage degradation tests as a measure of quality

It has been hypothesised that an important aspect of all life is the ability to maintain form and structure (reducing entropy),[24] and that this aspect of a crop at harvest will influence how it performs in storage.[25] A better keeping quality of organically grown produce is sometimes claimed to be sufficient to overcome any initial yield disparity with non-organically grown produce.[26] Many researchers have therefore compared the storage capabilities and qualities of organically and non-organically grown produce, and valid studies reviewed here have yielded the following results:

- *Dlouhy (1981)*[27]
  Organically grown potatoes had 29 per cent lower storage losses than non-organically grown potatoes (14.9 versus 20.9 per cent respectively)
- *Abele (1987)*[24]
  Forced-storage degradation tests on carrots, beetroots and potatoes indicated better product quality from lower fertilisation levels or organic fertilisation than non-organic fertilisation, while under optimal storage conditions only small differences occurred.
- *DeEll & Prange (1993)*[28]
  The percentages of marketable apples remaining after four and eight months storage were higher for non-organically grown apples than organically grown apples (mainly dependent on external appearances and linked by the authors to fungicide use by the non-organic orchards). No significant differences due to production methods were found for core browning or weight loss in storage. However, senescent breakdown, 'the browning and softening of apple flesh beginning immediately under the skin associated with ageing and advanced maturity', tended to be less in the organically grown than the non-organically grown apples.
- *Mader et al (1993)*[20]
  'Storability' of beetroot (percentage marketable,

18 Andersen, J-O, 2001, The Royal Veterinary and Agricultural University, Denmark, *personal communication, May 2001

19 Tingstad A, 'Capillary dynamolysis ("rising pictures") for the assessment of quality of foodstuffs', in Alfoldi T, Lockeretz W and Niggli U (eds.), *The World Grows Organic: Proceedings from the 13th IFOAM Scientific Conference*, Basel, Switzerland, 28–31 Aug 2000, p 310

20 Mader P, Pfiffner L, Niggli U, Plochberger K, Velimirov A, Balzer U, Balzer F and Besson J-M, 1993, 'Effect of three farming systems (biodynamic, bio-organic, conventional) on yield and quality of beetroot in a seven year crop rotation', *Acta Horticulturae* 339, p 10–31

21 Alfoldi Th, Mader P, Niggli U, Spiess E, Dubois D and Besson J-M, 1996, 'Quality investigations in the long-term DOC-trial', *Quality of Plant Products Grown with Manure Fertilization: Proceedings of the Fourth Meeting* (Juva, Finland, 6–9 July 1996). Darmstadt; Germany: Institute for Biodynamic Research, p 34–43

22 Schultz DG, Koch K, Kromer KH and Kopke U, 1997, 'Quality comparison of mineral, organic and biodynamic cultivation of potatoes: contents, strength criteria, sensory investigations and picture creating methods', *Agricultural Production and Nutrition, Proceedings of an International Conference* (Boston, MA, 19–21 Mar 1997), Lockeretz W (ed.), Medford, MA: School of Nutrition Science and Policy, Tufts University, p 115–120

23 Granstedt AG and Kjellenberg L, 1997, 'Long-term field experiment in Sweden: effects of organic and inorganic fertilisers on soil fertility and crop quality', in Lockeretz W (ed.) *Agricultural Production and Nutrition, Proceedings of an International Conference* (Boston, Ma, 19–21 March 1997), Medford, MA: School of Nutrition Science and Policy, Tufts University, p 79–90

24 Abele U, 1987, 'Product fertilisation and quality – mineral, organic, biodynamic', *Angewandte Wissenschaft* 345

25 Hoppe H, 2000, 'Measuring food quality', New European Quality Forum presentation at the 11th National Conference on Organic Food & Farming, (Royal Agricultural College, Cirencester, Jan 2000)

26 Pettersson BD, 1978, 'A comparison between conventional and biodynamic farming systems as indicated by yields and quality', *Proc. 1st Int. Res. Conf.*, IFOAM, Verlag, Wirz Aarau, p 87–94

27 Dlouhy J, 1981, 'Product quality in alternative agriculture', *Food Quality – Concepts and Methodology*, Elm Farm Research Centre Colloquium, 1990, p 30–35

28 DeEll JR and Prange RK, 1993, 'Postharvest physiological disorders, diseases and mineral concentrations of organically and conventionally grow McIntosh and Cortland Apples', *Canadian Journal of Plant Science* 73(1), p 223–230

29 Vogtmann H, Matthies K, Kehres B and Meier-Ploeger A, 1993, 'Enhanced food quality: effects of composts on the quality of plant foods', *Compost Science and Utilisation* 1, p 82–100

30 Raupp J, 1996, 'Quality investigations with products of the long-term fertilisation trial in Darmstadt – second period: fertilisation with total nitrogen equivalents', *Quality of Plant Products Grown with Manure Fertilization: Proceedings of the Fourth Meeting* (Juva, Finland, 6–9 July 1996). Darmstadt; Germany: Institute for Biodynamic Research, p 13–33

percentage rotten roots, weight loss) was similar for all farming systems (unfertilised, organic, non-organic, integrated).

- *Vogtmann et al (1993)*[29]
  Organically grown carrots and cabbage performed better in storage (measured by dry matter losses, colour, appearance, fungal growth, maintenance of structure, smell) than non-organically grown carrots and cabbage.
- *Raupp (1996)*[30]
  Organically grown potatoes had better storage qualities (percentage dry matter loss and darkening) than non-organically grown potatoes, while storage qualities of organically and non-organically grown beetroots were inconsistent (similar percentage dry matter loss but less spoilage losses for non-organically grown beetroot: four per cent compared to 13–19 per cent for organic).
- *Granstedt & Kjellenberg (1997)*[23]
  Organically grown potatoes suffered 15 per cent fewer storage losses (due to respiration and fungal damage) than the non-organically grown potatoes (averaged 22.7 versus 26.7 per cent respectively).
- *Weibel et al (2000)*[17]
  Forced-storage degradation tests (measuring water loss and fungal contamination) found no significant differences between apples from organic and non-organic (integrated) orchards.

While these studies suggest a better or at least equal keeping quality of organically grown produce, agriculture makes extensive use of controlled atmosphere storage facilities and post-harvest fungicide applications to reduce storage losses. Time since harvest, storage conditions and post-harvest waxing or fungicidal treatment of non-organically grown produce can all confuse the consumer perception of the relative keeping qualities of organically and non-organically grown produce.

5 | Discussion and conclusions

Viewed collectively, the valid and relevant scientific evidence indicates that organically grown foods are significantly different in terms of their safety, nutritional content and nutritional value from those produced by non-organic farming.

Good health should be defined as more than simply the absence of illness, to include the promotion of positive health, encompassing such aspects as abundant energy, resistance to stress, good mental and sound reproductive health.

The concept of food quality should recognise wider aspects than mere external appearances, including authenticity, functionality, biological and nutritional value, sensual and ethical dimensions. In the biological and nutritional areas of food quality examined here, the promotion of positive health is considered to be significantly dependant on the absence of toxins and presence of primary and secondary nutrients in foods.

Food safety

The public is becoming increasingly suspicious that the intensification of farming, while providing seemingly cheap and abundant food, is compromising food safety. Recent food scares have involved livestock production, yet concerns are also high regarding issues such as pesticide residues, food poisoning and genetic modification.

Pesticides and fertilisers
There is a degree of uncertainty over, firstly, the levels of pesticides contaminating non-organically produced foods and the environment and, secondly, the effects these levels of exposure can have on human health. Eating organically produced food minimises exposure to pesticide residues.

Studies have shown a link between excessive nitrogen fertilisation and increased plant susceptibility to pests and disease, necessitating the use of insecticides and fungicides.[1,2] Plants provided abundantly with nutrients, especially with nitrogen, are more likely to be attacked by aphids, while plants manured organically are less or not at all affected by aphids due to the lower water contents and thicker cell walls of the plants.[3] Crop losses due to insects have increased by around 20 per cent since 1945 despite a 3,300 per cent increase in the amount of pesticides used.[4] The thicker cell walls of organically managed crops may also protect them from disease, as was found in a study with maize.[5]

As manures and composts must be mineralised by the biological life in the soil before the nitrogen is widely available to the crop, excessive nitrogen fertilisation is much less likely than in non-organic farming where readily soluble nitrogen is typically applied in much higher doses.

The use of fertilisers and pesticides in non-organic farming must be weighed against the risks posed to the health of farmers working with them and consumers exposed to pesticide residues on food and in the environment. The presence of these residues in and on foods is not contested. The most recent survey results show that nearly half of all non-organic fruit and vegetables on sale in the UK carry pesticide residues. What is contested is just how significant these levels are, the synergistic effects of multiple residues, the extent and significance of residue variability from one piece of fruit or vegetable to the next, and the long-term effects of accumulations of these pesticides in humans.

Evidence of direct links between pesticides and ill-health is still emerging, with most evidence available from occupational and environmental exposures. There is, however, a small amount of evidence linking dietary pesticide exposures to human health, contributing to concerns over the long term health effects of chronic, low level exposure to combinations of pesticides over many years.

The British Society for Allergy, Environmental and Nutritional Medicine (BSAENM), a society of doctors who look for the causes of disease, believe there is already good evidence linking the rise in incidence of allergies and multiple chemical sensitivities with a general over exposure to chemicals, including pesticides, because of their immune dysregulating properties.[6] They point out that susceptibility to toxic effects in humans varies for a number of reasons, not least of which is deficiency of key nutrients needed for detoxification.

Additionally, organophosphate pesticides have been reported to have adverse effects on micronutrient status,[7,8] and various vitamins and minerals are utilised in greater quantities as chemical exposure increases.[6] Nutrient deficiencies are being increasingly recognised in apparently healthy individuals[9–11] and in those referred to hospital environmental allergy clinics.[12] The BSAENM point out that "when essential nutrients are in short supply, excretion of toxins may be impaired, growth, repair and immune system function adversely affected (even if only marginally) and the body more at risk from the toxic and teratogenic effects of even small exposures".[6]

Food poisoning

There appears to be no increased risk of food poisoning from agents such as E.coli or aflatoxins in organically grown compared with non-organically grown food.

The UK Food Standards Agency has concluded that there is no evidence to indicate that organically grown food is more prone to microbial or mycotoxin contamination than non-organically grown food, as confirmed by a recent Public Health Laboratory Services survey of 3,200 samples of uncooked, ready-to-eat organic vegetables which found either no or very low incidences of contamination, "indicating that overall agricultural, hygeine, harvesting and production practices were good".[13]

The strict organic guidelines for animal welfare and the composting of manures reduce the risks of E.coli contamination of organic produce.

There is no supporting evidence behind the suggestion that organic crops, because of the prohibition of fungicides, are more prone to fungal attack and thus more likely to be contaminated with aflatoxins. Artificially lush crops with thinner cell walls, as produced by the application of readily soluble nitrogen fertilisers,[3] may be more susceptible to fungal attack, necessitating the use of fungicides that may be more toxic than aflatoxins. It appears likely that storage, and not production conditions, are responsible for most aflatoxin production.

GMOs

Any conclusion upon the safety of introducing GM crops into the food chain and environment is premature as there is insufficient evidence to inform the decision making process at present, and serious and valid concerns persist among independent scientists and consumers alike.

Given the uncertainties surrounding the safety of GM foods, there appears to be an unnecessary urgency in the way genetic engineering is being introduced into food production. Some argue that while there may be hazards, the overall risk is low because the likelihood of these hazards causing a problem is small. Yet it can also be argued that any risk is significant given that this technology is likely to persist in nature and it will not be possible to recall it if serious problems are identified at a later date. It is for reasons such as these that the Soil Association advocates a strong adherence to the precautionary principle on this issue.

To date there have been no consumer benefits derived though genetic engineering of agricultural crops, and the much publicised 'golden rice', a prototype GM crop modified to contain beta-carotene in an attempt to address widespread vitamin A deficiency induced blindness in developing countries, may not be as beneficial as was hoped. It has been estimated that some nine kilograms of cooked golden rice would have to be consumed daily in order to acquire the RDA of vitamin A from this source.[14]

While the entire RDA needn't be supplied by this food alone, and indeed the entire RDA may not be required to prevent some vitamin A deficiency-related blindness, much simpler and more practical solutions have been put forward. These include promoting the use of and access to foods naturally rich in provitamin A, such as red palm oil. The considered opinion of the Food Ethics Council is that "technological fixes are rarely satisfactory ways of solving economic and social problems".[15*]

While it may be possible to reduce some of the risks posed by biotechnology by assessing the hazards over several years and in contained conditions, there are many other possible solutions to the problems of agriculture and food production which pose far fewer risks, involve far less uncertainty and already offer clear and substantial benefits. Farming of genetically modified crops poses a considerable threat to organic farming through inevitable cross-pollination. It has been suggested that the two cannot co-exist on an island the size of Britain,[16] and the consumer right to choose GM or non-GM foods, which has to date been publicly supported by the UK government, will be lost.

Antibiotics

There are concerns over the increasing risk to human health from antibiotic resistance developing in micro-organisms because of the misuse and overuse of antibiotics in non-organic livestock rearing.

There is growing suspicion of a link between increasing bacterial resistance to antibiotics and the misuse and overuse of antibiotics, including routine prophylactic use in non-organic livestock rearing. This issue is of mounting concern to governments and the medical profession. Some bacteria are already showing signs of resistance to one of the latest antibiotics to reach hospital wards.[17] The World Health Organisation has called for a reduction in the use of antibiotics in agriculture because of the risk to human health, adding that healthy animal husbandry would lessen the need for drugs which, it said, should never be used to prop up inadequate hygiene. Despite these concerns, many non-organic livestock farmers use antibiotics as growth promoters or for disease suppression by routinely adding them to feed and water. The routine use of antibiotics is prohibited in organic animal husbandry.

BSE

After extensive searches, no record has been found of any cases of Bovine Spongiform Encephalopathy (BSE), suspected of being linked to variant-Creutzfeldt-Jakob Disease (vCJD) in humans, in any animal born and reared organically.

Thorough records kept by the Soil Association and other certifiers confirm that cases of BSE that have been recorded in organic herds occurred only in animals that had been brought in from a non-organic source for conversion or as breeding replacements. The suspected mechanism of infection and a key suspected contributory factor, namely the feeding of animal proteins to cattle and the use of organophosphate treatments, are both prohibited in organic farming.

Food additives and ingredients

While more than 500 additives are permitted for use in non-organically processed foods, organic standards permit only a limited list of around 30 additives to be used in organic food products.

Food processing, often resulting in a reduction of nutrients and / or the addition of various additives, has been a significant development in food quality in recent decades. More than 500 additives are permitted for use in non-organically processed foods, including artificial preservatives, colourings and flavourings. As these now common ingredients have been linked with numerous health issues, organic standards permit only a limited list of additives which are allowed in organic food products only if the authenticity of the product is respected and the product cannot be produced or preserved without them.

Specific ingredients prohibited in organic food products due to their suspected harmful effects include hydrogenated fats, common in cakes, biscuits, margarines, pastry and many other processed foods and known to increase the risk of heart disease; and phosphoric acid, common in colas and linked to bone calcium depletion, fractures and osteoporosis.

Nitrate

The content of potentially toxic nitrate has been demonstrated to be higher in non-organically grown crops as a direct consequence of fertilisation practices.

As the quantities of nitrate normally occurring in food are likely to become harmful only under conditions in which it is reduced to toxic nitrite and nitrosamines, it is of interest that Vitamin C, known to inhibit this process, is often lower in non-organically fertilised crops that are high in nitrate. Further dietary exposure to nitrate occurs through drinking water.

Nitrate concentrations in ground water are gradually increasing through leaching of nitrogenous fertilisers,[18] and water boards in the UK spend around £16 million a year reducing concentrations in drinking water below the maximum allowable limit of 50mg / l.[19] It has been suggested that nitrate levels in vegetables, which constitute a greater contribution to the total dietary intake than drinking water, should also be monitored, controlled and reduced.[20]

Note: references not provided in this section may be found in the relevant sections of the report.

1 Hodges RD and Scofield AM, 1983, 'Effect of agricultural practices on the health of plants and animals produced: a review', in *Environmentally Sound Agriculture, 4th IFOAM Conference*, Cambridge, MA, Lockeretz K (ed.), Praeger, New York, p 3–34

2 Rydberg T, 1986, 'The response of barley varieties in conventional and biological growing', in Vogtmann H, Boehncke E, Fricke I (eds.), *The Importance of Biological Agriculture in a World of Diminishing Resources – Proceedings of the 5th IFOAM International Scientific Conference* (University of Kassel Germany, 27–30 Aug 1984) Verlagsgruppe Witzenhausen, p 310–316

3 Schuphan W, 1972, 'Nutritional value of crops as influenced by organic and inorganic fertiliser treatments', *Qualitas. Plantarum – Plant Foods for Human Nutrition* 23(4), p 333–358

4 Pimentel *et al*, 1990, *Handbook of Pest Management in Agriculture*, 2nd edition, Boca Raton, FL: CRC Press, and Pimentel D, Cornell university, as quoted by Lefferts LY and Blobaum R, 1992, 'Eating as if the earth mattered', *E Magazine*, Jan / Feb 1992, p 32

5 Lockeretz W, Shearer G, Sweeney S, Kuepper G, Wanner D and Kohl DH, 1980, 'Maize yields and soil nutrient levels with and without pesticides and standard commercial fertilisers', *Agronomy Journal* 72, p 65–72

6 Eaton KK and Anthony HM (moderators), 2000, 'Multiple chemical sensitivity recognition and management', Third Scientific Report of the British Society for Allergy, Environmental and Nutritional Medicine, *Journal of Nutr Environ Med* 10, p 39–84, 2000

7 Calabrese EJ, 1980, *Nutritional and Environmental Health: the Influence of Nutritional Status on Pollutant Toxicity and Carcinogenicity, vol 1, The Vitamins*, John Wiley, New York

8 Calabrese EJ, 1981, *Nutritional and Environmental Health: the Influence of Nutritional Status on Pollutant Toxicity and Carcinogenicity, vol 11, The Minerals*, John Wiley, New York

9 Block G and Abrams B, 1993, 'Vitamin and mineral status of women of childbearing potenial', *Ann NY Acad Sci* 678, p 244–54

10 Benton D, Haller J and Fordy J, 1997, 'The vitamin status of young British adults', *Internat J Vit Res* 67, p 34–40

11 Barclay MN and MacPherson A, 1992, 'Selenium content of wheat flour used for breadmaking in Scotland and the relationship between glutathione peroxidase levels in whole blood and bread consumption', *Brit J Nutrit* 68, p 261–270

12 Maberly DJ and Anthony HM, 1997, 'Serum zinc in a series of allergy patients', *J Nut Environ Med* 7, p 62–63

13 Public Health Laboratory Service 2001, 'The microbial examination of ready-to-eat organic vegetables from retail establishments', PHLS Environmental Surveillance Unit, London

14 Greenpeace, 2001, 'GE rice is fools gold', available at www.greenpeace.org / gehome

15 Mepham B, 2001, executive director of the Food Ethics Council, *personal communications, 2 May 2001

16 Greenpeace, 1999, Lindsay Keenan speaking at the London Organic Food and Wine Festival, Aug 1999

17 Gonzales RD, Schreckenberger PC, Graham MB, Kelkar S, DenBesten K and Quinn JP, 2001, 'Infections due to vancomycin-resistant enterococcus faecium resistant to Linezolid', *The Lancet* 357(9263), p 1179

Primary nutrients

The available valid scientific evidence reviewed here demonstrates a clear trend toward organically grown fruit and vegetables having higher levels of desirable components such as dry matter, essential minerals and vitamin C than non-organically produced fruit and vegetables.

