Effects of organic and 'low input' production methods on food quality and safety

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Abstract

The intensification of agricultural production in the last century has resulted in a significant loss of biodiversity, environmental problems and associated societal costs. The use of shorter rotations or monocropping and high levels of mineral fertilisers, pesticides and crop growth regulators may also have had negative impacts on food quality and safety. To reverse the negative environmental and biodiversity impacts of agricultural intensification, a range of different 'low input' farming systems have been developed and are now supported by EU and government support schemes. A range of recent reviews concluded that switching to low input, integrated or organic farming practices results in significant environmental benefits and increased biodiversity in agro-ecosystems. Some recent studies also reported higher levels of nutritionally desirable compounds (e.g. vitamins, antioxidants, mineral nutrients) in foods from organic and 'low input' production systems compared to food from conventional systems. The increasing demand and current price premiums achieved by foods from low input and especially organic production systems were shown to be closely linked to consumer perceptions about nutritional and health benefits of such foods. However, there are other studies reporting no significant differences in composition between low input and conventional foods, or inconsistent results.

There is currently a lack of ***(a)*** *factorial studies, which allow the effect of individual production system components (e.g. rotation design, fertility management, crop health management, variety choice) on food composition to be assessed and* ***(b)*** *dietary intervention or cohort studies which compare the effect of consuming foods from different production systems on animal and/or human health. It is therefore currently not possible to draw overall conclusions about the effect of low input production on food quality and safety. This paper will* ***(a)*** *describe the range of organic and other 'low input' standards, certification and support systems currently used,* ***(b)*** *summarise the currently available information on effects of organic and other low input crop production systems on the environment, biodiversity and food quality, and* ***(c)*** *describe the methodologies and results from subproject 2 of the EU-funded Integrated project QualityLowInputFood. This project focused on improving our knowledge about the effect of organic and low input crop and livestock production systems on food quality and safety parameters.*

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Introduction

One important reason for the increasing demand for foods from organic and low input production systems is the environmental, biodiversity and animal welfare benefits associated with these systems. Crop and livestock production in much of Western and Central Europe underwent major changes during the second half of the 20th century as a result of the intensification of agriculture (Stoate et al., 2001; Pyšek et al., 2005). In crop production, there was an increase in the use of water soluble, mineral N, P and K fertilisers and chemosynthetic crop protection products (herbicides, pesticides and fungicides and growth regulators). This coincided with the development of new crop varieties with higher yield potential especially under high input conditions (e.g. winter wheat varieties, which produced shorter stems and higher yields, due to the introduction of dwarfing genes) (Borojevic 2005; Verma et al. 2005). In addition, the diversity of cropping systems was reduced, with fields merged into larger units, field margin vegetation reduced, and shorter and less diverse rotations or even mono-cropping systems introduced. Also, spring sown arable crops were increasingly replaced by winter crops (Stoate et al., 2001; Pyšek et al., 2005). These changes resulted in significant increases in crop yields and certain quality characteristics (e.g. protein content and baking quality in wheat) (Borojevic 2005; Verma et al. 2005).

However, more recently a range of negative environmental impacts and associated societal costs of "high input" production systems have been identified. These include **(a)** increased surface and ground water pollution from leaching and/or run-off of mineral N and P fertilisers and chemosynthetic crop protection products (Porter et al. 1993; Drinkwater et al. 1998; Stolze et al. 2000; PAN 2002), **(b)** reduced biodiversity of bird, invertebrate and non-crop plant populations in agricultural eco-systems (Eggers 1984; Stoate 2001; Bengtsson 2005; Critchley et al. 2004&2006; Pyšek et al., 1991 & 2005; Berry et al. 2005; Fuller et al 2006) **(c)** a contribution to the depletion of the atmospheric ozone layer by the soil disinfectant methyl-bromide (Butler et al. 2002) and **(d)** increased energy use and associated CO_2 carbon emissions (Helsel 1992; Fluck 1992; Dubois et al. 1999; Cormack 2000; Pretty et al. 2002).

The impacts of agricultural intensification of the environment can also be linked to negative effects on important agronomic parameters. For example, there is increasing evidence that soil biological activity, organic matter content, structural stability/erosion resistance and inherent fertility (level of yield obtained per unit fertiliser input) has decreased in soils used for 'high input' crop production (Matson et al. 1997; Reganold et al. 1987&2001; Fließbach & Mäder 2000; Mäder et al. 2002; Hartmann 2006). Natural ecological/biological processes that increase the availability of mineral nutrients in soil (e.g. nitrogen fixation, and P and micronutrient uptake via symbiotic mycorrhizal fungi) and protect crops against pests and diseases (e.g. natural enemies of pests and antagonists of soil borne diseases) were also shown to be inhibited by specific agrochemical inputs (Mallarino & Wedin 1990; Sattelmacher et al. 1991; Ledgard & Steele 1992; Høgh-Jensen & Schjørring 1997; Whalen et al. 1998; Esjberg et al. 2002; Oehl et al. 2003; Hartmann 2006).