The conflicting and inconclusive results of previous literature reviews have not enabled a clear consensus to be reached, yet they have included a large number of studies that do not make fair and valid comparisons of the two agricultural approaches. In many comparative field trials, the organic experimental plots have not accurately represented organic farming methods as required by legal standards (eu2092/91), usually due to:

- Insufficient duration of the trial – organic farmers build fertility in the soil over many years, while many comparative studies are of only one or two seasons, and the addition of amounts of manure or compost to experimental plots for this short time is unlikely to result in the biological soil activity typically found on organic farms.
- Use of unapproved pesticides or other practices on 'organic' plots – this could interfere with the soil biological activity required for mineralisation of nutrients supplied in compost and manures, and is not representative of organic farming practices.

Also, shortcomings in analyses include:

- Mineral concentrations reported as a percentage of dry weight instead of wet weight. As the water content of non-organically grown produce is often found to be higher than in organically grown produce, the concentration of nutrients in organically grown produce is likely to be higher, though this difference is overlooked when researchers compare only dry-weight nutrient concentrations.

Comparative crop trials using recognised practices on post-conversion soils, surveys of certified organic farms and produce, and nutrient concentrations reported on a fresh-weight basis provide a more valid basis upon which to compare the nutritional content of organically and non-organically grown crops.

The limited number and heterogenous nature of studies comparing organically and non-organically grown cereals prevent any final conclusions regarding their comparative primary nutrient contents, though a review of 22 valid studies comparing organically and non-organically grown fruit and vegetables revealed trends as outlined in the table (right).

While organic produce had a higher nutritional content in a large proportion of valid studies, in almost as many, no consistent or significant differences were found. This lack of consistency may be expected given the many influences on crop quality. For example:

18 Addiscot TM, 1996, 'Fertilisers and nitrate leaching', in Hester RE and Harrison RM (eds.), *Agricultural Chemicals and the Environment, Issues in Environmental Science and Technology*, No 5, Cambridge, Royal Society of Chemistry, p 1–26

19 Pretty J, Brett, Gee, Hine, Mason, Morison, Raven, Rayment and van der Bijl, 2000, 'An assessment of the total external costs of UK agriculture', *Agricultural Systems* 65(2), p 113–136

20 Stopes C, Woodward L, Forde G and Vogtmann H, 1988, 'The nitrate content of vegetable and salad crops offered to the consumer as from organic or conventional production systems', *Biological Agriculture and Horticulture* 5, p 215–221

21 Warman P, 1998, 'Results of the long-term vegetable crop production trials: conventional vs. compost amended soils', *Acta Horticulturi* 469, p 333–341

22 Finesilver T, 1989, 'Comparison of food quality of organically versus conventionally grown plant foods', McGill Publications, available at http://eap.mcgill.ca/publications/eap_head.htm

23 MAFF, 2000, *Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209)*, 7th Edition, The Stationery Office

24 Abu-Ismaileh BE and Jordan LS, 1978, 'Some aspects of glyphosphate action in purple nutsedge', *Weed Science* 26(6), p 700–703

25 Calabrese E, 1980, *Nutritional and Environmental Health: the Influence of Nutritional Status on Pollutant Toxicity and Carcinogenicity, vol 1, The Vitamins*, John Wiley, New York

26 Comis D, 1989, 'Nitrogen overload may shrivel vitamin C content', discussing the work of Sharon Hornick of the USDA in *Agricultural Research*, July 1989, p 10–11

27 Lairon D, Ribaud P, Leonardi J, Lafont H, Gaudin G, and Reynier M, 1981, 'Analysis of vegetables produced by orthodox and biological methods; some preliminary results', in Stonehouse B (ed) *Biological Husbandry – a Scientific Approach to Organic Farming*, Stonehouse, Butterworths Publishers, p 327–328. Also published as Lairon *et al*, 1983, 'Studies of yield and food quality of vegetables grown under organic and mineral fertilisation', *Environmentally Sound Agriculture, 4th IFOAM Conference*, Cambridge MA, Selected Papers, Lockeretz W (ed.), Praeger, NY, p 408–409

28 Abele U, 1987, 'Product fertilisation and quality – mineral, organic, biodynamic', *Angewandte Wissenschaft* 345

29 DeEll JR and Prange RK, 1993, 'Postharvest physiological disorders, diseases and mineral concentrations of organically and conventionally grown McIntosh and Cortland Apples', *Canadian Journal of Plant Science* 73(1), p 223–230

30 Kolbe H, Meineke S, and Zhang WL, 1995, 'Differences in organic and mineral fertilisation on potato tuber yield and chemical composition compared to model calculations', *Agribiol. Res.* 48(1), p 63–73

31 Pommer G and Lepschy J, 1985, 'Investigation of the contents of winter wheat and carrots from different sources of production and marketing', *Bayerisches Landwirtschaftliches Jarbuch* 62, p 549–563

32 Worthington V, 1999, 'Nutrition and biodynamics: evidence for the nutritional superiority of organic crops', *Biodynamics*, July/August 1999, p 22–25

33 *The Surgeon General's Report on Nutrition and Health*, pub no. 88-50210 Washington DC, US Dept of Health and Human Services, 1988

34 MAFF (1996), *National Food Survey 1995*, Stationery Office, London, UK

35 MAFF (1998), *National Food Survey 1997*, Stationery Office, London, UK

36 Werbach M, *Nutritional Influences on Illness*, 2nd edition, Third Line Press, CA, 1993

Overall trend demonstrated within studies comparing the primary nutrient contents of organically and non-organically grown fruit and vegetables

Studies showing:

Higher primary nutrient content in organic crops
Dry matter content ■■■■■■■■■■ 10
Mineral content ■■■■■■■ 7
Vitamin C content ■■■■■■■ 7

Inconsistent or non-significant differences
Dry matter content ■■■■■■■■ 8
Mineral content ■■■■■■ 6
Vitamin C content ■■■■■■ 6

Higher primary nutrient content in non-organic crops
Dry matter content ■ 1
Mineral content ■ 1
Vitamin C content None

- Even though other influences on nutrient content were generally controlled in field trials and farm surveys, they might affect organic and non-organic systems differently. For example, significant nutrient differences might depend on the soil type: while soil types with low nutrient levels might produce significant differences between the systems, soils with high levels may not. Variety might affect the results in a similar way.
- Two years is the minimum conversion period before organically farmed produce can be sold as 'organic', but soil fertility continues to build up over the years, and thus differences in nutrient levels may increase over time. This could mean that some comparative trials might initially produce few differences due to the time under organic management.
- Other potential influences were not always controllable in the market surveys, such as soil type, climate and time since harvest.

Possible reasons for higher nutrient contents in organically grown crops include:

- *Soil biological activity*
  Organic standards are designed to protect and encourage soil micro-organisms, which are necessary to 'unlock' nutrients from the soil, form symbiotic relationships with plants and make nutrients available to them. Artificial fertilisers, herbicides and pesticides suppress these micro-organisms, thus diminishing the 'life' of the soil and hindering the many complex and often poorly understood biological processes needed for nutrient supply to the plants. The conversion period of two years required before a farm is awarded full organic status is partly to allow this soil microbiological life to recover and multiply.
- *Soil trace mineral depletion*
  Although it is generally accepted that all nutrients removed from the soil in crops should be replaced, modern non-organic agriculture usually only replaces the elements required for plant growth – nitrogen, phosphorus, potassium (these three being commonly referred to as 'NPK') and hence there is a continuing tendency in non-organic systems for trace nutrient deficiencies to develop and increase.[1] This has been supported by a long term field trial which found that, although equal yields were removed from the plots each year, soil tests after six years indicated that the non-organically fertilised soils were generally equal or higher in P and K, but lower than compost enriched soils in organic matter, Ca, Mg, Mn, Cu and Zn.[21]
- *Variety*
  The varieties of plants grown by non-organic farmers are likely to be selected to maximise yields or factors such as ease of harvesting, rather than on the basis of nutritional quality or resistance to pests or disease (which may reflect secondary nutrient contents). Therefore, differences in choice of cultivar between the two systems might result in differences in nutritional quality.[22]
- *Induced deficiencies*
  Interactions between large amounts of the major fertiliser elements and other major, minor or trace elements in the soil can interfere with the availability of some elements essential to crop growth or the human diet.[1,23]
- *Pest control*
  Pesticides may directly or indirectly affect certain functions of the plant involved in the synthesis or uptake of certain nutrients, as shown in field experiments.[24,25]
- *Level of fertilisation*
  For example, it has been shown that vitamin C levels decrease with higher rates of fertilisation regardless of whether it is synthetic or organic.[26] While excessive nitrogen fertilisation *is* possible in organic farming, because manures and composts must be mineralised by the biological life in the soil before the nitrogen is widely available to the crop, this is much less likely than in non-organic farming where readily soluble nitrogen is applied in typically much higher doses.
- *Yield differences*
  On average, organically grown crops give lower yields than non-organically grown ones, meaning the same area produces less biomass, and it has been suggested that this may account for some of the differences in nutrient availability to crops.
- *Higher dry matter contents*
  The consumer perspective of this report meant that fresh-weight contents were the appropriate basis for comparison of the nutrient contents of organically and non-organically grown produce. Could the differences demonstrated simply be the result of the higher dry matter contents? In some studies, the differences have only been significant on a wet-weight basis, and not on a dry-weight basis,[27] which suggests no inherent difference between produce from the two systems except that non-

organically grown crops are swelled with more water. On the other hand, differences in nutrient contents are often shown to be greater than differences in dry matter contents,[28–31] suggesting that there are systematic differences in nutrient availability and uptake between the two systems.

Further investigations are required to establish which of the potential reasons listed here are contributing to the differences shown.

Are these nutritient content differences important to human health?
This is an important question because statistical significance (as addressed in section 3) does not necessarily result in biological significance. Worthington (1999) answers this question thus: "We have seen now that organic crops have higher levels of nutrients most of the time. Still, it is easy to dismiss all of this as insignificant, since the absolute quantities of nutrients are small. For example, if there is 47 per cent more vitamin C, for most foods that amounts to no more than a few milligrams. Are these small differences of any consequence? A few years ago it would have been easy to brush them aside, but it is now known that there are many nutrient interactions and that small differences do matter. For example, an increase in vitamin C increases the effect of vitamin E, folic acid and iron. The increase in vitamin E then increases the effect of selenium and vitamin A. Vitamin A further increases the effect of iron, and so on. Because of these interactions, small increases (or equally decreases of toxic substances) of the many nutrients in a food can have a much bigger effect than would be expected from looking at the individual nutrient levels. Nutritionally speaking, the whole is greater than the sum of the parts. And small differences in nutrient levels can matter a lot".[32]

The US Surgeon General's *Report on Nutrition and Health*[33] stated that nutrition can play an important role in the prevention of such conditions as cardiovascular disease, cancer and diabetes. National food surveys have indicated that the average person in Britain is likely to be deficient in various nutrients.[34,35] Furthermore, studies have shown that low levels of various minerals correlate with many health conditions, including alcoholism, allergy, cancer, candidiasis, cardiomyopathy, chronic fatigue syndrome, diabetes, fatigue, headache, hypertension, obesity, premenstrual syndrome and rheumatoid arthritis.[36] Numerous advocates of alternative cancer treatments have stressed the importance of the exclusive use of organic produce.[37] The Nutritional Cancer Therapy Trust asserts "Those concerned with the fight against disease know that our bodies are designed to overcome disease processes before they become established. Our systems are readily disrupted by toxins and an absence of sufficient quantities of their essential building blocks".[38*]

The common underlying cause of many degenerative diseases is increasingly recognised as chronic multiple micronutrient malnutrition.[39] Dr Helen Fullerton observes "Micronutrient deficiencies are only recognised as scientifically proven when they are acute and cause a specific condition or disease (for example scurvy, beriberi, pellagra), but there has been a failure to recognise the symptoms of marginal deficiencies that contribute to reduced fitness and underachievement due to lowered vitality".[40] Common sub-clinical deficiency symptoms of various nutrients that contradict the prevailing view that nutrient deficiencies are rare include:

Mineral deficiency symptoms[41]

- *Calcium*
  Muscle cramps or tremors, joint pains, insomnia, brittle nails, eczema, nervousness.
- *Magnesium*
  Muscle twitch, tremors, personality changes, depression, anxiety, irritability, PMS, gastro-intestinal disorders.
- *Iron*
  Anaemia, constipation, brittle or spoon-shaped nails, tiredness, apathy, reduced brain function, headache.
- *Chromium*
  Poor glucose tolerance leading to sugar and stimulant cravings, irritability, drowsiness, need for frequent meals, poor weight control.
- *Manganese*
  Poor glucose tolerance, poor muscle co-ordination, dizziness or poor sense of balance.
- *Selenium*
  Premature ageing, growth retardation, higher risk of cancer and heart disease, poor fertility.
- *Zinc*
  Retarded growth, poor wound healing, poor sense of taste or smell, frequent infections, stretch marks, poor fertility.
- *Vitamin C*
  Susceptibility to infections, easy bruising, bleeding or tender gums, difficulty shifting infections, lack of energy.

In 1992 the USDA estimated the potential impact of improving the US national diet to encourage people to achieve the lowest level recommended daily allowance of energy, carbohydrates, vitamins and minerals:

Potential improvements in health problems[42]

- *Cancer*
  20 per cent reduction in incidence and death.
- *Heart and vascular conditions*
  25 per cent reduction of disease and death.
- *Respiratory and infectious diseases*
  20 per cent reduction in incidence.
- *Infant deaths*
  50 per cent reduction.
- *Maternal deaths*
  50 per cent reduction.
- *Congenital birth defects*
  20 per cent reduction.
- *Arthritis*
  50 per cent reduction.

- *Osteoporosis*
  75 per cent reduction.
- *Diabetes and carbohydrate disorders*
  50 per cent of cases avoided or improved.
- *Obesity*
  80 per cent reduction in incidence.
- *Mental health*
  10 per cent fewer disabilities.
- *Improved mental ability*
  Raise IQ by 10 points for persons with IQ of 70–80.
- *Alcoholism*
  33 per cent reduction in incidence and death.
- *Eyesight*
  20 per cent fewer people blind or with corrective lenses.
- *Allergies*
  20 per cent relieved.
- *Digestive problems*
  25 per cent fewer acute conditions.
- *Kidney and urinary problems*
  25 per cent reduction in death and acute conditions.
- *Dental health*
  50 per cent reduction in incidence, severity and cost.

It should be noted that these estimates are based on prevention rather than cure. Some estimate that the levels of micronutrients required to halt or reverse established degenerative disease states is higher than can be obtained through diet alone, and assert that supplementation, either directly or through food fortification, is the only way to get the amounts required.[39] Successful nutritional cancer therapies involve not only consumption of organically grown food but also enhanced nutrient intakes through organic juices and supplementation.[38]

Having said this, human observations and numerous animal feeding trials have confirmed significant positive health benefits from organic diets, especially in the areas of reproduction, early development and overall health. Possible positive health benefits from consuming organically grown food observed in humans include better overall health, better resistance to infections, more rapid convalescence and improved quality of semen.

Animal studies show better growth and reproduction in animals fed organically grown feed compared with those fed non-organically grown feed. Worthington concludes "Reproductive health, incidence and recovery from illness are sensitive measures of health status and should be given appropriate weight. Taking all of this into account, the available data is very strong with regard to the health benefits of organic feed and food".[32]

Could these differences in nutritional content be important to the economy?

Health spending is a major cost for the UK government. The NHS budget is £59 billion annually and there is always enormous pressure to increase funding. Physical and mental health problems also bring major costs to other government departments, such as social security, and to the economy as a whole through lost working days. As long as government

37 Bishop B, 'Organic food in cancer therapy', *Nutrition and Health* 6(2), p 105–109, 1988
38 Ashton C, 2001, director of the Nutritional Cancer Therapy Trust, *personal communication, 26 April 2001
39 Clayton P, 2001, *Heath Defence*, Accelerated Learning Systems Publishers, Aylesbury, UK
40 Fullerton, H (Dr), 1995, 'Soil nutrition', *Nutritional Therapy Today* 5(3), p 8–9
41 Kirschmann GJ and Kirschmann JD, 1996, *Nutrition Almanac*, 4th edition, McGraw-Hill Press, USA
42 Welt C, 1992, *Benefits from Human Nutrition Research*, USDA report
43 Staiger D, 'The nutritional value of foods from conventional and biodynamic agriculture', *IFOAM Bulletin* No 4, p 9–12
44 Brandt K and Mølgaard JP, 2001, 'Organic agriculture: does it enhance or reduce the nutritional value of plant foods?', *Journal of the Science of Food and Agriculture* 81, p 924–931
45 Duthie GG, Duthie SJ and Kyle JAM, 2000, 'Plant polyphenols in cancer and heart disease: implications as nutritional antioxidants', *Nutrition Research Reviews* 13, p 79–106
46 Friedman M, 1997, 'Chemistry, biochemistry and dietary role of potato polyphenols: a review', *Journal of Agriculture and Food Chemistry* 45, p 1523–1530
47 Haggerman AE, Riedl KM, Jones GA, Jovik KN, Rilchard NT, Hartzfeld PW and Reichel TL, 1998, 'High molecular weight plant polyphenols (tannins) as biological antioxidants', *Journal of Agriculture and Food Chemistry* 46, p 1887–1892
48 Fossard E, Bucher M, Machler, Mozafar A and Hurrell R, 2000, 'Potential for increasing the content and availability of Fe, Zn and Ca in plants for human nutrition', *Journal of the Science of Food and Agriculture* 80, p 861–879
49 Sanford LL, Deahl KL, Sinden SL and Ladd TL, 1992, 'Glycoalkaloid contents in tubers from Solanum tuberosum populations selected for potato leafhopper resistance', *Am Pot Journal* 69, p 693–703
50 Fenwick R, 1990, 'Natural toxins in food', in *Food Quality – Concepts and Methodology*, Elm Farm Research Centre Colloquium, 1990, p 27–29
51 Jensen KO, Larsen HN, Mølgaard JP, Andersen JO, Tingstad A, Marckman P and Astrup A, 2001, 'Organic food and human health', DARCOF-report no. 14, Danish Research Centre for Organic Farming, Tjele, Denmark

health policy focuses on treating symptoms as opposed to improving health, these costs are expected to increase. In comparison, only £3 billion is spent directly on UK agriculture each year by the Department for the Environment, Food and Rural Affairs under the Common Agricultural Policy, and only a very small fraction of this is targeted at encouraging and developing organic farming. In view of the overall cost of health problems, even a modest improvement in the health of the nation could result in important savings. Organic food production could provide a simple and cost-effective contribution towards reducing health costs and improving the population's health.

The US Surgeon General's *Report on Nutrition and Health* found that 68 per cent of diseases are related to diet.[33] This diet-related disease must represent a significant proportion of NHS annual costs, and while the key recommendation remains to increase total intake of fresh fruit and vegetables, if the nutritional advantages of organic produce discussed in this report brought about even a modest improvement in the health of the nation, savings on the NHS budget could be in the order billions of pounds a year; arguably more than would be needed to fund the research and conversion schemes recommended in section 6.

An improvement in the nation's health could also have a considerable impact on national economic performance, through fewer days off work, enhanced productivity and better mental health.[42]

New areas of research

The fertility of rabbits eating organic feed was significantly higher in Staiger's (1988) study.[43] The feed pellets were based on either organically or non-organically grown produce and demonstrated no measurable difference between them when tested for a wide range of nutrients and toxins. This suggests that researchers need to look beyond just known nutrients and toxins in determining the quality of foods. This could relate to nutrients that were not measured for, such as secondary nutrients, or some other aspect in food, which some call 'vitality'.

Secondary nutrients

It appears likely that a wide range of naturally occurring plant compounds such as flavonoids, carotenoids, glucosinolates and glycoalkaloids, are likely to occur in higher concentrations in organically grown than non-organically grown crops.

There are several thousand compounds in plants other than vitamins and minerals, and while many have previously been classified as 'natural toxins' due to adverse effects in high-dose rodent tests, their beneficial properties at naturally occurring low levels are being increasingly documented. Some believe these 'phytonutrients' are the most likely candidates for the health promoting effects of fruits and vegetables, the increased consumption of which are known to reduce the risks of the major causes of death in Western society, including cancer, cardiovascular disease and diabetes.[44] While secondary nutrients do appear to be broadly beneficial, further research is needed to more fully understand the potential toxicity, bioavailability and metabolism of these compounds in vivo,[45] given that some are toxic at naturally occurring concentrations (for example linamarin and solanin), some may be pro-oxidant,[45–47] and others can interfere with the absorption of other nutrients.[45,48]

Many secondary nutrients are known to be involved in plants' immune systems, protecting them from disease, attack and damage, and it is hypothesised that many modern varieties, chosen for their greater yields rather than their natural pest and disease resistance, tend to have lower levels of these compounds.[49] Also, that the use of pesticides to protect plants from disease and attack reduces the plants' reliance on their own natural protection systems, and therefore result in a lesser accumulation of these plant defence related compounds.[50]

In a recent review of comparative studies, Brandt and Molgaard (2001) observed that although the results of available studies are insufficient to draw any final conclusions, they tentatively estimated, on the basis of the currently available evidence, that "organically grown vegetables tend to have 10–50 per cent more secondary or 'plant defence related' compounds than conventionally cultivated vegetables". They concluded that "if these secondary metabolites are an important determinant of the nutritional value of fruits and vegetables in the diet of developed countries, organically grown fruit and vegetables would be expected to be more health promoting than those non-organically grown".[44]

Holistic approaches

A recent and thorough review of this subject, sponsored by the Danish government, concluded that picture forming methods "indicate a real and systematic quality difference between conventional and organic vegetables".[51]

Holistic qualitative analyses include morphological analyses of crystalline pictures formed by plant extracts in copper chloride solutions and storage degradation tests. Differences have been observed between produce of organic and non-organic agriculture using these methods, but more research is needed in this field before it can be generally accepted as a valid measure of food quality.

In seeking to reduce food quality solely to the determination of the chemical composition of foods it is easy to lose sight of other aspects, such as 'vitality' and the interaction between food and human beings, which often cannot be explained by chemical analyses. The results presented here demonstrate the potential of these holistic methods of quality determination, yet further refinements and validations are required before they can be generally accepted and more widely used.

Further studies are needed to compare accepted analytical approaches with these new holistic methods and to invalidate or confirm the hypothesised link between the organising forces or 'vitality' in foods and nutritional value. These methods are producing interesting results, but until these links are clearly shown, the qualitative differences suggested by these methods cannot be considered as significant as the differences demonstrated by other methods of quality determination.

Research needed

More research is required to investigate the trends seen in the existing data, to clarify the exact relationships between agricultural management and nutritional quality, and to redress the balance of the many studies based on poor design or analysis. The following guidelines are recommended for future research projects:

- *Field trials*
  Data should only be collected from trials conducted on soil that has been organically and non-organically managed for at least the two previous years as required for organic certification, and care should be taken to ensure typical non-organic and recognised organic practices are used (for example, they comply with IFOAM or Soil Association standards).
- *Farm surveys*
  Farms should be paired to control variables such as crop variety, planting and harvest dates, climate, weather and soil type, and organically certified farms should be compared with farms employing typical non-organic practices.
- *Market surveys*
  Samples should be paired, as well as possible, to control variables such as origin, time since harvest and variety, and organically certified samples should be compared with non-organic samples.

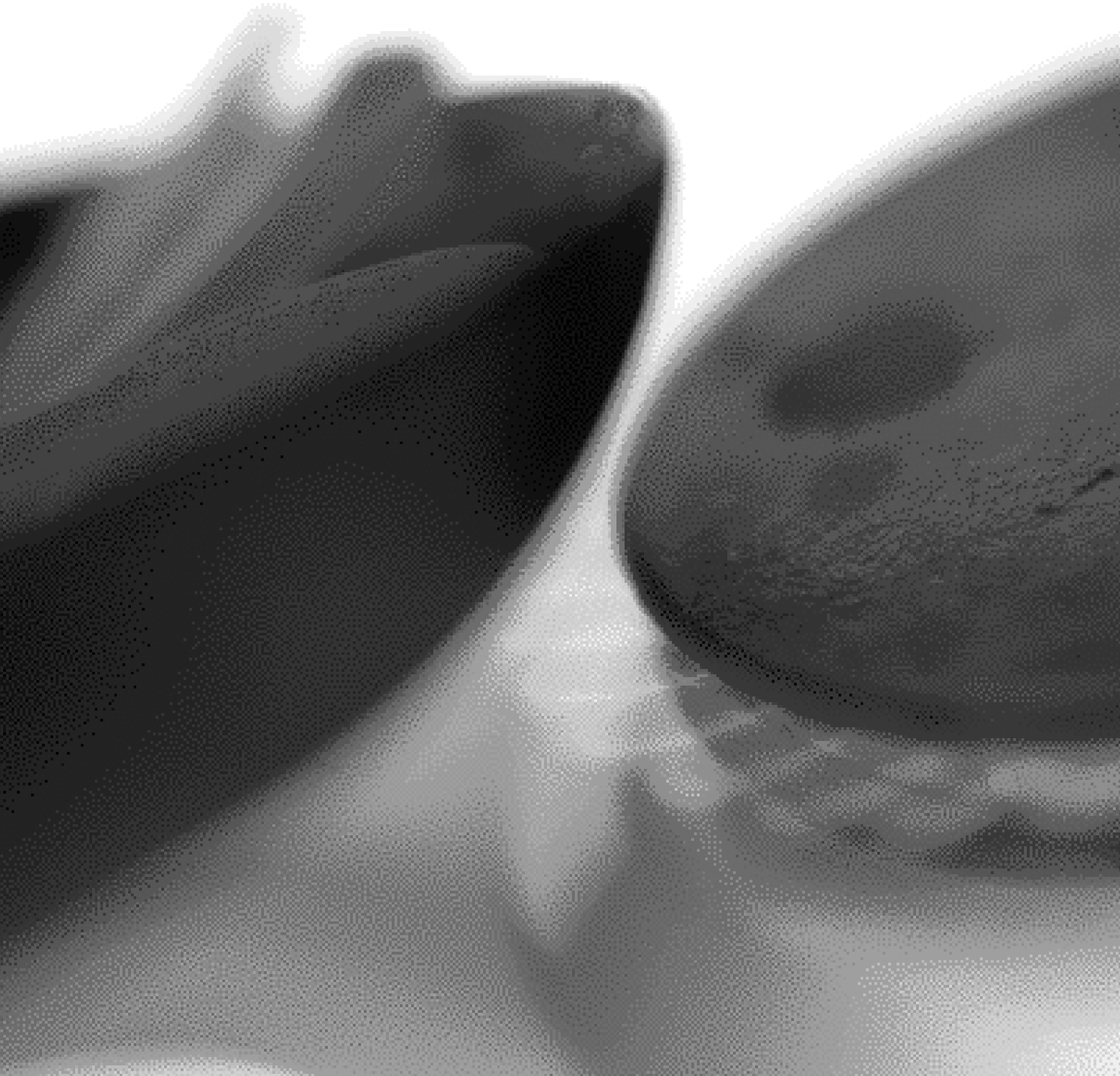
Analysis

- Research should be conducted using the most current methods and analytical techniques, and data should be tested for statistical significance.
- Mineral concentrations should be expressed on a fresh-weight basis.
- Studies should compare as wide a variety as possible of primary nutrients, secondary nutrients and toxins important to both plant and animal health.
- Various foods, including fruits, vegetables, cereals, meat, dairy and processed foods should be examined and compared.

Style

In addition to the already accepted methods of comparative analysis such as vitamin and mineral detection, new areas of qualitative research should be investigated further, including:

- Human observations and studies. For example, Dr Robert Thomas, Hospital Doctor of the Year 2000, is planning a major trial with cancer patients and organic food.
- Further investigation of secondary nutrients, both to establish their benefits or toxicity and also to compare levels in organically and non-organically cultivated crops.
- Holistic methods of quality detection including biocrystallisation, standardised or computer-assisted morphological analysis of the resulting pictures, and how they relate to observable health effects.



6 | Recommendations

To consumers

The best way of increasing one's nutrient intake remains increasing consumption of fruits and vegetables, and the fresher the better.

Regarding the comparative benefits of organically and non-organically grown foods, the available valid scientific evidence reviewed here supports the view that eating organically grown food is likely to improve one's intake of minerals, vitamin C and antioxidant secondary nutrients while reducing exposure to potentially harmful pesticide residues, nitrates, GMOs and artificial additives used in food processing.

The uncertainties and available evidence on the safety of pesticide residues suggest that when non-organic produce cannot be avoided, some consumers may wish to carefully wash it to reduce external pesticide residues, and the government has advised that peeling is a sensible additional precaution when preparing fruit for small children.

To farmers

The available evidence on the health effects of occupational pesticide exposure and crop nutrient analyses suggest that converting to organic farming can protect your own health and improve the nutritional quality of your crops. Government support is available for conversion and consumer demand is growing by 40 per cent a year. Advice and assistance are available through numerous organisations including the Soil Association, ADAS, HDRA, the Organic Conversion Information Service, the Scottish Agricultural Colleges, and the Elm Farm Research Centre.

Genetically modified crops are clearly being rejected by European consumers. Farmers must therefore weigh any perceived benefits of GM crops against the unknown and largely unquantifiable risks and lack of market demand.

Economic analyses have shown improved incomes through organic farming. Increased labour costs and potentially lower yields are offset by the reduced need for expensive inputs such as chemical fertilisers, herbicides and pesticides and the premium prices available for organic produce.[1–3]

To researchers

More standardised primary comparative food quality research is needed to confirm the trends seen in the existing data and to clarify the exact relationships between agricultural management and nutritional quality. All areas of food quality should be further researched, including food safety, primary nutrients, undesirable nutrients, secondary nutrients, and overall health outcomes. This could include long-term properly managed field trials, paired farm comparisons (ensuring the organic farms are certified and the non-organic farms represent typical non-organic practices), shopping basket surveys (ensuring the organic produce is certified and the samples are of comparative variety and origin) and multi-generation animal feeding or human observation studies. The potential for greater toxicity due to synergistic effects of multiple pesticide residues on produce should be fully examined. Nutrient analyses comparing organically and non-organically grown produce should include a wide range of trace minerals and secondary nutrients. Holistic measures of crop quality such as picture forming methods should also be further developed and validated.

Agricultural research should be directed toward a better understanding of agro-ecosystems and how to maintain them, rather than towards the destruction or replacement of biological systems with more energy consuming and industrialised methods.[4] Further investigations are required to determine which factors are contributing to differences in nutrient contents between organically and non-organically grown crops. Research into improving organic agriculture is also needed, as present day organic agricultural methods are far from fully developed and there is a lot of room for improvement, especially in the complex area of soil microbiological activity and promotion of symbiotic relationships between micro-organisms and crops.

To government

The evidence presented in this report indicates significant links between agricultural methods and food quality. Given these links, strategic investment in organic farming would have a major impact on public health, offering tangible benefits and an avoidance of the many potential and known risks posed by the continued use of artificial pesticides, fertilisers and genetic manipulation.

The pesticide residue monitoring programme could be expanded both in sample size and variety of foods tested each year, including organic foods for comparison. The scale of the current monitoring is poor compared to programmes in many other EU countries. An action plan for sustainable farming should include:

- Financial support for farmers wishing to convert to an organic system (especially arable and horticultural producers) to supply the growing demand for organic produce and reduce the UK's dependence on imports, as well as post-conversion organic stewardship payments for organic farmers in recognition of the health and environmental benefits of organic farming. Every EU member state except the UK provides continuing stewardship payments to organic farmers.
- Initiation and funding of research projects comparing organically and non-organically grown produce as well as research to improve organic agricultural systems further.
- A government 'health of the nation' initiative involving DEFRA and the department of health linking farming and food production methods with the environment, food safety and human health.

Development of UK organic farming would improve consumer access to fresh, organic food and reduce dependence on imports.

These programmes could be funded in whole or in part by a 'polluter-pays' tax on pesticides, ensuring that farmers using pesticides or agro-chemical companies pay for the externalised costs of non-organic agriculture such as cleaning pesticides from drinking water, approving pesticides and monitoring residues, the medical and economic costs of ill-health caused by acute and chronic exposures, and loss of biodiversity. Such a move would acknowledge research into the true cost of using pesticides in food production, and call into question the belief that non-organically grown food is cheaper than organically grown food.[5]

1 Reinken G, 1986, 'Six years of biodynamic growing of vegetables and apples in comparison with conventional farm management', in Vogtmann H, Boehncke E, Fricke I (eds.), *The Importance of Biological Agriculture in a World of Diminishing Resources – Proceedings of the 5th IFOAM International Scientific Conference* (University of Kassel Germany, 27–30 Aug 1984) Verlagsgruppe Witzenhausen, p 161–174

2 Harwood RR, 1984, 'Organic farming research at the Rodale Research Centre', in Kral DM and Hawkins SL (eds.), *Organic Farming: Current Technology and its Role in a Sustainable Agriculture*, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison WI, p 1–17

3 Reganold JP, Glover JB, Andrews PK and Hilman HR, 2001, 'Sustainability of three apple production systems', *Nature* 410, p 926–930

4 Vogtmann H, 1984, 'Organic farming practices and research in Europe', in Kral DM and Hawkins SL (eds.), *Organic Farming: Current Technology and its Role in a Sustainable Agriculture*, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison WI, p 19–35

5 Pretty J, Brett, Gee, Hine, Mason, Morison, Raven, Rayment and van der Bijl, 2000, 'An assessment of the total external costs of UK agriculture', *Agricultural Systems* 65(2), p 113–136

7 | Appendix

Ninety-nine papers claiming or claimed to make a direct comparison of organically and non-organically grown crops were found and reviewed. Brief summaries and explanations of validity assessments are presented here.

Product fertilisation and quality – mineral, organic, biodynamic
Abele U (1987); Institute of Biodynamic Research, Darmstadt, Germany
Angewandte Wissenschaft 345

A four year field trial comparing the effects of organic (composted cattle manure and urine plus biodynamic field preparations) and non-organic (NPK) fertilisation regimes at low, medium and high levels of application on carrots, beetroot and potato. Overall, data from the third and fourth years showed organically grown crops had significantly higher minerals P and K, equivalent dry matter and minerals Ca and Mg, and lower nitrate contents, and better storage capabilities than non-organically grown crops. Organically grown potatoes had significantly higher vitamin C than non-organically grown potatoes, while organically grown carrots had lower or equivalent vitamin A (carotene) and C contents.
valid?
Yes, comparison of vegetables from the third and fourth year of a field trial using proper organic and non-organic fertilisation practices (first and second year data not included in this review, as they comprise a theoretical conversion period). Rye comparisons are not included in this review as the only relevant comparisons were of minerals P and K, which is insufficient to fulfil the validity criteria (see section 3.2.3).

Significance of fertilisation for the post-harvest condition of vegetables, especially spinach
Ahrens E, Elsaidy S, Samaras I, Samaras F & Wistinghausen E (1983); Institut fur Mikrobiologie und Landeskultur, Justus-Leibig-Universitat and Institut fur Biologische-Dynamische Forschung, Geissen and Darmstadt, Germany
Environmentally Sound Agriculture – 4th IFOAM Conference – Selected Papers (Cambridge MA), Lockeretz W (ed), Praeger, New York, p 229–246

Two one year field trials comparing the effects of organic (composted stable manure or biodynamic manures and preparations) and non-organic (NPK) fertilisation on spinach. Comparing yield, dry matter, nitrate and vitamin C contents, and nitrite formation in storage, the data showed lower nitrate and higher vitamin C contents in organically grown spinach at harvest, and less nitrite formation in organically grown spinach during storage. Differences in dry matter and yields were inconsistent or not significant. The authors conclude that "with limited nitrogen supply, one obtains higher quality, whereas with higher nitrogen, even with organic fertilisation, somewhat lower quality is obtained".
valid?
No, due toinsufficient duration on soils with unspecified histories, thus may not properly represent soil conditions in organic and non-organic agriculture.