In livestock production, there has been an increase in "indoor" production systems, stocking densities, flock sizes and feeding of energy and protein concentrate feeds. This has been accompanied by an increase in the use of veterinary medicines and growth promoters (e.g. antibiotics, anthelmintics), and pesticides (e.g. organophosphorus sheep dips) throughout the developed world, and animal growth hormones in North America (Vaarst et al. 2004; Diaz-Gonzalez 2007; Hirt & Zeltner 2007; Sundrum 2007; Biavati & Santini 2007; Klocke & Walkenhorst 2007; Weller et al

2007). The increase in external input use paralleled changes in the type of livestock breeds (e.g. a rapid expansion in the use of Holstein Friesian genotypes at the expense of local/traditional breeds) and breeding strategies (e.g. the introduction of hybrid breeding programmes in pork and chicken production)(Vaarst et al. 2004; Hirt & Zeltner 2007)

These changes resulted in significant increases in the productivity of animals (e.g. liters of milk per cow; numbers of eggs per laying hen), and in livestock output per unit land area. The intensification of livestock production was also associated with reduced lifespan for many types of livestock, due to animals reaching slaughter weights, becoming non-productive or showing reductions in fertility earlier (Younie & Wilkinson 2001; Vaarst et al 2004).

In addition, the intensification of livestock production systems resulted in significant environmental burdens, such as erosion, overgrazing, nutrient pollution and increased animal health and welfare problems (Vaarst et al. 2004; Cooper et al 2007)

A range of ‘low input’ production strategies/standards/schemes have been developed to reverse or minimise the negative environmental, biodiversity and animal welfare impacts of intensification. These can be divided broadly into 3 groups **(a)** organic farming standards (EU 1991 & 1997), **(b)** integrated/low input and/or animal welfare based standards/certification schemes (e.g. Farm assured, LEAF 2006, GAP, Nature’s choice, free-range) (EFSIS 2006, LEAF 2006, Eurepgap 2006, TESCO 2006) and **(c)** government agri-environment schemes/standards (e.g. UK countryside stewardship scheme, Swiss Verordnung über die Direktzahlungen an die Landwirtschaft) (DEFRA 2006a&b; Swiss Federal Office for Agriculture 2006). It should be noted that there is some overlap between organic and other ‘low input’ certification schemes under **(a)** and **(b)** and government agri-environment schemes. Most importantly organic and integrated quality assurance schemes often qualify for support payments under government agri-environment schemes. However, the level of restrictions on the use of ‘inputs’ (e.g. mineral N and P fertilisers, chemosynthetic pesticides, plant growth regulators) and level of definition/prescription of production practices (e.g. tillage, cropping systems/rotations, field margin/non-crop vegetation management) that need to be introduced to counteract/reverse negative impacts of intensification differ between certification schemes and standards.

Another main reason for the increasing demand for “low input” foods and the price premiums achieved by organic foods, is the consumer perception that they are “healthier”, “more nutritious”, “tastier” and “safer” than foods from intensive conventional production systems (Anonymous 1998, Oughton & Ritson 2007). However, until now scientific investigations have not been of sufficient scale and design to provide a definitive understanding of the extent to which agricultural production systems affect these qualities (Woese et al. 1997; Brandt & Mølgaard 2001; Anonymous 2002; Cooper et al. 2007). Also, there are currently no organic or ‘low input’ production standards and/or government support schemes that focus specifically on reversing potential negative impacts of agricultural intensification on the nutritional and sensory quality and safety of foods.

The **main aim** of subproject 2 of the Integrated Project QualityLowInputFood (QLIF, www.qlif.org/) is therefore:

- to quantify the effect of organic and “low input” prodction methods on food quality and safety and human/animal health impacts associated with the consumption of foods/feeds from low input systems

Subproject 2 was subdivided into 3 main workpackages (WPs) which in turn focused on the following **specific objectives**:

WP2.1 Effect of crop management practices (organic, “low input” and conventional) on the nutritional quality of foods

WP2.2 Effect of livestock management practices (organic, “low input” and conventional) on the nutritional quality and safety of foods

WP2.3 Effect of organic food consumption on livestock and human health

The background and current “state of the art” with respect to these objectives is described in separate sections below.