Nutritional study of vegetables grown on a revitalised soil in Australia
Alenson C (2000); Organic Retailer and Growers Association of Australia, Austrailia
Elm Farm Research Bulletin 49, May 2000
A ten year field trial examining the effects of organic soil regenerative techniques (including the application of compost and rock minerals) on beans, tomato, capsicum and silverbeet (chard). Comparing fresh-weight concentrations of the minerals Ca, K, Mg, Fe, and Zn in these crops with supermarket-purchased non-organic produce, the study showed how poor quality ("worn-out, depleted") volcanic soil can be restored to a high level of fertility using organic methods of supplying minerals and organic matter, and how the resulting crops can show considerable nutritional superiority to non-organically grown produce.
valid?
No, the heterogenous samples compared introduce too many uncontrolled variables, such as the time since harvest and source (affecting soil type, climate, weather, length of season)

Quality investigations in the long-term DOC-trial
Alföldi Th, Mäder P, Niggli U, Spiess E, Dubois D & Besson J-M (1996); Research Institute of Organic Agriculture (FiBL), Therwil, Switzerland
Quality of Plant Products Grown with Manure Fertilization – Proceedings of the Fourth Meeting (Juva, Finland, 6–9 July 1996). Darmstadt; Germany: Institute for Biodynamic Research, p 34–43

Results from three years within the second seven year crop rotation of a 14 year field trial comparing the effects of organic (fresh and composted farmyard manure plus slurry) and integrated (NPK plus manure) fertilisation practices on a rotation of potatoes, wheat, beetroot, wheat, barley, and two years of grass-clover. Comparing dry matter contents plus minerals P, K, Ca, Mg, Mn, Zn and Cu, the organically grown potatoes had less K Mg and Cu. Only a few significant differences were identified in the mineral contents of the grains. Organically grown barley had more Ca, Cu and Zn, while organically grown wheat had more Cu but lower Zn than the non-organically grown crops. Grass-clover comparisons were reported on a dry-weight basis only and the beetroot trials were reported more comprehensively in Mäder 1993 so are not reviewed here.
valid?
Yes, comparison of potatoes, barley and wheat from a long-term field trial managed according to organic and 'best practice' integrated fertilisation methods (involving crop rotation and manure application) , so few differences are found.

Pineapples cultivated by conventional and organic methods in a soil from a banana plantation: a comparative study of soil fertility, plant nutrition and yields
Alvarez CE, Carracedo AE, Iglesias E & Martinez MC (1993); Instituto de Productos Naturales y Agrobiologia de Canarias and the Universidad de la Laguna, Tenerife, Spain
Biological Agriculture and Horticulture 9(2), p 161–171

A two year trial comparing the effects of organic (garden waste compost) and non-organic (NPK) fertilisation practices on Red Spanish pineapples.

Comparing yields, leaf nutrient concentrations, sugar contents, growth rates, and soil characteristics the data showed no significant differences between the two crops except lower yields (fruit without crown) from the organically grown plants. Mineral concentrations were only measured in the inedible portion of the plants ('D' leaves), and showed mixed results.
valid?
No, due to insufficient duration in homogenous soil, and lack of nutritional quality comparisons relevant to this review.

Health foods versus traditional foods: a comparison
Appledorf H, Wheeler WB & Koburger JA (1973); Food Science Department, University of Florida, Gainesville, USA
Journal of Milk and Food Technology 36(4), p 242–244

A one-off market survey comparing protein / fat / carbohydrate / moisture composition, microbial content, pesticide levels and PCB contamination of 'health foods' ("obtained from health food stores") and 'traditional' foods ("obtained from a chain store supermarket") involving single samples of bread, milk, cheese, cashews, peanut butter, rice, honey, wholewheat cereal, blackberry preserve, ice-cream, pecans, pancake mix, mayonnaise, tomato juice, almonds, rice cereal, dried apples, fig bars, brazil nuts, apple juice, apple butter, corn snacks, dates and coconut. Only minor differences were detected.
valid?
No, due to limited size and ambiguity of samples compared (not organic versus non-organic).

Effect of organic manures on quality of vegetables
Assano J (1984); Plant Protection and Environment Division, Vegetable and Ornamental Crops Research Station, Japan
Japan Agricultural Research Quarterly 18(1), p 31–36

A field trial of unspecified duration comparing the effects of 'organic' (rapeseed cake and bark compost plus PK) and non-organic fertilisation on success-ive crops of eggplant, cucumber and tomato (in a green-house) and cabbage, radish and lettuce (outdoors). Comparing yields, appearances, vitamin C and sugar contents, the data showed lower yields but better appearance of the organically grown crops, no consistent effect on vitamin C contents, and a trend toward higher sugar contents in organically grown crops.
valid?
No, due to unknown duration of the trial and non-representative fertilisation practices (super phosphate and potassium chloride added to 'organic' plots).

Organic vs inorganic nutrition and horticultural crop quality
Barker A (1975); University of Massachusetts, USA
HortScience 10, p 50–53

Single season pot trials comparing the effects of organic (dried cow manure, sewage sludge, cottonseed meal, castor pomace, dried blood) and chemical (ammonium nitrate) nitrogen sources applied at various rates including a control (no nitrogen applied) on tomato and spinach, repeated over two and three years (tomato and spinach respectively) with new soil each year. Comparing yields, nitrate content and appearance (nitrogen deficiency assessment), the data showed organic fertiliser (cow manure) gave lower yields and crop nitrate contents due to a slower mineralisation rate.
valid?
No, due to insufficient duration in soil with no organic history, thus does not sufficiently represent soil conditions on certified organic farms.

Comparison of taste quality between organically and conventionally grown fruits and vegetables
Basker D (1992); Department of Food Science, Agricultural Research Organisation, The Volcani Centre, Israel
American Journal of Alternative Agriculture 7(3), p 129–136

A farm survey comparing the produce from certified organic and non-organic farms. Comparing the taste of tomatoes, carrots, spinach, sweetcorn, grapes, bananas, mangoes, grapefruit, oranges, plus additionally for tomatoes and bananas: dry matter, P, K and nitrate (tomatoes only) contents, the data showed higher P and K in non-organically grown tomatoes (nitrate content was not significantly different), higher K and dry matter in non-organically grown bananas, and inconsistent or not significant differences in taste between the organically and non-organically grown produce. Where differences in taste were found, they appeared more dependent on the level of maturity / ripeness of the samples (which had not been fully controlled).
valid?
Yes, comparison of dry matter, P, K and nitrate contents of fruit and vegetables collected from organic and non-organic farms.

Variation in mineral composition of vegetables
Bear FE, Toth SJ & Prince AL (1948); Rutgers University, New Jersey, USA
Proceedings of the Soil Science Society of America 13, p 380–384

A nation-wide farm and soil survey comparing the effects of soil types, designated as 'organic' or 'inorganic', on snap beans, cabbage, lettuce, tomato, spinach. Comparing minerals P, Ca, Mg, K, B, Mn, Fe, Co, Mo and Cu, the study demonstrated the influence of soil type (and quite likely differences in clay mineralogy, soil organic matter and biological soil activity) on the mineral composition of crops, with various differences observed between different geographic regions of the United States. Wide variations were found in the mineral contents in vegetables of the same varieties, further demonstrating the influence of soil type and climate.
valid?
No, as this study was not a comparison of organic and non-organic farming methods or crops as is commonly (mis)reported.

Long term effects of organic or mineral fertiliser treatment on the composition of lettuce and potatoes
Blanc D, Gilly G, Leclerc J & Causeret J (1984); Station d'Agronomie et de Physiologie Vegetale, IRNA, France
Sciences des Aliments 4 (special issue), p 267–272

A one year field trial on soil appropriately fertilised for the previous 25 years comparing the effects of non-organic (NPK) and organic (ovine and bovine manure) fertilisation practices on lettuce and potatoes. Comparing yield, vitamins b-carotene, B1, 2, 6 and C, and dry-weight mineral concentrations of P, K, Ca, Mg, Cu, Fe, Zn, Mn and B, the data showed that organically fertilised crops had significantly higher yields and comparable (no significant differences) vitamin contents. (Dry-weight mineral comparisons are not included in this review)
valid?
Yes, comparison of vitamin contents of vegetables from a field trial managed organically and non-organically for the previous 25 years.

Influence of crop rotation, manure and fertilisers on the bread making quality of wheat
Borghi B, Giordani G, Corbellini M, Vaccino P, Guermandi M & Tolderi G (1995); Istituto Sperimentale per la Cerealicoltura, Italy
European Journal of Agronomy 4(1), p 37–45

A 12 year field trial comparing the effects of crop rotation, organic (manure) and non-organic (NPK) fertiliser applications on wheat. Comparing yield and baking quality, the data showed that crop rotations had positive effects on yield, but the best yield/protein quality combination was achieved with the highest rate of non-organic fertilisers even in the absence of manure.
valid?
No, due to the lack of nutritional quality comparisons relevant to this review.

Influence of organic fertilisation on certain nutritive constituents of crops
Brandt CS and Beeson KC (1951); US Department of Agriculture, Long Island Vegetable Research Farm, USA
Soil Science 71(6), p 449–454

Two studies are reported: firstly a one or two (potatoes only) season pot trial comparing the effects of organic (horse manure) and non-organic (NPK) fertilisation on the ascorbic acid and b-carotene contents of potatoes, carrots and green beans. And secondly a two season field trial in soil that had been appropriately fertilised for 25 years comparing the effects of organic (horse manure) and non-organic (NPK) fertilisation on the ascorbic acid, Fe and Cu contents of potatoes only. No significant differences attributable to the source of plant nutrients were found in either study.
valid?
No, due to an insufficient duration in soil with no organic history in the first study and the discontinuation of long-term fertilisation practices two seasons prior to the second study, with no organic fertiliser applications made prior to or during this trial. Further, the age of the study creates uncertainty that the non-organic soil condition and fertilisation practices are comparable to current soil conditions (regarding for example, potential nutrient depletion) and fertilisation practices.

Metals in grains sold under various labels – organic, natural and conventional
Chang P and Salomon M (1978); University of Rhode Island, USA
Journal of Food Quality 1, p 373–377

A two year market survey comparing the mineral Cu, Fe and Zn and heavy metal Cd and Pb contents of non-organic, 'natural' and organically labelled barley, brown rice, corn meal and lentils. Differences were either inconsistent or not statistically significant.
valid?
No, insufficient sample sizes for any meaningful data, as indicated by the extremely wide differences in mineral contents between the individual samples of the same grains taken in the two consecutive years.

Nutrient composition of tomatoes home grown under different cultural procedures
Clarke RP & Merrow SB (1979); Vermont Agricultural Experiment Station, USA
Ecology of Food and Nutrition 8, p 37–46

A two year farm survey comparing the effects of organic and non-organic cultural practices as 'customarily used' by three pairs of 'home-grown' tomato growers. Comparing dry matter, fresh weight minerals P, Ca, Mg, Fe and Zn, vitamins carotene and ascorbic acid, and protein contents as well as yields, the data did not differentiate between the two cultural practices on the basis of nutrient composition.
valid?
No, due to lack of organic certification details and the absence of information on the actual practices employed by each grower or the soil histories prior to the trials.

Postharvest physiological disorders, diseases and mineral concentrations of organically and conventionally grown McIntosh and Cortland apples
DeEll JR & Prange RK (1993); Agriculture Canada Research Station, Kentville, Nova Scotia, Canada
Canadian Journal of Plant Science 73(1), p 223–230

A two year farm survey comparing the post-harvest physiological disorders, diseases and mineral concentrations of apples from seven pairs of organically and non-organically managed orchards (certified by Canadian Organic Crop Improvement Association). No significant differences were found in dry matter, Ca and Mg contents, while organically grown apples had higher concentrations of P and K.
valid?
Yes, comparison of dry matter content and fresh weight mineral concentrations in organically and non-organically grown apples.

The quality of plant products under conventional and biodynamic management
Dlouhy J (1977); Uppsala University/Scandinavian Biodynamic Research Circle, Ultuna, Sweden
Biodynamics 124, p 28–32

A three year field trial comparing the effects of non-organic (chemical fertilisers plus pesticides) and organic (farmyard manure compost, meat-scrap meal, K/Mg salts and biodynamic preparations) cultural practices on potatoes, wheat and barley/clover grown in rotation. Comparing dry matter, ascorbic acid, protein quality, nitrate, yield, cooking traits, taste, and storage losses, the data showed that organically grown potatoes had better cooking traits and fewer storage losses, while most other differences were not statistically significant (as would be expected during conversion).
valid?
No, the majority of data (two out of three years) was gathered during a theoretical conversion period when produce is not legally 'organic', and third year data, which would be valid, is unavailable as the data is expressed as average results from the three years. The trial was continued and is reported in Dlouhy 1981 (see below).

Product quality in alternative agriculture
Dlouhy J (1981); Uppsala University/Scandinavian Biodynamic Research Circle, Ultuna, Sweden
Food Quality – Concepts and Methodology, Elm Farm Research Centre Colloquium, 1981, p 30–35

A six year field trial comparing the effects of non-organic (chemical fertilisers plus pesticides) and organic (farmyard manure compost, meat-scrap meal, K/Mg salts and biodynamic preparations) cultural practices on potatoes, wheat and barley/clover grown in rotation. Comparing dry matter, ascorbic acid, protein quality, nitrate, yield, cooking traits, taste, and storage losses, the data showed that organically grown potatoes had higher dry matter (seven per cent) and ascorbic acid (13 per cent) contents, better protein quality (EAA index), lower nitrate (22 per cent), better cooking traits and taste qualities, lower yield (24 per cent) but also fewer storage losses (29 per cent).
valid?
Yes, comparison of crops from a field trial of good duration using non organic and organic cultural practices. While the data is presented as average results from all years, the years of full organic status (4) exceed the years in conversion (2). Data presented on a dry-weight basis could be converted to a fresh-weight basis with the information given on dry matter contents.

Effect of soil management practices on yield and foliar nutrient concentration of dry beans, carrots and tomatoes
Eggert FP (1983); University of Maine, Leeds and Stillwater, Maine, USA
Environmentally Sound Agriculture, 4th IFOAM Conference, Cambridge MA, Selected Papers, Lockeretz W (ed.), Praeger, New York, p 247–259

Results from two five year field trials comparing the effects of mulching, deep tillage, organic (poultry or stable manure compost, rock phosphate, lime) and chemical (NPK, lime, S-K-Mg) fertilisation on a three year crop rotation of dry beans, carrots, and tomatoes. Comparing yields and dry-weight basis mineral (NPK, Ca, Mg) contents, data from the third year on (as years one and two are considered to be the conversion period) showed a slight trend toward higher yields in organically grown crops and inconsistent differences in the mineral contents, though as they are reported on a dry-weight basis they are not included in this review. The authors recommended, on the basis of their study, organic soil management practices for dry beans and mulching of tomatoes.
valid?
No, due to the lack of nutritional quality comparisons relevant to this review.

Response of three vegetable crops to organic and inorganic nutrient sources
Eggert FP & Kahrmann CL (1984); University of Maine, Leeds, Stillwater and Warren, Maine, USA
Kral DM and Hawkins SL (eds.) *Organic Farming: Current Technology and its Role in a Sustainable Agriculture*, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison WI, p 97–111
A separate publication of the University of Maine's field trial study (above), this time additionally reporting results of a further three year field trial comparing the effects of non-organic and organic fertilisation practices (as previously reported) on a three year crop rotation of dry beans, carrots and tomatoes. Third year data (which is all that is relevant as the first two years comprise a theoretical two year conversion period) showed no differences in the beta-carotene concentration in carrots, but higher ascorbic acid concentrations in organically grown tomatoes (though all data is presented on a dry-weight basis so is not included in this review).
valid?
No, as does not add sufficiently to the data previously presented in Eggert 1983.

Grain quality of hull-less spring barley from different cropping systems
Ehrenbergerova J, Vaculova K & Zimolka J (1997); Mendel University of Agriculture and Forestry, Czech Republic
Rostlinna Vyroba 43(12), p 585–592

A three year field trial comparing the effects of non-organic treatments (chemical fertilisation and pesticide application) with "no chemical treatments" (the latter not including any typical organic farming practices) on nine varieties of spring barley. Comparing contents of protein, amino acids, starch, b-glucans, fat and fatty acids, the data demonstrated the significance of variety and weather conditions, which both affected almost all studied characteristics.
valid?
No, due to the absence of an organic comparison.

Effect of rhizobium inoculation, organic and chemical fertilisers on yield and physical properties of faba bean seeds
El Sheikh EAE & El Zidany AA (1997); Department of Biochemistry and Soil Science, Faculty of Agriculture, University of Khartoum, Shambat, Sudan
Plant Foods for Human Nutrition 51(2), p 137–144

A one season field trial comparing the effects of rhizobium inoculation, organic (chicken manure) and non-organic (urea and sulphur) fertilisation on faba beans. Comparing yields, bean sizes (100-seed weight) and cooking qualities (non-soakers and hydration co-efficient), the data showed inoculation significantly improved yields from both fertilisation practices, and organic fertilisation resulted in increased yields and better 'cookability' than non-organic fertilisation.
valid?
No, due to insufficient duration on soils with unspecified histories and lack of nutritional quality comparisons relevant to this review.

The Apelsvoll cropping system experiment iii. Yield and grain quality of cereals
Eltun R (1996); The Norwegian Crop Research Institute, Apelsvoll Research Centre, Kapp, Norway
Norwegian Journal of Agricultural Sciences 10(1), p 7–22

A four year field trial comparing the effects of non-organic (mineral fertilisation and chemical plant protection), integrated (less mineral fertilisation and integrated plant protection) and organic (farmyard manure and mechanical plant protection) practices on barley, oats and wheat. Organically grown cereals were significantly lower yielding, and had significantly lower protein contents than the non-organically grown cereals. No pesticide residues were found in any samples, and no significant differences were found in levels of pest (aphid) attack, cadmium content, disease (except organically grown wheat in one year which suffered significantly more powdery mildew) or mycotoxin contamination (despite claims to the contrary by Kirschmann and Thorvaldsson, 2000, *Eur J Agron* 12, p 145–161).
valid?
No, as the quality parameter relevant to this review, grain protein content, is presented in such a way that does not allow separation of valid and invalid data (expressed as an average of the final three years of the trial, which includes one year of a theoretical conversion period).