WP2.1 Effect of crop management practices (organic, “low input” and conventional) on the nutritional quality of foods

In European and North American diets, foods derived from crop plants contribute substantially to satisfying the recommended dietary intake of some essential minerals (Ca, Mg, Fe, Se, Cu, Zn, etc.) and vitamins (vitamin C, beta-carotene, folate etc.). It was also shown that supplementation of foods with the same compounds in the form of pills does not provide the same benefits to health as increasing the intake of the plant foods (Pool-Zobel et al. 1997). There is also a growing consensus that increased consumption of whole grain cereals and fresh vegetables and fruit will improve human health in many developed countries (e.g. Ness & Powles 1997; Veer et al., 2000; Michels & Wolk 2002; Liu et al., 2003; Hannum 2004; Seal 2006).

However, there is still controversy about which compounds in plants are responsible for the beneficial health impacts associated with increased fruit and vegetable consumption. Crops contain secondary metabolites (e.g. phenolics, glucosinolates, other organic sulphur compounds, sesquiterpene lactones, fructans) which have beneficial physiological/pharmacological properties such as anti-neoplasia, antioxidant and anti-allergic effects, platelet aggregation inhibition, interference with cancer promotion mechanisms and pro-biotic activity (Wattenberg et al., 1980; Frankel et al., 1993; Rice-Evans et al., 1996; Bernart et al., 1996; Waterhouse et al., 1998; Kim et al., 1999; Hecht 1999; Ernst & Feldheim 2000). These compounds are therefore thought to be involved in the well documented beneficial effects of vegetable consumption on health (Pool-Zobel et al., 1997; Ness & Powles 1997; Van Poppel et al., 1999; Veer et al., 2000; Greenvald et al., 2001; Briggs et al., 2001). However, there is little knowledge about the relative nutritional value of individual compounds in plant foods, when they are eaten as part of a typical European or North American diet. Many of these compounds are also important for the sensory quality of fruit and vegetables, in particular the secondary metabolites, which define characteristic flavours, aromas and colours of each product. However, there are only a very small number of sound scientific studies comparing sensory quality between organic and conventional crops (Mäder et al., 1993; Reganold et al., 2001; Brandt & Mølgaard 2001; Wszelaki 2005)

On the other hand, crop plants may contribute significantly to the intake of a range of undesired compounds, which are considered hazardous if consumed in too high quantities. This includes nitrate (> 60% of nitrate is taken up with cereals and vegetables) (McKnight et al. 1999; Leifert 2000), heavy metals (e.g. lead and cadmium) (Karavoltsos et al., 2002; Shimbo et al., 2001), pesticide residues (Baker et al., 2002; Benbrook 2002) and mycotoxins (Schollenberger et al., 1999; Obst et al., 1998). Some secondary plant metabolites are also known to have negative impacts on health when they occur in too high concentrations, e.g. glycoalkaloids, glucosinolates and polyacetylenes (Rosa et al., 1998).

Many compounds mentioned above show substantial variations in content in comparable foods, and several hypotheses have been published on how the production system, in particular organic farming as compared with conventional farming, could affect nutritional value and/or other qualities (e.g. Avery 1998; Trewavas 2001 & 2004; Brandt & Mølgaard 2001).

Several studies and reviews have indicated systematic differences in concentrations of minerals, essential amino acids, vitamins, secondary metabolites and mycotoxins in crops produced in different production systems (conventional, 'low input' and/or organic) or specific components (e.g. fertility practices) of such systems (Leclerc et al., 1991; Pither 1990; Woese et al., 1997; Mayer 1997; Schollenberger et al., 1999; Ren et al. 2001a; Birzele et al., 2002; Asami 2003; Lombardi-Boccia 2004). Sensory and technical quality has also been shown to vary with production system (Mäder et al., 1993; Weibel et al., 2000; Reganold et al., 2001; Pedersen et al., 2001). However, other studies report no significant differences or inconsistent results (Basker 1992; Jorhem & Slanina 2000; Fjelkner-Modig et al., 2001; Malmauret et al., 2002; Bourn & Prescott 2002; Carbonaro *et al.*, 2002). Also, many of these studies did not use organic and conventional samples matched for potentially confounding factors such as variety, area of origin, soil and climatic conditions during production and/or length of storage, which are also known to affect the chemical composition of crops (Locasio et al., 1984; Vogtmann et al., 1993; de Meeus et al., 2002; Asami 2003). Furthermore, many studies did not take into consideration the considerable variation in agronomic practices within each cultivation system (Brandt & Mølgaard 2001).

On the other hand, concerns were raised by scientists about increased health risks associated with enteric pathogen transfer and contamination with noxious compounds (e.g mycotoxins or heavy metals) in organic and 'low input' production systems associated with the use of animal manures and omission of pesticides (e.g. Trewevas 2001, Finamore et al., 2004). There is currently insufficient data to substantiate or dismiss these concerns, and there is therefore a need for controlled experiments to identify and quantify mycotoxin and enteric pathogen contamination risks in different crop production systems.

It is known that deleterious effects of toxicants can be either enhanced or reduced by other compounds, but most possible interactions are unknown, and with today's knowledge it is impossible to predict the resulting effect on health when the levels of many different compounds change simultaneously (Furst 2002).

From the currently available information, it is therefore not possible to conclude to what extent overall production system and specific production system components affect the content of nutritionally relevant compounds in crops. However, even relatively small systematic differences in food composition can have significant effects on health. For example a 20% increase in the most important health promoting compounds in vegetables was calculated to correspond to an increase in vegetable consumption from 250g/day to 300 g/day, which would lead to 6 months longer life expectancy (Gundgaard et al. 2002, using data from Veer et al. 2000). It is therefore essential to establish long-term factorial experiments which minimise confounding factors and allow the effect of principal production system components (rotation design, soil management, fertilisation and crop protection methods) to be identified.

In the QLIF-IP such experiments were established as part of WP2.1 and focused on identifying the effect of, and interactions between, four principal production system components (rotation design, fertilisation regimes, crop protection practices and variety/rootstock choice) on **(a)** crop yield, **(b)** pest, disease and weed pressure (and associated need for crop protection inputs) and **(c)** crop quality parameters (including contents of mycotoxins, pesticide residues, minerals, vitamins, antioxidants and other secondary plant metabolites). Experiments used factorial designs thus allowed interactions between factors to be identified (see e.g. Leifert et al. 2007). However, they also allowed comparisons to be made about the effect of growing crops according to organic, low input and conventional standards, on crop yield, health, quality and safety parameters.

Work under WP2.1 focused on arable (wheat, potato), field vegetable (cabbage, lettuce, onion) and greenhouse crops (tomato). In associated studies that were not part of the QLIF project barley, wheat and carrots were studied. Work on specific commodities under WP2.1 was closely integrated with workpackages under SP3 aimed at improving organic and low input production systems for wheat (WP3.5.2), lettuce (WP3.4) and tomato (WP3.3.2, WP3.5.3)(see also summary paper and WP-specific papers for SP3).

Complete data sets from 2 field seasons are now available for some commodities (e.g. wheat, potato and tomato) and some results have been reported (see Lehesranta et al 2007; Cooper et al 2006 and these proceedings; Lueck et al 2006 and these proceedings; Giotis et al 2006; Theodoropoulou these proceedings).

One of the main overarching results was that mineral, mycotoxin, protein and secondary metabolite levels and composition can be significantly affected by one or more of the four main production system components (rotation design, fertilisation regime, crop protection practice and variety/rootstock choice) included in studies. For example, protein profiles in potato were only significantly affected by fertility management, while crop protection practices and rotational position (whether potato were grown after wheat or grass clover) had no significant effect (Lehesranta et al. 2007). On the other hand, protein content in wheat was significantly increased by conventional fertility management, but reduced by conventional crop protection practices (C. Leifert unpublished). For a range of compounds plant analyses showed significant interactions between crop protection (use or non use of chemosynthetic pesticides) and fertilisation practices (fertilisation based on organic matter or chemosynthetic mineral NPK fertilisers).

In several cases, such interactions resulted in low input systems (which omitted either mineral fertiliser or pesticide use compared to conventional systems which used both) showing the highest level of undesirable compounds (e.g. mycotoxin loads and pesticide residues in wheat; Lueck et al these proceedings). This indicates that with respect to certain quality parameters, foods produced in “integrated” or “low input” crop protection systems are inferior to both organic and conventional systems.

For one processing quality parameter (protein content in wheat, which is closely correlated to bread making quality) studies under WP2.1 consistently showed lower levels in the organic compared to the conventional production systems. However, studies under WP3.5.2 showed that the use of long-straw wheat varieties and improved management of grass-clover leys preceding wheat crops can increase both yields and protein levels of bread making wheat (see Wilkinson et al. 2006 and these proceedings).