The Apelsvoll cropping system experiment iv. Yield and quality of potatoes, forage crops and entire cropping systems
Eltun R (1996); The Norwegian Crop Research Institute, Apelsvoll Research Centre, Kapp, Norway
Norwegian Journal of Agricultural Sciences 10(1), p 23–41

A four year field trial comparing the effects of non-organic (mineral fertilisation and chemical plant protection), integrated (less mineral fertilisation and integrated plant protection) and organic (farmyard manure and mechanical plant protection) practices on potatoes. Organically grown potatoes gave significantly lower yields and had significantly higher dry matter contents than non-organically grown potatoes, though varietal differences were observed to influence both of these parameters. No pesticide residues were found in any samples, and no significant differences were found in cadmium contents, tuber defects or disease incidence (except integrated and organically grown potatoes in one year which suffered significantly greater damage from potato cicada).
valid?
No, as the quality parameter relevant to this review, potato dry matter content, is presented in such a way that does not allow separation of valid and invalid data (expressed as an average of all years of the trial, which includes two years of a theoretical conversion period).

Effects of different fertilisation practices on the growth, yield and dry matter content of carrot
Evers AM (1988); Espoo Research Centre, Finland
Journal of Agricultural Science in Finland 60, p 135–152

A study comparing the yield and dry matter contents of carrots from a two year field trial employing non-organic (NPK) fertilisation practices with carrots obtained from two organically (compost) fertilised one year field trials (grown from the same seeds but in a different geographical location and soil type to the non-organic trials). Organic fertilisation resulted in lower yields and comparable dry matter contents of carrots.
valid?
No, due to insufficient duration of the organic trial on soil of unspecified history.

Effects of different fertilisation practices on the carotene content of carrot
Evers AM (1989); Espoo Research Centre, Finland
Journal of Agricultural Science in Finland 61(1), p 7–14

A study comparing the carotene contents of carrots from a two year field trial employing non-organic (NPK) fertilisation practices with carrots obtained from two organically (compost) fertilised one year field trials (grown from the same seeds but in a different geographical location and soil type to the non-organic trials). Carotene concentrations (as a percentage

of dry weight) were higher in the organically grown carrots.
valid?
No, due to the insufficient duration of the organic trial on soil of unspecified history.

Effects of different fertilisation practices on the Ca, Mg, NO3-N, N, P, K, ash and dietary fibre content of carrot
Evers AM (1989); Espoo Research Centre, Finland
Journal of Agricultural Science in Finland 61, p 99–111

A study comparing the P K Ca Mg and nitrate contents (on a dry-weight basis) of carrots from a two year field trial employing non-organic (NPK) fertilisation practices with carrots obtained from two organically (compost) fertilised one year field trials (grown from the same seeds but in a different geographical location and soil type to the non-organic trials). Few significant or consistent differences were found (Dry-weight concentrations could be adjusted to fresh-weight concentrations using the data in Evers 1988).
valid?
No, due to insufficient duration of the organic trial on soil of unspecified history.

Influence of organic and mineral fertilisers on yield and quality of potatoes
Fischer A & Richter C (1986); Germany
Vogtmann H, Boehncke E, Fricke I (eds.), *The Importance of Biological Agriculture in a World of Diminishing Resources – Proceedings of the 5th IFOAM International Scientific Conference* (University of Kassel Germany, 27–30 Aug 1984) Verlagsgruppe Witzenhausen, p 236–248

A farm survey comparing the yields, nitrate and vitamin C in potatoes from 20 farms, nine of them non-organic/integrated (using chemical fertilisers, manures and pesticides), and 11 organic (using manures and composts, crop rotations and no pesticides). Organically grown potatoes, though lower yielding, were found to contain much lower nitrate and much higher vitamin C levels.
valid?
Yes, while no organic certification details were given for the organic farms, the details of specific practices employed were sufficient to confirm their status.

Characteristics of organically and conventionally grown potatoes
Ginger MW (1988); Potato Marketing Board, Sutton Bridge Experimental Station, Lincolnshire, UK
Annual Review 1988

A farm survey examining the taste and storage characteristics of non-organically grown and (Soil Association certified) organically grown potatoes. No significant differences were found in the storage characteristics of the organically and non-organically grown potatoes (weight loss, soft rotting, skin quality and disease levels). Taste panels preferred organically grown potatoes both before and after six months storage (fewer 'off flavours').
valid?
No, due to the lack of nutritional quality comparisons relevant to this review.

Effects of fertilisers on vegetable production, 2: effects of nitrogen fertilisers on nitrogen content and nitrate accumulation of spinach and beetroot
Goh KM & Vityakon P (1986); Lincoln College, Canterbury, New Zealand
New Zealand Journal of Agricultural Research 29, p 485–494

Single season pot trials comparing the effects of five different nitrogenous fertilisers (ammonium sulphate, ammonium sulphate plus N-serve, potassium nitrate, poultry manure and urea) at five application rates (0, 150, 300, 450 or 600 kg N/ha) on the nitrate contents of spinach and beetroot. The data confirmed that increasing applications of nitrogen fertiliser generally increased nitrate accumulation in the crop.
valid?
No, due to insufficient duration in soil with no organic history, thus does not sufficiently represent soil conditions on certified organic farms.

Long-term field experiment in Sweden: effects of organic and inorganic fertilisers on soil fertility and crop quality
Granstedt AG & Kjellenberg L (1997); Nordic Research Circle for Biodynamic Farming, Jarna (1958–90), plus Uppsala (1971–76) and Jarna (1971–79), Sweden
Lockeretz W (ed.), *Agricultural Production and Nutrition, Proceedings of an International Conference* (Boston, Ma, 19–21 March 1997), Medford, MA: School of Nutrition Science and Policy, Tufts University, p 79–90

Results from a 32 year field trial plus two shorter 'daughter' experiments (six and nine years) comparing the effects of non-organic (NPK) and organic (composted manures plus biodynamic preparations) fertiliser treatments applied to a four year crop rotation of summer wheat, clover/ grass mix, potatoes and beets. Results from the six year trial in Uppsala are reported elsewhere (Dlouhy 1981) so are not included here. Only results of potatoes and wheat are presented. Organic potatoes were equal yielding in the 32 year trial, though significantly lower in the nine year trial partly due to higher losses caused by phytophthora since pesticides were used in the non-organic treatments. Compared to non-organically grown potatoes, those organically grown had significantly higher dry matter contents, significantly lower losses after six to seven months in storage, significantly lower susceptibility to phytophthora infection (where no pesticides were used) and better 'organisational traits' as demonstrated by crystallisation tests. There was no significant difference in the crude protein content of the organically and non-organically grown wheat, though organically grown wheat had significantly higher protein quality (EAA index), and also better 'organisational traits'.
valid?
Yes, a comparison of the long-term effects of non-organic and organic fertilisation practices on potatoes and wheat.

Comparative investigation of concentrations of major and trace elements in organic and conventional Danish agricultural crops, 1: Onions (*Allium cepa* Hysam) and Peas (*Pisum sativum* Ping Pong)
Gundersen V, Bechmann IE, Behrens A & Sturup S (2000); Plant Biology and Biochemistry Department, Riso National Laboratory, Denmark
Journal of Agricultural and Food Chemistry 48, p 6094–6102

A farm survey comparing the mineral contents of onions and peas collected from 11 non-organic and ten organic production areas. Comparing the fresh-weight mineral concentrations of 63 elements and using multivariate data analysis to consider interactions between the elements, organic onions were found to have significantly higher levels of Cu, Fe and Mo, and significantly lower levels of B, Ca and Co than non-organically grown onions. Comparing 55 elements, organic peas were found to have significantly higher P and significantly lower Cu and Se than non-organically grown peas, plus significantly lower levels of the heavy metal Cd. Other significant differences were found in minerals not known to be essential, though the majority of differences were inconsistent or not statistically significant.
valid?
Yes, a thorough comparison of mineral contents of organically and non-organically cultivated crops. While no certification details were given for the organic farms, details of practices employed and history (minimum two years organic) are sufficient to confirm their status.

Content of flavonols and selected phenolic acids in strawberries and vaccinium species: influence of cultivar, cultivation site and technique
Hakkinen SH and Torronen AR (2000); University of Kuipio, Finland
Food Research International 33(6), p 517–524

A farm survey comparing the phenolic acid (a class of secondary metabolites) content of three varieties of strawberries from farmers practising either organic or non-organic cultivation. Similar levels of phenolic acids were found in two varieties of strawberries regardless of cultivation technique, while in a third variety, the organically cultivated berries had a 12 per cent higher concentration of total phenolics compared to those non-organically cultivated. Overall, cultivation techniques had no consistent effect on the levels of phenolic compounds in strawberries.
valid?
No, as the compounds compared may have been influenced by the long-term frozen storage of the samples. While no certification details for the organic farms were given, the author was contacted and confirmed that

the strawberries were produced using correct and controlled organic practices. However the samples were analysed after seven to nine months of frozen storage, which the authors point out might have had an influence on the phenolic contents.

Influence of locality and way of cultivation on the nitrate and glycoalkaloid content in potato tubers
Hamouz K, Cepl J, Vokal B and Lachman J (1999); Czech University of Agriculture, Czech Republic
Rostlinna Vyroba 45(11), p 495–501

The results of 12 three year field trials comparing the effects of influences of locality, variety, year and (in two locations) method of cultivation (non-organic versus ecological: "without using any chemical protection or fertilisers") on the nitrate and glycoalkaloid contents of potatoes. Third year data (which is all that is relevant as the first two years comprise a theoretical two year conversion period) showed significant differences in tuber nitrate contents between different locations, plus lower nitrate and higher glycoalkaloid contents in ecologically grown potatoes, though the differences were not statistically significant.
valid?
No, as no organic fertilisation practices were documented and the avoidance of chemical protection and fertilisers alone is not properly representative of organic husbandry. The influence of avoidance of pesticides on the secondary nutrient content is relevant and is therefore included in section 3.3.

Influence of environmental conditions and way of cultivation on the polyphenol and ascorbic acid content in potato tubers
Hamouz K, Lachman J, Vokal B & Pivec V (1999); Czech University of Agriculture, Czech Republic
Rostlinna Vyroba 45(7), p 293–298

Same field trials as described in Hamouz, Cepl *et al*, 1999 (above), covering the same time period, but reporting instead the vitamin C and polyphenol contents of potato tubers. Third year data showed higher ascorbic acid and polyphenol contents in ecologically grown potatoes, though the differences were not statistically significant.
valid?
No, as no organic fertilisation practices were documented and the avoidance of chemical protection and fertilisers alone is not properly representative of organic husbandry. The influence of avoidance of pesticides on the secondary nutrient content is relevant and therefore included in section 3.3.

Comparison of chemical composition and taste of biodynamically and conventionally grown vegetables
Hansen H (1981); State Research Centre for Horticulture, Denmark
Qualitas Plantarum – Plant Foods for Human Nutrition 30(3/4), p 203–211

A two year field trial in four locations on adjacent fields on neighbouring organic and non-organic farms comparing the effects of their different cultivation methods on potatoes, carrots, beetroots, curly kale and white cabbage. Inconsistent and usually not significant differences were found in the dry-weight P, K, Ca, Mg and nitrate contents, crystallisation analyses and storage tests. A soil analysis showed higher trace elements (Mg, Cu) and organic matter (humus) in organically managed soil. Taste tests showed no consistent preference trend, but the organically grown crops tended to be scored more highly than the non-organically grown crops.
valid?
No, due to uncertainty regarding the previous history of the soil and the specific fertilisation practices employed in either the non-organic or organic trials (no details were given regarding the certification of the organic farms).

Organic farming research at the Rodale Research Center
Harwood RR (1984); The Rodale Research Center, Kutztown, Pennsylvania, USA
Kral DM and Hawkins SL (eds.) *Organic Farming: Current Technology and its Role in a Sustainable Agriculture*, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison WI, p 1–17

Data reported from a field trial examining the effects of increasing levels (0, 50, 150, 250 kg N/ha) of either non-organic (ammonium nitrate) or organic (fermented chicken manure) fertilisers on the nitrate and vitamin C contents of Pak Choi (Chinese cabbage). Direct comparisons are not possible as the data is presented on a dry-weight basis, but the trends within each fertilisation regime are worthy of comparison: increasing nitrogen application as ammonium nitrate dramatically increases nitrate content and decreases vitamin C content, while increasing nitrogen application as manure has no such effect.
valid?
No, due to uncertainty over the duration of the trial that the data represents.

Sensory quality and chemical composition in carrots: a multivariate study
Hogstad S, Risvik E and Steinsholt K (1997); Norwegian Food Control Authority, Matforsk Norwegian Food Research Institute and Dept. of Food Science, Agricultural University of Norway, Norwegian Crop Research Institute, Apelsvoll Research Centre, Landvik, Norway
Acta Agricultuarae Scandanavica Section B, Soil and Plant Science 47(4), p 253–264

A farm survey comparing the dry matter, carotene, protein, nitrate and sugar content, plus sensory qualities of carrots from 14 farms (five non-organic, nine organic) and two single season non-organic field trials at a research centre. The organic research centre trials were invalidated because of insufficient history of organic cultivation of the soil and the use of pesticides to control a severe pest attack, and have not been included in the comparative data by the authors. The data showed significantly higher dry matter, carotene, true protein, and total sugar contents in organically grown carrots, which were also judged as significantly juicier, sweeter, crisper and of better total flavour strength than the non-organically grown carrots in sensory evaluations. Nitrate contents were not significantly different.
valid?
Yes, a comparison of carrots from organic farms, non-organic farms, and non-organic field trials. While no certification details were given for the organic farms, details of practices employed and history (minimum two years organic) are sufficient to confirm their status.

Crop rotation impacts on potato protein
Honeycutt CW (1998); USDA Agricultural Research Service's New England Plant, Soil and Water Laboratory, Newport, Maine, USA
Plant Foods for Human Nutrition 52(4), p 279–291

A two year replicated field trial comparing the relative influences of crop rotation and nitrogen fertiliser on the protein content of potatoes. The study demonstrated how rotation crops alfalfa, vetch and lupin can make significant contributions to the nitrogen content of the soil and thus the protein content of subsequently grown crops.
valid?
No, no organic fertilisation practices were employed or compared.

Effect of fertiliser practices on the nutritional quality of crops
Hornick SB & Parr JF (1990); USDA Agricultural Research Service, Beltsville, Maryland, USA
Agricultural alternatives and nutritional self-sufficiency for a sustainable agricultural system that respects man and his environment – Proceedings of the 7th IFOAM International Scientific Conference (Ouagadougou, 2–5 Jan 1989), Witzenhausen, Ekopan, p 244–254

Single season replicated greenhouse pot studies examining the effects on the yield and ascorbic acid content of crops by increasing the rate of organic (sewage sludge compost or cattle manure) fertilisation of green beans and Swiss chard, and non-organic (NPK) fertilisation of kale. All studies showed increasing levels of fertilisation increased yields but decreased ascorbic acid contents of the crops.
valid?
No, due to insufficient duration in soil with no organic history.

Effect of different levels of nitrogen and farm yard manure on yield and quality of spinach
Kansal BD, Singh B, Bajaj KL and Kaur G (1981); Punjab Agricultural University, Ludhiana, India
Qualitas Plantarum – Plant Foods for Human Nutrition 31, p 163–170

A single season replicated field trial comparing the effects of different levels of chemical (nitrogen as urea applied at 0, 30, 60 and 90 kg/ha) and organic fertilisation (farmyard manure at 0, 10 and 20 tonnes/ha) on the yield and nutrient composition of spinach. Comparing dry-weight mineral P, Fe, Mn, Zn, Cu concentrations and fresh weight vitamins beta carotene and VitC, the organic fertilisation gave lower yields and vitamin contents. (Dry-weight mineral comparisons are not included in this review).
valid?
No, due to insufficient duration on soil with no organic history.

Differences in organic and mineral fertilisation on potato tuber yield and chemical composition compared to model calculations
Kolbe H, Meineke S & Zhang WL (1995); Institute for Plant Nutrition, Germany
Agribiol. Res. 48(1), p 63–73

A three year field trial conducted on experimental plots that had been fertilised organically (compost and cattle farm yard manure) and non-organically (NPK) for the previous 30 years comparing the effects of these different fertilisation practices on potatoes. Organically grown potatoes gave 10–20 per cent higher yields, had higher Mg, K and vitamin C contents, and lower nitrate than the non-organically grown potatoes. Concluded that an optimal soil condition as well as a specific quantity and quality of nutrient supply is supported by continued organic fertilisation.
valid?
Yes, this is a significant paper showing the long and short term benefits of organic fertilisation.

Research on organically versus conventionally grown vegetables
Kopp HJ (1992); University of Hohenheim experimental farm, Germany
Kopke U and Schultz DG (eds.) *Organic Agriculture, a key to a sound development and a sustainable environment – Proceedings of the 9th IFOAM Conference* (Sao Paulo, Brazil, 16 Nov 1992), Tholey-Theley, Germany, p 324–330

A three year field trial on plots that had been previously cultivated organically or non-organically for more than ten years, comparing the effects of organic and non-organic cultural practices (appropriate insecticide sprays and equal amounts of nitrogen applied either as chemical fertiliser or cattle manure respectively) on beetroot, cabbage, carrots, tomatoes and lettuce. The study compared all parameters (K, Mg, phenolic compounds, nitrate, betanine, carotenes, and ascorbic acid) on a dry-weight basis which prevent their inclusion this review, though organically grown crops did compare favourably in terms of higher Mg and ascorbic acid contents and lower nitrate. The paper also reports lower fresh weight nitrate contents and higher phenolic compounds in organically grown carrots from an affiliated experiment, but insufficient information on this other study prevented its inclusion also.
valid?
No, as the study, while agriculturally valid, makes no useful comparisons (dry-weight nutrient comparisons are not included in this review).

Analysis of vegetables produced by orthodox and biological methods; some preliminary results
Lairon D, Ribaud P, Leonardi J, Lafont H, Gaudin G, and Reynier M (1981); Group de Researche en Agriculture Biologique (GRAB), France
Biological Husbandry – a Scientific Approach to Organic Farming, Stonehouse B (ed), Butterworths Publishers, p 327–328
See also: Lairon *et al*, 'Studies of yield and food quality of vegetables grown under organic and mineral fertilisation', in *Environmentally Sound Agriculture, 4th IFOAM Conference, Cambridge MA, Selected Papers*, Lockeretz W (ed.), Praeger, New York, p 408–409

A market survey comparing vegetables sold in orthodox markets with those purchased in "co-operative stores distributing biologically grown produce". Organically and non-organically labelled potatoes, leeks, kale, cos lettuce and turnips were purchased and analysed for 45 differentcompounds, finding 25 significant differences (despite the small sample sizes) in favour of organically grown produce including higher dry matter, K, Ca, Mg, Fe, Cu, Mn essential amino acids and lower nitrate. It is worth noting that no significant differences were found on a dry-weight basis, but due to the higher dry matter content of organically grown produce significant differences were present when data was compared on a fresh-weight basis.
valid?
Yes, a comparison of store-bought organically and non-organically grown produce. While no certification details are given for the organic produce, the author was contacted who confirmed that the organic samples were certified as such.