Also, in some crops (e.g. cereals), the use of mineral fertiliser based fertilisation regimes increased the susceptibility of plants to diseases (e.g. powdery mildew, lodging and *Fusarium* spp.), while the same disease remained at very low levels when organic fertility management practices were used (see Cooper et al 2006 and these proceedings for further information). This supports the hypothesis that the use of highly water soluble, and therefore readily plant available, mineral fertilisers (especially N-fertilisers) will increase the need for the use of pesticides and other crop protection products. Crop protection products such as chlorocholine chloride (CCC) have also been shown to result in significant residues in crops (see Lueck et al. these proceedings) and have been shown to potentially have negative effects on animal health (Sorensen et al 2006; Benbrook 2002 & 2007). This provides further evidence for the hypothesis that increased mineral fertiliser use results in an increased need to use chemosynthetic pesticides and thereby indirectly affects human health.

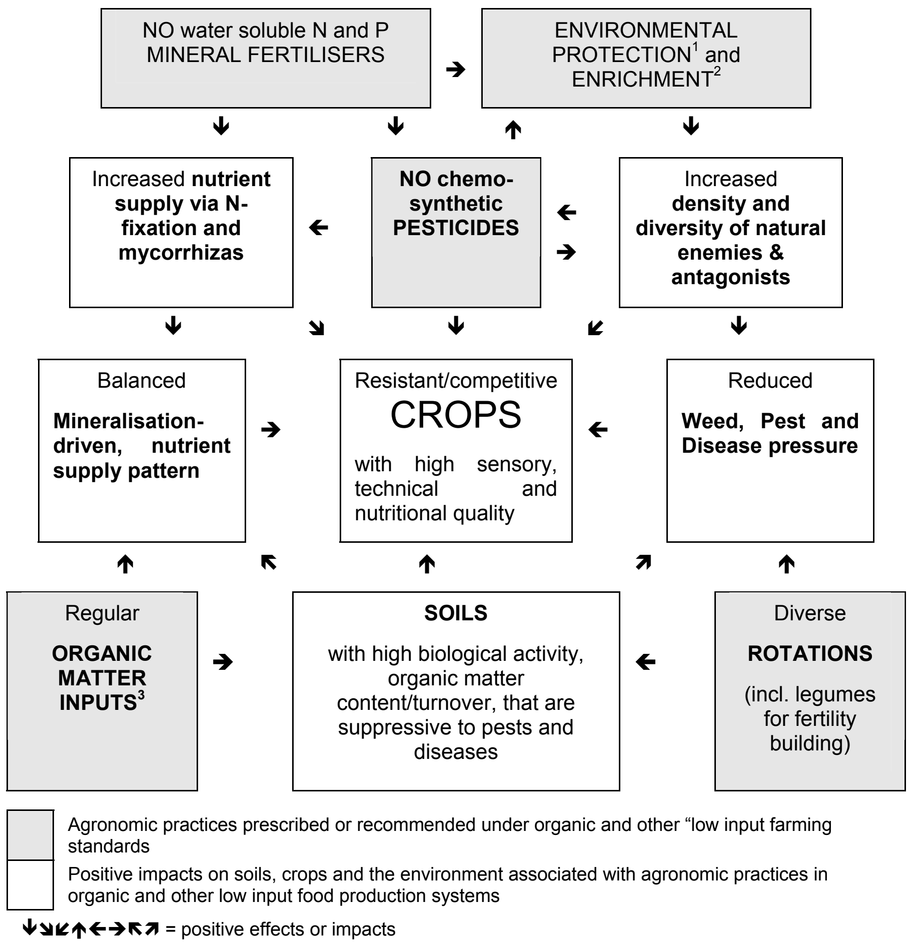
Although complete data sets are not yet available for many of the crops included in trials under WP2.1, the data collected so far support the underlying ecological hypotheses and the logical framework (see Figure 1) that forms the basis for organic crop production principles and standards (see e.g. Niggli 2007).

WP2.1 is closely integrated with other WPs under SP2. For example, it provided samples/materials) for the investigations into the effect of consumption of foods from organic and conventional farming systems on pig-reproductive health (WP2.3.1), and immune status in experimental rats (WP2.3.2). First results from these studies are also included in these proceedings (Baranska et al., Rembialkowska et al. and Soerensen & Højsgaard in these proceedings).

WP 2.2 Effect of livestock management practices (organic, "low input" and conventional) on the nutritional quality and safety of foods

Results from recent surveys in some European countries suggest that livestock products (e.g. milk meat, eggs) from organic and "low input" livestock production systems result in an **(a)** improved nutritional composition (e.g. Hirt &Zeltner 2007; Weller et al 2007)**, (b)** lower levels of veterinary medicine (e.g. antibiotic, anthelmintic) use (e.g. Klocke et al 2007; Maurer et al 2007) and **(c)** a reduced risk for development of antibiotic-resistant faecal *E.coli* (e.g. Hoyle et al 2004) and **(d)** reduced risk of faecal E. coli O157 shedding in the faeces (Diaz-Gonzalez 2007).

On the other hand, concerns were raised by scientists about increased risks of enteric pathogen transfer associated with extensive outdoor livestock rearing systems and the use of animal manures from such systems (e.g. Trewevas 2001, Finamore et al., 2004). Although no scientifically sound scientific evidence were presented it is important to assess whether or not such concerns are justified.



1 measures to minimise pollution (e.g. N-leaching and P-run off) and soil erosion events associated with agricultural activities (e.g. non-cropped field margins, fertility catch crops)

2 measures taken to increase biodiversity on farms (introduction of non crop vegetation e.g. woodlands, hedges, non-cropped field margins, beetle-banks)

3 animal and green manures, manure and waste based composts etc.

Figure 1. Logical Framework for Organic (and other 'low input') crop production systems (redrawn with permission from Leifert et al 2007)

WP2.2.1 Effect of dairy management practices (organic, "low input" and conventional), and nutritional regime on the nutritional quality, health status and shelf life of milk

Surveys into the nutritional quality of livestock products (e.g. milk, meat) have indicated that there may be significant differences in nutritional composition, taste and shelf life between organic, "low input" and conventional systems (Fedele et al 2001; Nielsen et al 2002; Butler et al. 2006 and these proceedings). In particular, differences in livestock feeding regimes appear to affect the composition of nutritionally relevant components in milk. This includes the fatty acid composition (Dewhurst et al., 2003; Ellis et al. 2006) and the content of conjugated linoleic acid (CLA) (Chilliard et al., 2001; Bergamo et al. 2003), which has been linked to a reduced risk of obesity in humans (Riserus et al., 2001). Animal products with a high content of polyunsaturated fatty acids, CLA, antioxidants such as carotenoids and vitamin E (compounds which are often increased in milk from fresh grass forage fed animals) are preferable from a nutritional point of view, but the same compounds make the food more susceptible to oxidation, resulting in a greater risk of accumulation of undesirable off-flavours (Hemingway, 1999**,** Nielsen et al.,2002; Butler et al. 2006; Hirt & Zeltner 2007; Sundrum 2007).

However, there is limited information on the relative importance of specific production system components (breed, feeding and veterinary regimes, husbandry methods) for differences in quality observed between production systems. In particular, previous surveys within one country led to opposing conclusions about differences between organic and conventional milk quality (Lund 1991; Fedele et al 2001; Toledo et al. 2002). This result reflects regional variations in the degree of similarity of management practices between organic and conventional farmers (Butler et al these proceedings).

QLIF studies under WP2.2.1 clearly demonstrated that milk from organic and low input, grazing-based dairy production systems have significantly higher levels of the nutritionally desirable unsaturated fatty acids: vaccenic acid, conjugated linoleic acid and α-linolenic acid (the main omega-3 fatty acid found in milk) when compared to milk from conventional production systems (Figure 2, Butler et al. 2006; these proceedings and unpublished). On the other hand levels of nutritionally undesirable saturated fatty acids were significantly lower.

Levels of fat soluble antioxidants (α-tocopherol, β-carotene, lutein and zeaxanthine) were also found at significantly higher levels in milk from organic and low input production systems. Apart from being linked to potential positive health impacts in humans, these antioxidants are also known to be important for animal health (e.g. protection against mastitis) and to prevent the development of off-flavours in milk and dairy products (Bergamo et al 2003; Butler et al. 2006; these proceedings). It is interesting to note that the proportion of cows treated with antibiotics against mastitis was significantly lower in organic and low input herds compared to the conventional herds included in the study (Butler et al. 2006; these proceedings and unpublished).The level of difference between organic and conventional production systems differed between European countries and was greatest in the UK and smallest in Italy (Butler et al. unpublished).