Effect of organic and mineral nitrogen fertilisation on the yield and nutritive value of butterhead lettuce
Lairon D, Spitz N, Termine E, Ribaud P, Lafont H, & Hauton J (1984); Group de Researche en Agriculture Biologique (GRAB), France
Qualitas Plantarum – Plant Foods for Human Nutrition 34, p 97–108

Results from a replicated one season field trial comparing the effects of equal rates of nitrogen applications as either non-organic (ammonium nitrate or Chilean nitrate of soda) or organic (castor oil seed cake) fertilisation on butterhead lettuce. Comparing yields, dry matter, P, K, Ca, Mg, Na, Fe, Mn, Cu and amino acid contents, no significant differences were found. The nitrate contents of organically grown lettuces were significantly lower.
valid?
No, due to insufficient duration on soil with no organic history.

Effects of organic and mineral fertilisations on the contents of vegetables in minerals, vitamin C and nitrate
Lairon D, Termine E, Gautier S, Trouilloud M, Lafont H & Hauton J (1986); Group de Researche en Agriculture Biologique (GRAB), France
Vogtmann H, Boehncke E, Fricke I (eds.), *The Importance of Biological Agriculture in a World of Diminishing Resources – Proceedings of the 5th IFOAM International Scientific Conference* (University of Kassel Germany, 27–30 Aug 1984) Verlagsgruppe Witzenhausen, p 249–260
See also the peer-reviewed French-language journal *Sciences des Aliments* as Termine *et al* 1984, vol. 4, p 273–77

Results from four comparative studies conducted in south-east France comparing the effects of organic versus non-organic fertilisation. The pot trial, buried pot trial and field trial were all excluded from this review due to insufficient duration (one, one and two seasons respectively) in soil with no organic history. The fourth experiment, a farm survey, compared the crops from paired organic (certified by Nature et Progres) and non-organic farms. The farms from each pair were located close to one another to ensure similar soil type and climate. Four crops of identical or comparable varieties were grown – lettuce (at five farm pairs), potato (two), leek (one), and carrot (eight). Statistically significant data reveals a trend of comparable Fe content, lower nitrate, Mn and K, and higher contents of P Mg Ca and Cu in organically grown vegetables, though overall the data were inconsistent.
valid?
Yes, a comparison of crops from certified organic and non-organic farms.

Vitamin and mineral contents of carrot and celeriac grown under mineral or organic fertilisation
Leclerc J, Miller ML, Joliet E & Rocquelin G (1991); Research Station for the Quality of Vegetables and Fruits, Burgundy region, France
Biological Agriculture and Horticulture 7, p 339–348

Results from a two year farm survey involving 12 pairs of organic and non-organic farmers growing carrots and celeriac. Each pair was matched for locality, soil type, variety and growing period, and crops were analysed for dry matter, vitamins (b-carotene C, B_{12356}), minerals (P, K, Ca, Mg, Cu, Zn, Fe, Mn) and nitrate. While many parameters favoured the organically grown crops, only a few were statistically significant: organically grown carrots had higher b-carotene and vitamin B1, while organically grown celeriac had higher dry matter, VitC and P and lower nitrate contents. The higher Zn in non-organically grown celeriac was thought to be the result of pesticide

pollution, and not as a result of fertilisation.
valid?
Yes, comparison of carrots and celeriac from well matched pairs of certified organic and non-organic farms.

Preliminary results on contents of resveratrol in wine of organic and conventional vineyards
Levite D, Adrian M & Tamm L (2000); Research Institute of Organic Agriculture (FiBL), Switzerland
Proceedings of the 6th International Congress on Organic Viticulture (25–26 Aug 2000, Basel, Switzerland), p 256–257

A farm survey of wine in which resveratrol content (an antioxidant phenolic compound in the skin of red grapes) was, on average, 26 per cent higher in organically than in non-organically produced wines in paired comparisons of the same grape variety (within a range of -10 to +50 per cent).
valid?
Yes, a comparison of the secondary nutrient content of organically and non-organically produced wine. While no certification details were given for the organic vineyards, the author was contacted and confirmed that they were certified by Biosuisse.

Maize yields and soil nutrient levels with and without pesticides and standard commercial fertilisers
Lockeretz W, Shearer G, Sweeney S, Kuepper G, Wanner D & Kohl DH (1980); Washington University (St Louis), Western Corn Belt, USA
Agronomy Journal 72, p 65–72

A four year farm survey involving 26 neighbouring pairs of mixed (grain / livestock) organic and non-organic maize farms. A limited number of parameters were investigated, including maize yield (comparable / non-significant difference) and crude protein content (12 per cent higher in non-organic). Some soil properties (higher organic matter in organically managed soils), and the incidence of disease (stalk rot significantly lower on organic farms) were also compared. Greater differences in yield were observed between pairs than within them, suggesting the strong influence of location, soil type, cultivar and planting date.
valid?
Yes, comparison of the protein contents of maize from organic and non-organic farms. While certification details of the organic farms are not given, the detailed descriptions of practices and history (minimum four years organic) are sufficient to confirm their status.

Effect of three farming systems (biodynamic, organic, conventional) on yield and quality of beetroot in a seven year crop rotation
Mader P, Pfiffner L, Niggli U, Plochberger K, Velimirov A, Balzer U, Balzer F & Besson J-M (1993); Joint project of the Swiss Federal station of Agriculture, Chemistry and Hygiene of Environment, Berne, and the Research Institute of Biological Husbandry, Oberwil, Therwil, Switzerland
Acta Horticulturae 339, p 10–31

Results from the second seven-year crop rotation (1985–1991) of the long-term Swiss DOC field trial begun in 1978 comparing the effects of organic, non-organic (NPK) and integrated (NPK plus manure) fertilisation on beetroot. While this trial was designed mostly as a comparison of organic and integrated farming methods (as reported in Alfoldi *et al* 1996), this paper also included data for plots receiving chemical only (NPK) fertilisation, which is taken here as the non-organic comparison. Compared to these 'NPK-only' crops, the organically grown beetroot were of equivalent yields and vitamin C content, but had higher dry matter and lower nitrate contents. Mineral comparisons (P, K, Ca, Mg) were reported on a dry-weight basis, and the data for dry matter contents which would allow this to be adjusted to wet-weight concentrations is not given. However the study does confirm that the organically grown crops had a higher dry matter content than the non-organically grown crops, and taking this into account, we can confirm the following trends: On a fresh-weight basis, organically grown beetroot had higher P and Mg contents than non-organically grown beetroot, while Ca and K contents were comparable. Compared to the integrated farming crops (NPK plus manure), the organically grown beetroot yielded around 25 per cent lower, but was lower in nitrate and was significantly preferred in animal feeding trials with rats. Picture forming methods of analysis were consistently able to group samples according to production method, demonstrating the accuracy of this method of analysis.
valid?
Yes, comparison of beetroot from long term organic, non-organic (chemical fertiliser only) and integrated field trials.

Yield, nitrate and sensory properties of spinach as influenced by organic and mineral nitrogen fertiliser levels
Maga JA, Moore FD & Oshima N (1976); San Luis Valley Research Centre, Colorado State University, USA
Journal Sci. Food Agriculture 27, p 109–114

A single season field trial comparing the effects of organic (dried blood) and non-organic (ammonium sulphate) nitrogen fertilisers on spinach. All plots received treble super phosphate during seeding. Comparing yields, nitrate contents and taste, the data showed significantly higher yields in the non-organically fertilised plots, and nitrate levels in the crops were closely related to the level of nitrogen application regardless of type. Taste preferences were not observed.
valid?
No, due to insufficient duration of the trial on soil with no organic history, and inappropriate fertilisation (super phosphate) not properly representative of organic farming practices.

The effect of manurial conditions on the nutritive and vitamin values of millet and wheat
McCarrison R (1926); The Indian Research Fund Association of the Pasteur Institute, Coonoor, Southern India
Indian Journal of Medical Research 14, p 351–378

A one year field trial with millet and wheat on experimental plots that had been fertilised chemically (ammonium sulphate, potassium sulphate and superphosphate) or organically (cattle or farmyard manure) for the previous 14 years. Analyses showed higher levels of vitamin A in the organically grown wheat, more vitamin B in the organically grown millet, increased second generation yields (of 11 per cent) from the seeds of organically grown plants, and a higher nutritive value of the organically grown grains in rat feeding trials (based on higher growth rates with equal dietary intakes).
valid?
No, the age of this study introduces uncertainties regarding the farming practices and analytical and scientific methods employed that prevent its inclusion in this review.

Quality of plants grown with compost from biogenic waste
Meier-Ploeger A, Duden R and Voghtmann H (1989); University of Fulda, Dept of Nutrition and Home Economics, Research Farm of the University of Kassel, Germany
Agriculture, Ecosystems and Environment 27, p 483–491

A single season replicated field trial comparing the influence of NPK, biogenic waste compost, farmyard manure compost or commercial organic fertilises on the yields, vitamin C, sugar and nitrate contents, storage quality and sensory qualities of cabbage, beetroot and tomatoes. Yields were comparable for NPK and commercial organic fertiliser, but lower for the plots receiving biogenic waste or farmyard manure composts. Compost treatments led to superior results in terms of storage quality, higher vitamin C and sugar contents, and lower nitrate contents.
valid?
No, due to insufficient duration on unspecified soil.

Carotenoid composition of a leafy vegetable in relation to some agricultural variables
Mercadante AZ, Rodriguez-Amaya DB (1991); Universidade Estadual de Campinas, Sao Paolo, Brazil
Journal of Agric. Food Chem. 39, p 1094–1097

A farm survey examining the carotenoid composition of kale as influenced by season (summer versus winter), cultivar (two varieties) and agrochemical application ('natural' farm versus neighbouring farm using NPK, ethylpara-

thione insecticide and glyphosate herbicide). Variety and season were found to affect the carotenoid content in various ways, but all carotenoids (incl-uding b-carotene) were significantly higher in all samples of kale from the natural farm than those obtained from the neighbouring farm that utilised agrochemicals, "probably due to residual herbicide (glyphosate) in the soil". This confirmed research showing that glyphosate can cause a significant reduction in plant carotenoid contents (Abu-Ismaileh and Jordan, 1978).
valid?
No, due to lack of certification details or clarification of the agricultural practices employed on the 'natural' farm, this is not a clear comparison of organic and non-organic agricultural practices.

Nutritive value of wheat from the Rothamstaed Broadbalk field
Miller DS & Dema IS (1958); National Institute for Medical Research, London; Broadbalk experimental fields at Rothamsted, UK
Proceedings of the Nutrition Society 17, p 94–95

Analysis of wheat flour which was later used in a rat feeding trial. Contrasting fertiliser treatments ('dung' versus 'artificial') had been continued for more than 100 years at the time of the study, and analysis showed the organically grown flour to have higher levels of vitamin B2, equivalent levels of P K and Mg and lower levels of Ca Mn vitamins B1 and B3, fat and protein (dietary value). There were no differences between the reproductive performance of the animals fed on wheats from the various plots (including a control of no fertiliser).
valid?
No, due primarily to the age of the study, which creates uncertainty that the fertilisation practices, analytical and scientific methods employed are comparable to current practices, which prevents its inclusion in this review.

Effects of forms and rates of organic and inorganic nitrogen fertilisers on the yield and some quality indices of tomatoes
Montagu KD & Goh KM (1990); Department of Soil Science, Lincoln University, Canterbury, New Zealand
New Zealand Journal of Crop and Horticultural Science 18(1), p 31–37

A single season pot trial comparing the effects of organic (commercial blood and bone, composted sawdust/chicken manure) and non-organic (potassium nitrate and ammonium sulphate) fertilisation on yields, vitamin C and lycopene contents and visual quality of tomatoes. The data showed that increasing rates of nitrogen application, regardless of source, significantly decreased the vitamin C contents and visual quality of tomatoes, while increasing rates of application of blood and bone, potassium nitrate and ammonium sulphate increased yields and lycopene content.
valid?
No, due to insufficient duration in soil with no organic history.

Yield, storage ability, quality and chemical composition of carrot, cabbage and leek at conventional and organic fertilising
Nilsson T (1979); Swedish University of Agricultural Science, Alnarp, Sweden
Acta Horticulturae 93, p 209–223

A two year field trial comparing the effects of various levels of organic (farmyard and dried poultry manure) and non-organic (NPK Mg plus micronutrients) fertilisers on carrot, cabbage and leek. Crops were analysed for yield, dry matter, VitC, carotene, nitrate, and dry-weight mineral concentrations (K, Ca, Mg). Yields, dry-matter and vitamin C contents were largely uninfluenced by the different fertilisers used. Nitrate contents were higher in the organically grown crops and were substantially reduced by halving the fertilisation rates for all fertiliser types. The authors concluded that organic fertilisers do not result in produce with a higher nutritive value.
valid?
No, due to insufficient duration in soil with no organic history.

Influence of organic and inorganic fertilisers on the chemical composition of three eggplant cultivars
Ogbadu GH & Easmon JP (1989); Department of Biochemistry, Ahmadu Bello University, Zaria, Nigeria
Tropical Science 29(4), p 237–246

A one year field trial comparing the effects of organic (poultry manure) and chemical (calcium ammonium nitrate, NPK) fertilisation on three varieties of eggplant. Comparing dry matter, protein, vitamin C, mineral P, K, Ca, Mg, Cu, Fe and nitrate contents, the data showed inconsistent or not significant differences between the two methods of fertilisation, and variety appeared to have some influence.
valid?
No, due to insufficient duration in soil with no organic history.

Effect of compost on nutrient quality of food
Pain AK (1962); Central Sericultural Research Station, Bengal, India
Compost Science 3(1), p 40–41

A five year field trial examining the effects of applications of (mulberry-waste) compost, bovine manure or no fertiliser (control) on the nutritive value of mulberry leaves used for silk production. The data showed that leaf yields, leaf composition and cocoon/silk production were roughly equal for trees with compost and manure applications, which were far superior to the unfertilised controls.
valid?
No, as makes no comparison with non-organic fertilisation practices.

Organic and mineral fertilisers compared by yields, quality and composition of spinach
Peavy WS & Grieg JK (1972); Kansas State University, USA
Journal of American Horticultural Science 97, p 718–723

A two year field trial comparing the effects of organic (bovine manure applied in the first year only) and non-organic (NPK) fertilisation on the yields, dry matter, P, K, Ca, Mg, Mn, Fe and Zn contents of spinach. Little or no difference due to the type of fertilisation was found in dry matter, K, Mg, Mn or Zn contents, while organic fertilisation significantly increased Fe and P contents and reduced the yields of spinach. Differences in Ca contents were inconsistent from crop to crop. Growing season (autumn, winter, spring) appeared to be a strong influence on many parameters compared.
valid?
No, due to insufficient duration in soil with no organic history.

A comparison between the conventional and biodynamic farming systems as indicated by yields and quality
Pettersson BD (1978); Agricultural University in Uppsala and The Scandinavian Research Circle, Jarna, Sweden
Toward a Sustainable Agriculture – Proceedings of the IFOAM Conference (Sissach, Switzerland), p 87–94

A three year field trial comparing the effects of non-organic (NPK plus pesticides) and organic (manuring plus biodynamic preparations) farming methods on a three year crop rotation of potato, spring wheat and barley. All data is presented as an average of the three years, although the first two years of the organic trial should be considered as a theoretical conversion period for the experimental plots, given that no information regarding their previous history was given. Organically grown potatoes were lower yielding but superior in all the qualitative characteristics - higher vitamin C, more organised crystallisation pictures, better taste, fewer cooking defects, and better storage capabilities. Both the wheat and barley had a higher protein quality (EAA index).
valid?
No, as the majority of data is from the theoretical conversion period of the first two years of the trial, and the third year data, which would be valid, is not presented separately.

Quality of organic-grown food – an experimental, multifactorial approach on vegetables for example
Pfeilsticker K (1992); Institut fur Lebensmittelwissenschaft und Lebensmittelchemie, Reinische Friedrich-Welhelms University, Bonn, Germany
Kopke U and Schultz DG (eds.), *Organic Agriculture, a Key to a Sound Development and a Sustainable Environment – Proceedings of the 9th IFOAM Conference* (Sao Paulo, Brazil, 16 Nov 1992), Tholey-Theley, Germany , p 331–337

A three year field trial comparing the effects of organic (composted manure plus biodynamic preparations) and non-organic (NPK plus pesticides) fertilisation on the dry matter, sugar, nitrate and mineral (K, Mg, Fe, Mn, Zn and Cd) concentrations and taste of cauliflower, cabbage, lettuce, carrots and celery. Statistical evaluations of the data were conducted (especially factorial and discriminant analyses), and while the paper concludes that a "significant distinction of organically and non-organically cultivated samples is possible", the data is not presented in such a manner that allows a clear and unambiguous appreciation of the nature of those distinctions.
valid?
No, lack of clarity in the data presentation makes direct comparisons of the organically and non-organically grown samples impossible.

Effects of poultry manure and mineral fertilisers on the quality of crops
Pimpini F, Giardini L, Borin M & Gianquinto G (1992); Istituto di Agronomia generale e Cultivazioni erbacee, Experimental Station of the Agricultural University of Padova, Italy
Journal of Agricultural Science 118(2), p 215–221

A five year field trial comparing the effects of organic (poultry manure) and non-organic (mineral) fertilisation on one year each of potato, sugar beet, onion, tomato, and spinach, in that order. Only data from the third year on will be included in this review as the first two years comprise a theoretical conversion period for the experimental plot, which excludes data on potatoes and sugar beet. No significant differences were found in the dry matter or contents of onion, tomato and spinach; the organically grown spinach had slightly lower raw protein content, and most parameters in the tomato analysis were processor-orientated and not relevant to this review.
valid?
Yes, limited but nevertheless valid comparison between organically and non-organically grown crops in a five year field trial.