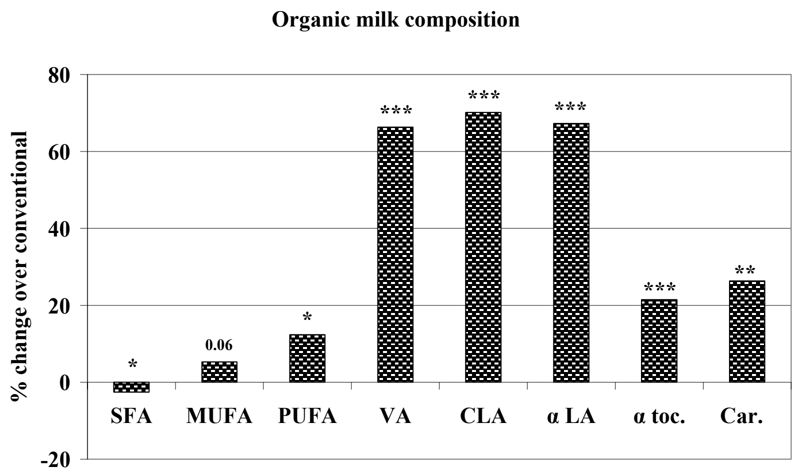


Figure 2. Composition of milk from organic farms, relative to that from conventional farms. SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; VA, vaccenic acid; CLA, conjugated linoleic acid; α LA, alpha linolenic acid; α toc, α-tocopherol; Car, carotenoids. ANOVA p values for the difference between organic and conventional mik: * p<0.05. ** p<0.01. *** p<0.001.

When associations between production system components (dietary regimes, breeds and health parameters) were investigated via multivariate analyses feed composition (the levels of grazing, conserved forage and concentrate feeds used) were found to be most closely related to milk composition, but breed also had an effect (Butler et al. 2006; these proceedings and unpublished).

For **dairy production systems** the data collected so far provide further support for the underlying ecological hypotheses and strategies to guarantee animal welfare and product quality (e.g. the focus on maximising outdoor grazing periods and basing ruminant diets on forage, rather than energy of protein concentrate feeds), that form the basis for organic livestock production principles and standards (see e.g. Niggli 2007).

WP2.2.3 Effect of pig management practices (conventional, "low input" and organic) and transport on the risk of pathogen shedding at slaughter.

The shedding of enteric pathogens by livestock at slaughter poses a significant risk for the transfer of pathogens into the food chain (Hald et al. 1999; Isaacson et al. 1999). Recent studies showed that the proportion of pigs from organic production systems testing positive for antibodies against *Salmonella* was not different from pigs reared in indoor production systems, while the proportion of antibody positive pigs tended to be higher in conventional free-range production systems (Hald et al. 1999). However, the methodologies (test for *Salmonella* antibodies) used in this and similar studies may not have accurately reflected pathogen transfer risk (Jones et al. 2001). For example, when livestock test positive for antibodies against specific enteric pathogens, this may not be associated with high levels of pathogen shedding in the faeces which is a more objective indicator of pathogen transfer risk. The presence of antibodies could on the contrary (i) indicate that the animal has acquired immunity through exposure to the pathogen at an early development stage and (ii) be associated with low levels of pathogen shedding. Certain feeding regimes and stress associated with transport of livestock have also been shown to increase pathogen shedding in pigs (Brunsgaard 1998; Isaacson et al. 1999).

In the QLIF IP these deficiencies in knowledge studies are being addressed under WP2.2.3 which focuses on identifying if and how production systems affect the risk of pathogen shedding associated with the high frequency of exposure to enteric pathogens in free-range production systems.

First results indicate that the antibody tests used to estimate pathogen transfer risk do not give a true reflection of the level of *Salmonella* shedding at slaughter. In fact pigs from organic production systems which show a higher level of positive results in the Salmonella antibody test (indicating exposure to the pathogen on farms) showed lower levels of faecal *Salmonella* contamination at the farm and at slaughter (see Bonde & Soerensen these proceedings).

WP2.3 Effect of organic food consumption on livestock and human health

Consumer demand for foods produced using organic, and to a lesser extent other ‘low input’, crop production methods has increased rapidly over the last 20 years (Anonymous 2002b; Weir & Calverly, 2002; Hamm et al., 2002). Characteristics known to be associated by consumers with crop foods from ‘low input’ production systems (and in particular certified organic systems) include ”healthier”, “tastier”, “GM-free”, and/or “protective of the environment and biodiversity” (Kuznesof & Ritson, 1996; Schifferstein & Opuis, 1998; Goodman & Du Puis, 2002; Lockie et al., 2002; Sanalidou et al., 2002; Zanoli & Naspetti, 2002; Verhoog et al., 2003). Perceived health benefits associated with organic foods are mainly based on the prohibition of the use of chemosynthetic pesticides, plant and animal growth regulators and many food additives (e.g. colourings; hydrogenated fats, processing aids and preservatives) and the prescribed minimum use of veterinary medicines (Hamm et al., 2002; Zanoli & Naspetti, 2002; Verhoog et al. 2003). While some physiological effects of foods produced in different production systems can be assessed in *in vitro* experiments or other single factor studies (e.g. Ren et al. 2001b; Grinder-Pedersen et al., 2003; Caris-Veyrat et al., 2004; Finamore et al., 2004), the fundamental question remains whether or not the combined effects of the various differences between farming systems can result in significant overall changes in the nutritional composition of food that are relevant for human health. It is therefore thought to be important to investigate the impact of organic, low input and/or conventional food consumption on farms and in experimental animal models that can indicate the potential for human health impacts.