Analytical survey of the nutritional composition of organically grown fruit and vegetables
Pither R & Hall MN (1990); Campden Food and Drink Research Association, Gloucestershire, UK
Technical Memorandum 597, MAFF Project 4350

A MAFF commissioned market survey comparing the nutrient composition of products sold as organically grown and those not so labelled. Thirty paired samples of each fruit/vegetable (apples, carrots, green cabbage, potatoes, and tomatoes) were purchased from supermarkets, healthfood shops, greengrocers and farmshops and analysed for the following: dry matter, vitamin C, total sugars, Fe and K, plus carotenes (carrot and tomatoes), and Ca, Zn (potatoes). The authors concluded that there were "substantive differences in levels of various nutrients between certain fruits and vegetables sold as organic and those sold as conventional". Organically grown produce was found to have significantly higher levels of vitamin A/total carotenes (tomatoes), vitamin C (apples and tomatoes), potassium (apples, carrots and tomatoes), iron (potatoes) and zinc (potatoes). No significant differences were found between organically and non-organically grown cabbages. Differences in dry matter contents were inconsistent or not significant, and all other comparisons found non-significant differences. Comparative potato samples 11–23 are not included in this review because throughout the study samples were paired as closely as possible on the basis of country of origin, variety and appearance, however for this subset of the potato samples this was not the case, and appears to have made a substantial impact on the data (in favour of non-organic), bringing its reliability into question.
valid?
Yes, a comparison of organically and non-organically grown produce as purchased from UK retailers. In the absence of certification details of the organic vegetables, we contacted the author who confirmed that the organic samples were certified as such.

Investigation of the contents of winter wheat and carrots from different sources of production and marketing
Pommer G & Lepschy J (1985); Bavarian Centre for Earth Culture and Crop Production, Feising-Munich, Germany
Bayerisches Landwirtschaftliches Jarbuch 62, p 549–563

A market survey conducted in 1982 comparing the nutrient contents of 20 one kilogram samples of organically and non-organically grown carrots purchased from 'bioshops' and 'normal shops'. Comparing minerals K, Ca, Mg, Cu and Zn, the non-organically grown carrots had significantly higher K contents, no significant difference was evident in the Ca content, and organic carrots had significantly higher Mg, Cu and Zn. Organic carrots had significantly higher dry matter, alpha and beta carotene (vit A) contents than non-organically grown carrots., and significantly lower nitrate contents (just 29 per cent of the non-organic level)
valid?
Yes, a comparison of the nutrient contents of carrots purchased from 'bioshops' and 'normal' shops in Germany. While certification details were not given, the authors took care to avoid the 'grey market', confirming the authenticity of samples with the assistance of organic associations and the farmers themselves. Mineral contents were compared on a dry-weight basis, however the dry matter content data allowed conversion of the mineral content data to a percentage of fresh-weight basis. Winter wheat data are not included as it is not clear that a comparison of organic and non-organic samples was made (samples were obtained from organic farms, bioshops and warehouses [lagerhauser], though it is not clear that the warehouses were non-organic, and would not be a valid like-for-like comparison anyway).

Qualitative comparison between commercial 'traditional' and 'organic' tomato products using multivariate statistical analysis
Poretta S (1994); Stazione Sperimentale per l'Industria delle Conserve Alimetari, Parma, Italy
Acta Horticulturae 376, p 259–270

A market survey comparing samples of 'traditional' (non-organic) and 'organic' tomato products (usually passata/strained tomatoes) obtained from ten major Italian tomato processors (five traditional and five organic). The majority of parameters compared were technical processing characteristics and are not relevant here, however samples from one of the five 'traditional' processors contained pesticide (metalaxyl) and degraded fungicide (ETU – ethylenethiourea) residues (the latter being "quite high – 94ug/kg as compared with a maximum value of 26ug/kg found in the (industrial) literature").
valid?
No, due to the lack of quality comparisons relevant to this review. Lack of organic certification does not rule the study out as it was conducted after 1993 when it became illegal in the EU to label foods as organic without proper certification.

Quality investigations with products of the long-term fertilisation trial in Darmstadt – Second period: fertilisation with total nitrogen equivalents
Raupp J (1996); Institute for Biodynamic Research, Darmstadt, Germany
Quality of Plant Products Grown with Manure Fertilization: Proceedings of the Fourth Meeting (Juva, Finland, 6–9 July 1996). Darmstadt; Germany: Institute for Biodynamic Research, p 13–33

Reports the results from two periods of investigation – the first period (1981–84) examines fertilisation requirements to achieve comparable yields, but does not add substantially to the data reported previously in Abele, 1987, so is not included in this review. The second period (1985–95) involves long-term field trials (on the same plots) with wheat, carrots, beetroot, and potatoes, applying equal amounts of nitrogen in either organic (composted cattle manure, urine, and biodynamic field preparations) or non-organic (NPK) fertilisers. Limited comparisons are presented, however, yields tended to be higher in non-organically grown crops, storage capabilities were inconsistent (organically grown potato better but organically grown beetroot worse), protein contents were lower in organically grown wheat, and nitrate contents were lower in organically grown beetroots (no results available for any other crops). Increased fertilisation levels caused higher yields with all crops.
valid?
Yes, is a comparison of protein contents in wheat plus nitrate contents and storage capabilities of organically and non-organically grown crops from a long-term field trial.

Yield, product quality and soil life after long-term organic or mineral fertilisation
Raupp J (1997); Institute for Biodynamic Research, Darmstadt, Germany
Agricultural Production and Nutrition, Proceedings of an International Conference (Boston, MA, 19–21 Mar 1997), Lockeretz W (ed.), Medford, MA: School of Nutrition Science and Policy, Tufts University, p 91–101

A republished version of Raupp 1996. Additional data presented on soil microbiological parameters, showing that organically managed soil has higher organic matter content, microbial biomass and soil enzymatic activity.
valid?
No, as is a republished version of Raupp 1996 and does not add substantially to the previously reported data.

Examination of some microbiological and biochemical parameters and tests of product quality used in a long-term fertilisation trial
Raupp J (1998); Institute for Biodynamic Research, Darmstadt, Germany
American Journal of Alternative Agriculture 13(3), p 138–144

A republished version of Raupp 1996. Asserts that quality comparisons should include parameters beyond those that can be directly analysed in the food or crop, to include political, social, psychological, economic and environmental impacts during production and processing.
valid?
No, as is a republished version on Raupp 1996 and does not add substantially to the previously reported data.

Nitrat in gemuse
Rauter W & Wolkerstorfer W (1982); Bundesanstalt fur Lebensmitteluntersuchung, Salzburg, Austria
Z Lebensmittel Untersuchung und Forschung 175, p 122–124

A market survey comparing the nitrate contents of 1,477 samples of non-organic, 'organic' and glasshouse cultivated vegetables. Nitrate contents were lower in 17 of the 18 vegetables studied by an average of around 40 per cent (for example carrots 60 per cent, endive 54 per cent and radish 14 per cent lower). The one exception, organically grown spinach, had 15 per cent higher nitrate levels than the non-organically grown spinach. Glasshouse produced vegetables contained significantly higher levels of nitrate, with up to twice the levels of the non-organically produced crops.
valid?
No, due to absence of certification details of the organic vegetables, and the unknown source of the samples.

Sustainability of three apple production systems
Reganold JP, Glover JB, Andrews PK and Hilman HR (2001); Washington State University, USA
Nature 410, p 926–930

A six year field trial comparing the effects of organic (compost, non-chemical weed control, organically certified biological controls), non-organic (synthetic fertilisers, pesticides, herbicides, chemical fruit thinners) and integrated (compost and synthetic fertilisers, bark mulch and herbicides for weed control) management on golden delicious apples. All three systems gave similar yields. Comparing fruit-flesh mineral contents of P, K, Ca, Mg, B and Zn from the fourth year on, inconsistent or not significant differences were found, though were compared on a dry-weight basis so are not included in this review. In taste tests the organic system produced sweeter and less tart apples
valid?
No, while agriculturally valid and providing useful information on yields, taste, and the environmental and economic sustainability of organically, integrated and non-organically grown apples, it was not stated in the report whether the mineral concentrations were reported on a fresh- or dry-weight basis. Comparing it to other apple studies it was apparent that the data was reported and compared on a dry-weight basis, thus potentially eliminating differences that may have resulted from differing dry-matter contents.

Six years of biodynamic growing of vegetables and apples in comparison with conventional farm management
Reinken G (1986); Rhineland Chamber of Agriculture, Auweiler Experimental Station for Fruit and Vegetable Growing, Cologne, Germany
Vogtmann H, Boehncke E, Fricke I (eds.), *The Importance of Biological Agriculture in a World of Diminishing Resources – Proceedings of the 5th IFOAM International Scientific Conference* (University of Kassel Germany, 27–30 Aug 1984) Verlagsgruppe Witzenhausen, p 161–174

A discussion of farm management issues using organic and non-organic cultural practices with apples and eleven different vegetables. While this study confirmed that non-organically grown fruit and vegetables were higher yielding, the paper focuses mainly on farm management issues, such as labour requirements (more required for organic), financial returns (greater for organically grown crops), fruit grading and injury (favouring non-organic), and soil properties (favouring organically managed soil).
valid?
No, due to the lack of quality comparisons relevant to this review.

The nutritive and sensory quality of carrots and white cabbage from organic and conventional farms
Rembialkowska E (2000); Warsaw Agricultural University, Torun, Plock and Warsaw, Poland
Proceedings from the 13th IFOAM Scientific Conference 2000, p 297

A farm survey involving ten non-organic / intensive and ten certified organic farms (EKOLAND), comparing the effects of their different cultural practices on carrots and white cabbage. Organically grown crops were lower yielding (by 25–37 per cent), but were characterised by lower nitrate levels (three-four times less) and better taste. Organically grown cabbage contained more dry matter (15 per cent), vitamin C (30 per cent), K (35 per cent), but less Ca (19 per cent) than non-organically grown cabbage. Organically grown carrots contained less nitrites (46 per cent), and three times more Cd (however "the level of heavy metals was generally low in all samples").
valid?
Yes, comparison of cabbage and carrots from non-organic and certified organic farms.

Vitamin and mineral content of spinach under the influence of different forms and quantities of nitrogen
Reuff B (1970); Institut fur Gemisebau, Weinhenstephan, Munich, Germany
Landwirtschaftliche Forschung 25, p 106–114

A two year field trial comparing the effects of organic (composted farmyard manure) and non-organic (ammonium sulphate) fertilisation on the yields, minerals Mn, Fe, Cu and Mo (on a percentage of dry-weight basis), and vitamin A (carotene) B1, B2 and C contents (fresh-weight basis) of spinach. Organically cultivated spinach was lower yielding, with increased nitrogen fertilisation correlated with increased yields. Vitamin contents were even (B1, C) or higher (B2, A) in non-organically grown spinach, and inconsistent results were observed in the mineral content comparisons.
valid?
No, due to insufficient duration on soil with no organic history, and minerals are compared on a dry-weight basis.

Integrated research on production systems and product quality
Rutkoveine V, Baltramaityte D & Stancevius A (2000); Lithuanian University of Agriculture
Proceedings from the 13th IFOAM Scientific Conference 2000, p 301

A nine year replicated field trial comparing the effects of organic and non-organic farming (with appropriate fertilisation and plant protection measures) on barley, winter wheat and sugar beet. Organically grown crops gave lower yields by around 27 per cent. Organic cultivation resulted in diminished processing characteristics in wheat (protein 28 per cent and gluten 35 per cent down), but improved the sugar content and processing characteristics of sugar beet (better sugar extraction / output). No details regarding nutrients were given so no nutrient comparisons can be included.
valid?
Yes, is a comparison of protein content of organically and non-organically grown wheat and barley from a long-term field trial.

The response of barley varieties in conventional and biological growing
Rydberg T (1986); Saby, Sweden
Vogtmann H, Boehncke E, Fricke I (eds.), *The Importance of Biological Agriculture in a World of Diminishing Resources – Proceedings of the 5th IFOAM International Scientific Conference* (University of Kassel Germany, 27–30 Aug 1984) Verlagsgruppe Witzenhausen, p 310–316

A one year field trial comparing the effects of organic and non-organic (NP fertilisation) cultivation methods on the yield, seed size (1,000-seed weight) and starch contents of barley. The organic plots had not been treated with chemical fertilisers or pesticides for the previous 12 years. No fertilisation details are given for this period, and no fertilisation was applied to the organic plots during the trial. Grain yields were consistently higher for barley grown with non-organic fertilisation, while no differences were found in the other parameters compared. Significantly more weed growth was observed in the non-organically grown plots.
valid?
No, due to unknown or non-existent fertilisation of the organic plots, either prior to or during the trial.

Studies on the effects of organic vs inorganic form of nitrogen on the quality of okra
Saleha A (1992); Indian Institute of Horticultural Research, Bangalore, India
Journal of Maharashtra Agricultural Universities 17(1), p 133–134

A three year replicated field trial with okra, comparing the effects of chemical (ammonium sulphate) and organic fertilisers (farmyard manure, poultry manure and horse manure) applied in equal doses of 40kg N/ha in pure chemical and organic forms as well as in various combinations, including a control which received no nitrogen. A constant basal dose of 50kg P_2O_5 and 30kg K_2O/ha were applied uniformly to all plots, so the trial only compared the effect of various sources of nitrogen. Comparing total carbohydrates, crude fibre, protein and ascorbic acid, third year data (eighth harvest) showed that organically grown okra contained more vitamin C and total carbohydrates.
valid?
No, due to inappropriate P and K fertilisation of the organic plots.

The influence of compost or NPK fertilisation on yield, vitamin C and nitrate content of spinach and spinach beet
Schudel P, Eichenberger M, Augstburger F, Kläy R & Vogtmann H (1979); Forschungsinstitut fur Biologischen Landbau, Oberwil, Germany
Schweizerische Landwirtschaftliche Forschung 18, p 337–349

A one year field and pot trial comparing the effects of organic (compost) and non-organic (NPK) fertilisation on the yields, dry matter, vitamin C and nitrate contents of spinach beet and two varieties of spinach. The data showed higher dry matter and vitamin C contents and lower nitrate contents in the organically grown spinach and spinach beet. Variety was observed to influence the yield, nitrate and vitamin C contents of spinach.
valid?
No, due to insufficient duration on soil of unspecified history.

Quality comparison of mineral, organic and biodynamic cultivation of potatoes: contents, strength criteria, sensory investigations and picture creating methods
Schultz DG, Koch K, Kromer KH & Kopke U (1997); Institute of Organic Agriculture and the Institute of Agricultural Engineering, Rheinische Friedrich-Wilhelms-University in Bonn, Darmstadt, Germany
Agricultural Production and Nutrition – Proceedings of an International Conference (Boston, MA, 19–21 Mar 1997), Lockeretz W (ed.), Medford, MA: School of Nutrition Science and Policy, Tufts University, p 115–120

Data from four years of an 18 year field trial comparing the effects of non-organic (potassium chloride) and organic (composted farmyard manure) fertilisation on the dry matter, sugar, starch contents and sensory qualities of potatoes. Inconsistent or not significant differences were found in dry matter contents. Intensified fertilisation generally diminished tuber starch/dry matter and sensory qualities (taste, consistency, colour and smell).
valid?
No, due to improper fertilisation of the non-organically fertilised plots (as stated by the authors).

Determining the quality of organic produce: extended quality parameters and quality index
Schultz DG, Zedow E & Kopke U (1992); Institute of Organic Agriculture, University of Bonn, Germany
Kopke U and Schultz DG (eds.), *Organic Agriculture, a key to a sound development and a sustainable environment – Proceedings of the 9th IFOAM Conference* (Sao Paulo, Brazil, 16 Nov 1992), Tholey-Theley, Germany, p 338–348

A one year field trial comparing the effects of different organic fertilisation practices ('fresh' – six month old – horse manure, fully composted horse manure (two years) and biodynamic preparations) and sunlight exposure (northerly or southerly aspect of raised bed) on the dry matter, nitrate, protein and carbohydrate contents of carrots. The data showed that 'fresh' manure resulted in higher dry matter, nitrate, lower amino-acid (protein) and higher carbohydrate contents in carrots than the composted manure. The more shadowed northerly aspect resulted in higher dry matter, lower nitrate, amino acid (protein) and carbohydrate contents in carrots than the less shadowed southerly aspect of the raised beds.
valid?
No, due to absence of non-organic comparisons, and limited duration of the trial on soil of unspecified history.

Nutritional value of crops as influenced by organic and inorganic fertiliser treatments
Schuphan W (1974); Bundesanstalt fur Qualitatsforschung pflanzlicher Erzeugnisse, Geisenheim, Germany
Qualitas Plantarum – Plant Foods for Human Nutrition 23(4), p 333–358

A 12 year field trial comparing the effects of organic (composted stable manure) and non-organic (NPK) fertilisation on the yields and dry matter, minerals P, K, Ca, Mg and Fe, vitamin C, protein and nitrate contents of spinach, savoy, potatoes and carrots (chosen for their representative morphologies – a rosette, a big terminal bud, a stem tuber and a storage root). Organically grown crops were lower yielding (by 20–56 per cent), but were characterised by higher dry matter (23 per cent), minerals P (13 per cent), K (18 per cent), Ca (10 per cent) and Fe (77 per cent – determined in spinach only), vitamin C (28 per cent), relative protein (18 per cent) and methionine (23 per cent – determined in potatoes and spinach only), and lower nitrate levels (93 per cent). The author concluded "that the consumer would benefit from a higher nutritional value of products of organic management is beyond question, as confirmed by 12 years' investigations".
valid?
Yes, a comparison of the nutritional contents of produce from a long-term field trial using organic and non-organic fertilisation practices.

A comparison of crude protein, moisture, ash and crop yield between organic and conventionally grown wheat
Shier NW, Kelman J & Dunson JW (1984); Department of Home Economics, Nutrition and Dietetics, Indiana University, Bloomington, Indiana, USA
Nutrition Reports International 30(1), p 71–76

Farm survey comparing the crude protein and moisture content of wheat from 18 paired non-organically and organically managed farms (average seven years previous organic cultivation). No significant or consistent differences found.
valid?
Yes, while no organic certification details were given for the organic farms, history of organic cultivation, definitions given for organic and non-organic farming practices and membership of the Organic Growers of Michigan Co-operative, Inc. were judged sufficient to confirm their status.

Organic foods vs. supermarket foods: element levels
Smith B (1993); Doctors Data Inc., West Chicago, Illinois, USA
Journal of Applied Nutrition 45(1), p 35–39

A two year market survey comparing the nutrient contents of non-organic and organically labelled specimens of apples, pears, potatoes and corn of similar varieties and sizes, plus wheat flour and grain purchased from both catalogues and markets in the Chicago area. Comparing the contents of 19 essential minerals and four heavy metals on a fresh-weight basis, it was found that organically labelled produce had an average of more than twice the nutrient contents of non-organically labelled produce and 25–40 per cent

lower levels of heavy metals Al, Pb and Hg.
valid?
No. This paper is often cited in support of organic produce, though the absence of certification details for the organic produce, and lack of confidence in the accuracy of organic labelling in Chicago in 1991 (after consultation with the Illinois Chapter of the Organic Crop Improvement Association) prevent its inclusion in this review.

The effects of fertilisation and manuring on the contents of some nutrients in potato
Srikumar TS & Ockerman PA (1990); University of Lund, Jarna, Sweden
Food Chemistry 37(1), p 47–60

A single season field trial comparing the effects of organic (raw and composted manure plus biodynamic preparations) and non-organic (NPK plus trace minerals Cu, Fe, Zn and Mn) fertilisation on potatoes. Comparing dry matter, protein, minerals Zn, Fe, Cu, and Mn, the data showed the application of chemical fertiliser increased the dry matter content but lowered the Fe content by 11–45 per cent. Higher application of chemical fertiliser increased protein and Fe but decreased Zn contents, while Cu and Mn contents remained unchanged. The authors concluded, 'the study indicates a complex pattern of trace element contents due to the application of different manuring and fertilisation techniques'.
valid?
No. Insufficient duration on soils with unspecified histories, thus may not properly represent soil conditions in organic and non-organic agriculture.

The effects of organic and inorganic fertilisation on the content of trace elements in cereal grains
Srikumar TS & Ockerman PA (1991); University of Lund, Hornby, Sweden
Food Chemistry 42(2), p 225–230

A single season field trial comparing the effects of organic (raw and composted manure plus biodynamic preparations) and non-organic (NPK plus trace minerals Cu, Fe, Zn and Mn) fertilisation on wheat and oats. Comparing yields and trace minerals Zn, Fe, Cu, Mn and Se, organic fertilisation of wheat resulted in comparable yields, higher Cu and Se and lower Mn, Zn and Fe contents. Organic fertilisation of oats resulted in higher Mn and Se but lower yields, Cu Zn and Fe contents.
valid?
No. Insufficient duration on soils with unspecified histories, thus may not properly represent soil conditions in organic and non-organic agriculture.

The nitrate content of vegetable and salad crops offered to the consumer as from organic or conventional production systems
Stopes C, Woodward L, Forde G & Vogtmann H (1988); Elm Farm Research Centre, UK, in conjunction with the Department of Alternative Agriculture, University of Kassel
Biological Agriculture and Horticulture 5, p 215–221

A two year 'preliminary' market survey comparing the winter nitrate contents of non-organic and organically labelled lettuce, cabbage and beetroot in both years and potato and carrots in the first year only, purchased from supermarkets, wholesalers and growers. Samples were poorly matched in terms of their cooked/uncooked state (beetroot), variety and source of supply, no certification details for the organic samples were given, and no tests of statistical significance were applied. The authors concluded "Peak nitrate concentrations may be lower in organically produced vegetables, although there is considerable variation".
valid?
No, due to the absence of organic certification details plus the poor matching and insufficient sizes of samples.

Chemical evaluation of vegetables grown with conventional or organic soil amendments
Svec L, Thoroughgood C and Mok HCS (1976); Department of Plant Science and College of Home Economics, University of Delaware, Newark, Delaware, USA
Communications in Soil Science and Plant Analysis 7(2), p 213–228

A two year field trial comparing the effects of organic (fresh cattle manure, cottonseed meal, blood meal and rock phosphate) and non-organic (NPK) fertilisation on tomatoes, potatoes, peppers, lettuce, onions and peas grown in plots that had been uncultivated for three years. Comparing yields, minerals P, K, Ca and Mg (dry-weight basis so not relevant to this review), vitamin C (wet-weight basis) and taste, few significant or consistent differences were found and the authors concluded "it would not be realistic to expect nutritive, taste or yield advantages from the organic method of vegetable production compared to the use of conventional fertilisers".
valid?
No, due to insufficient duration on soil with no organic history.

Minerals and protein content, test weight and yield variations of hard red spring wheat grain as influenced by fertilisation and cultivar
Syltie PW & Dahnke WC (1983); Department of Soils, North Dakota State University, Fargo, North Dakota, USA
Qualitas Plantarum – Plant Foods for Human Nutrition 32, p 37–49

A two year field trial comparing the effects of various ratios of NPK and micro-nutrient fertilisation on wheat. Comparing yields, protein content, and minerals P, K, Ca, Mg, Zn, Mn and Fe, the data showed that nitrogen application was the most significant influence on yield and grain composition.
valid?
No, due to the absence of organic fertilisation comparisons.

Influence des techniques de fertilisation organique et min'rale sur la valeur nutritionelle de l'gumes
Termine E, Lairon D, Taupier-Letage B, Gauthier S & Hauton JC (1984); Group de Researche en Agriculture Biologique (GRAB), South-east France
Sciences des Aliments 4, p 273–277

A republished version of Lairon *et al* 1986, reporting results from the same farm pairs: there is a tendency to find lower K and Mn, and higher Mg, Ca and Cu contents in organically grown vegetables. Nitrate contents in organically grown crops were lower in summer but higher in winter than non-organically grown crops. The authors conclude "well managed organic fertilisations could be useful to improve the nutritional value of vegetable crops".
valid?
No, as does not add anything to the findings previously reported in Lairon *et al* 1986.

Yield and content in nitrate, minerals and ascorbic acid of leeks and turnips grown under mineral or organic nitrogen fertilisations
Termine E, Lairon D, Taupier-Letage B, Gauthier S, Lafont R & Lafont H, (1987); l'Instutit National de la Sante et de la Recherche Medicale, GRAB, and Laboratoire de Geologie du Quaternaire Centre National de la Recherche Scientifique, France
Plant Foods for Human Nutrition 37, p 321–332

A one season pot trial comparing the effects of organic (composted sheep manure and wood chip/farm yard manure compost) and non-organic (NPK) fertilisation on leeks and turnips. Trials were conducted in homogenised soil in buried containers. Comparing yields plus dry matter, nitrate, minerals P, K Ca, Mg, Fe, Cu and Mn, and vitamin C contents, the data showed higher yields in manure fertilised turnips, higher nitrate contents in NPK and blood-meal fertilised crops, and few significant or consistent differences in mineral or vitamin C contents.
valid?
No, due to insufficient duration in soil with no organic history.

Enhanced food quality: Effects of composts on the quality of plant foods
Vogtmann H, Matthies K, Kehres B & Meier-Ploeger A (1993); University of Kassel, University of Fulda, Bund Deutcher Entsorger, Germany
Compost Science and Utilisation 1, p 82–100

A three year field trial on a farm where the organic experimental plots had been organically cultivated for the previous ten years comparing the effects

of organic (composted farmyard manure, household waste compost) and non-organic (NPK) fertilisation on cabbage (first year), carrots (second year) and potatoes (third year). The data showed that non-organic fertilisers reduced the dry matter concentrations of crops (significantly in cabbage), while composts significantly reduced nitrate contents and improved the vitamin C to nitrate ratio of vegetables (though vitamin C contents did not differ significantly). Vegetable yields for compost treatments were lower during the first two years but did not differ significantly after the third year.
valid?
Yes, comparison of the vitamin C, nitrate and dry matter contents of organically and non-organically fertilised vegetables.

Accumulation of nitrate in leafy vegetables grown under contrasting agricultural systems
Vogtmann H, Eichenberger M, Ott P, Temperli A & Künsch U (1984); University of Kassel, Research Institute of Biological Husbandry, Swiss Federal Research Station for Aboriculture, Switzerland
Biological Agriculture and Horticulture 2, p 51–68

A farm survey comparing the nitrate contents of lettuce from seven paired organic and non-organic commercial vegetable producers. Organically grown lettuce contained significantly less nitrate than the non-organically grown lettuce in the optimal growing season (May–October).
valid?
Yes, a comparison of the nitrate content of organically and non-organically grown lettuce. In the absence of certification details for the organic farms, we contacted the author who confirmed that the farms were in fact certified. The pot and field trials with spinach, Swiss chard and lettuce are not included here as they were only conducted over one season.

Results of the long-term vegetable crop production trials: conventional vs. compost amended soils
Warman P (1998); Nova Scotia Agricultural College, Canada
Acta Horticulturi 469, p 333–341

A seven year field trial comparing the effects of organic (composted manure, straw, grass clippings and food waste) and non-organic (NPK) fertilisation in a vegetable crop rotation of. This long-term trial was conducted because of "concern that the long-term effects of fertilisation would not be evaluated [in Warman and Havard 1996 – see below] since the plots were abandoned after each production year". Crop yields from the paired plots were comparable from the fourth year on, while soil analyses in the seventh year showed the compost-amended soil to have equal or lower P and K but higher levels of Ca Mg Mn Cu Zn and organic matter (C). No analyses of nutrient contents are documented. The author concluded, however, that "In some years, compost provides a higher level of available nutrients than the literature would predict, possibly because the soil environment is more conducive to mineralisation from long-term organic applications".
valid?
No, this study is agriculturally valid but no nutritional comparisons relevant to this review are made.

Yield, vitamin and mineral content of four vegetables grown with either composted manure or conventional fertiliser
Warman P & Havard K (1996); Nova Scotia Agricultural College, Canada
Journal of Vegetable Crop Production 2(1), p 13–25

Three one-year field trials comparing the effects of organic (composted chicken or beef manure) and non-organic fertilisation on sweetcorn, potatoes, carrots and cabbage. Non-organic fertilisation and pest control followed Nova Scotia soil test recommendations, and the organic plots were managed according to the guidelines established by the Organic Crop Improvement Association. Comparing yields, minerals P, K, Ca, Mg, S, B, Mn Cu and Zn, and vitamins A (as beta-carotene), C and E, the authors concluded that there were relatively few differences between the vegetables grown using the two different production systems.
valid?
No, as "a different site was used each year, thus the crops were not affected by previous fertilisation", which is clearly not representative of organic or non-organic agricultural practices.

Yield, vitamin and mineral content of organically and conventionally grown carrots and cabbage
Warman P & Havard K (1996); Nova Scotia Agricultural College, Canada
Agriculture, Ecosystems and Environment 61, p 155–162

Three one-year field trials comparing the effects of organic (composted chicken or beef manure) and non-organic fertilisation on carrots and cabbage. Non-organic fertilisation and pest control followed Nova Scotia Soil Test recommendations, and the organic plots were managed according to the guidelines established by the Organic Crop Improvement Association. Comparing yields, minerals P, K, Ca, Mg, S, B, Fe, Mn, Cu and Zn, and vitamins C and E, the authors concluded that there were relatively few differences between the vegetables grown using the two different production systems.
valid?
No, is a republished portion of Warman and Havard (1996 a), and is excluded for the same reason.

Yield, vitamin and mineral content of organically and conventionally grown potatoes and sweetcorn
Warman P & Havard K (1998); Nova Scotia Agricultural College, Canada
Agriculture, Ecosystems and Environment 68(3), p 207–216

Three one-year field trials comparing the effects of organic (composted chicken or beef manure) and non-organic fertilisation on potatoes and sweetcorn. Non-organic fertilisation and pest control followed Nova Scotia soil test recommendations, and the organic plots were managed according to the guidelines established by the Organic Crop Improvement Association. Comparing yields, minerals P, K, Ca, Mg, S, B, Mn, Cu and Zn, and vitamins C and E, the authors concluded that there were relatively few differences between the vegetables grown using the two different production systems.
valid?
No, is a republished portion of Warman and Havard 1996 a, and is excluded for the same reason.

Are organically grown apples tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality
Weibel FP, Bickel R, Leuthold S and Alfoldi T (2000); Research Institute of Organic Farming (FiBL), Northwest and Northeast Switzerland
Acta Horticulturae 517, p 417–426

A farm survey comparing the dry matter content, minerals P, K, Ca, Mg and Se, vitamins C and E, phenolic compound contents, taste, animal feeding preference, storage degradation and (picture forming) vital quality of apples from five pairs of certified organic (Bio-inspecta) and integrated / non-organic orchards matched for location (pairs were within 1km of each other), variety (Golden Delicious), micro-climate, soil conditions and planting system. The data showed the organically grown apples to have significantly higher P content (31.9 per cent), higher technical quality (14.7 per cent), more phenolic compounds (18.6 per cent), a better taste (15.4 per cent) and higher vital quality (65.7 per cent). No significant differences were found in the mineral K, Ca, Mg and Se or vitamin C and E contents, animal feeding preferences or storage degradation tests. The picture forming method distinguished 100 per cent correctly the organic and integrated samples and was closely in line with technical quality.
valid?
Yes, a comparison of apples from organic and integrated / non-organic orchards that demonstrates the correlation between holistic methods of quality determination (picture forming methods) and standard chemical analyses. While no certification details were given for the organic farms, the author was contacted to confirm their certification.

Concerning the quality of spinach from biological cultivation
Wilberg E (1972); Department of Plant Nutrition, University of Hohenheim, Stuttgart, Germany
Landwirtschaftliche Forschung 25, p 167–169

A market survey conducted in 1969 comparing the nutritional contents of 12 samples each of non-organic and organically labelled spinach purchased in healthfood shops and greengrocers supplied by growers around Stuttgart. Comparing vitamins A (carotene) B1 and C, minerals P, K and Ca, nitrate

and dry matter contents, few significant differences were found.
valid?
No, due to a lack of certification details for the organically labelled samples and an inability to establish any degree of confidence in the accuracy of organic labelling in healthfood shops in Stuttgart in 1969.

Amino acid composition of grain protein of maize grown with and without pesticides and standard commercial fertilisers
Wolfson JL & Shearer G (1981); Centre for the Biology of Natural Systems, Washington University, Illinois, Iowa, Minnesota, Missouri and Nebraska, USA
Agronomy Journal 73, p 611–613

A four year farm survey comparing the yields and protein contents of maize from fourteen pairs of organic and non-organic fields on operating commercial farms matched for location (median distance 300m), variety, planting date and soil type. Maize yields were 11 per cent lower from organically managed fields, and organically grown maize had an 11 per cent lower protein concentration than the non-organically grown maize. Lysine and methionine, the limiting amino acids in maize, were significantly higher in organically grown maize.
valid?
Yes, a comparison of maize from organic and non-organic farms. While no certification details were given for the organic farms, details of practices employed and history (minimum 4 years organic) are sufficient to confirm their status.

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Further reading

To purchase a copy of *The Organic Directory* at the offer price of £5.99 (normally £7.95) or a book list please phone the Soil Association mail order book service on 0117 914 2446.

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The Soil Association

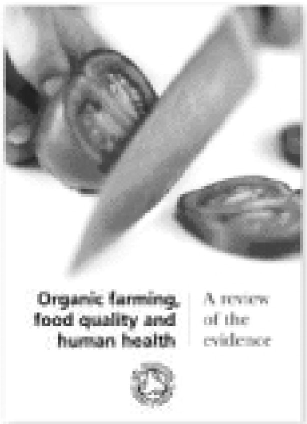
The Soil Association is a membership charity which was founded in 1946 by a group of farmers, scientists and nutritionists, who were concerned about the way food was produced. It is at the centre of the campaign for safe, healthy food, an unpolluted countryside and a sustainable farming policy in Britain and world wide.

The organisation has now grown in scope and complexity but the core is essentially simple; there are direct links between the health of the soil, plants, animals and humans, and organic agriculture is a sustainable system of food production which is based on these interconnections: healthy soil, healthy food, healthy people.

To achieve this end, the Soil Association is working in many different areas:

- Policy. Working to achieve change in food and farming systems through lobbying and policy work.
- Campaigns. Joining forces with members, supporters and other like minded groups to campaign for the elimination of GMOs from the food chain; promoting the responsible use of antibiotics in farming; working in partnership with conservation agencies to protect wildlife and biodiversity.
- Setting organic standards to ensure the integrity of organic food and other products. Soil Association Certification Ltd, a subsidiary company, runs the certification scheme used by 80 per cent of UK licensed operators and awards the Soil Association symbol.
- Providing professional, technical support to farmers and growers with the aim of increasing the amount of land farmed organically and providing more jobs in the countryside.
- Promoting organic food so that people everywhere will have the opportunity to buy and eat organic food, be it from a local market, a box scheme, a corner shop or a supermarket.

The Soil Association provides modern, practical solutions to the challenges facing society today.



Organic farming, food quality and human health
A review of the evidence

"This is an important document that has brought together a wide range of scientific literature in one place to show that there are proven benefits to both food safety and human health from the production and consumption of organically produced food."
Elm Farm Research Centre

"We welcome this comprehensive review of the quality of organic food, which for the first time brings a significant body of information to a wider audience, demonstrating proven benefits, but recognising the need for further research."
HDRA

"The Soil Association's review summarises strictly scientifically and in a comprehensive way the state of research into organic food."
The Research Institute of Organic Agriculture (FiBL), Switzerland

"A thorough and well- prepared review of the area. I can't see how it would have been possible to provide more definitive evidence than what has been assembled."
Kirsten Brandt PhD, Danish Institute of Agricultural Sciences

"We congratulate the Soil Association on their fair and thorough review of the evidence. We have long believed the micronutrient deficiencies common in our patients have their roots in the mineral-depletion of soils by intensive agriculture, and suspect that pesticide exposures are contributing to the alarming rise in allergies and other illnesses. We join with the Soil Association in pressing the government to substantially increase the inducements for farmers to farm organically: in our view this would be of immense benefit to the health of this country."
The British Society for Allergy, Environmental and Nutritional Medicine

"The scientific evidence presented in this report supports our experience that organic food provides the nutrient concentrations and freedom from unnatural toxins necessary for remission from cancer and continued good health."
The Nutrition Cancer Therapy Trust

"People are applying the precautionary principle to their own lives by purchasing food that has not been produced by industrial methods. From the simple stance of hazard avoidance, organically produced food is the best option that we have."
Dr Vyvyan Howard (Toxico-Pathologist), University of Liverpool

"This report offers plausible arguments for going organic."
Health Which?

"In the practice of nutritional medicine, organic produce is a component of therapy for the chronically sick. Our primary reason for using organic foods was to avoid the toxicity that would be inevitably detrimental to healing. This review, however, greatly strengthens our position in regarding organic produce as nutritionally superior. No one denies that more research is needed to amplify the conclusions of the review, but the authors are to be congratulated upon both a comprehensive and thorough going overview of the subject and upon their critical appraisal of it."
Dr Lawrence Plaskett, Principal, The Plaskett Nutritional Medicine College

"Eating organic is neither a fad, nor a luxury. This comprehensive scientific assessment shows that it is a necessity."
Patrick Holford, founder of the Institute for Optimum Nutrition

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