Under WP3.2 two separate studies were carried out to provide additional information on the potential effects of consumption of organic and low input foods on animal and human health:

WP2.3.1. Effect of chlorocholine chloride (CCC) residues in feed wheat on pig reproductive health/ performance

WP2.3.2 Effect of feeding cereals and vegetables produced in organic, low input and conventional production systems on the immunological status of rats

WP2.3.1. Effect of ChloroCholine Chloride (CCC) treatments of feed wheat on pig reproductive health/ performance

Consumer concerns about residues of chemosynthetic pesticides and plant growth regulators, (PGRs) continue to be a main driver for the increase in demand for foods from organic and other low input systems. However, while it has been shown that crops from organic and low input systems contain no or reduced levels of pesticide/PGRs (e.g. Baker et al., 2002, Lueck et al. these proceedings), there is substantial controversy about potential health impacts of residues from the currently permitted crop protection inputs. While certain groups of pesticides that were used widely in the past (e.g. organochlorines, methyl-bromide) have been associated with negative environmental and/or health impacts (Laseter & Rea 1983; Sterling & Arundel 1986; Stephens et al., 1995; Høyer et al., 1998; Thielemans et al., 1999; Garry et al., 1996; Mensink & Katan 1990; Fuglsang et al., 1993; Faustini 1996; Charlier et al., 2003), pesticide regulators and many scientists argue that these problems have been addressed by subsequent prohibition or restrictions on the use of the particular pesticides. However, there is still concern about some substances which are still permitted for use (e.g. organophosphorus carbamate compounds), additive effects of pesticide mixtures and/or mixtures of pesticides and other agrochemicals, and/or recently introduced compounds and their combinations that may have as yet unidentified negative effects on health (Porter et al., 1993; Boyd et al., 1990; Ohlo 1999; Porter et al., 1999; Eskenazi et al. 2000; Thiruchelvam et al., 2000; Schreinemachers 2000; Alavanja et al., 2003; Curl et al., 2003). In particular the potential role of pesticides and plant growth regulators in the increasing incidence of allergies, behavioural disorders and reproductive problems is still considered an open question by some scientists (Alm et al., 1999; Porter et al., 1999; Tanaka et al., 2001; Holsapple 2002; Luebke 2002; Wade et al., 2002).

In the QLIF IP this issue was addressed in an animal study under **WP2.3.1**. Different to other animal models where negative effects of CCC on reproductive health were clearly demonstrated (Sorensen et al. 2006), the studies carried out under WP2.3.1 could so far not dtects a significant effect of CCC residues in wheat on pig fertility. This is described in detail in the paper by Sorensen & Højsgaard in these proceedings.

WP2.3.2 Effect of feeding cereals and vegetables produced in organic, low input and conventional production systems on the immunological status of rats

There have been a small number of studies, which tested the effect of organic and conventional foods on health bio-markers in animal tissues, and dietary intake and bio-availability of specific compounds (e.g. flavonoids, antioxidants) in humans. For example, a study using rat intestinal and splenic lymphocyte proliferation capacity as a bio-marker for toxic compounds in feeds, showed that rats fed conventional wheat had significantly lower lymphocyte proliferation activity than rats fed organically grown wheat, even though the organic wheat sample used had higher levels of mycotoxins (Finamore et al., 2004). A Danish cross-over intervention study showed that human subjects given specific diets composed of organic foods had a 40% higher intake of flavonoids, but findings were inconclusive with respect to bio-availability and physiological health impacts (Grinder-Pedersen et al., 2003). In a French study tomato paste made from organic tomatoes was found to have higher concentrations of vitamin C and lycopene than paste made from conventional tomatoes, but there were no differences in the plasma levels of these compounds in a short-term intervention study in which volunteers were fed tomato paste made from organic and conventional tomatoes (Caris-Veyrat et al. 2004).

There are virtually no sound data from medium or longer term dietary intervention studies with animal models or humans, that compare the health effects of food produced in organic, low input and conventional production systems. The main reason for this lack of data is the logistical difficulty in ensuring continuous, standardised food supplies for matching organic, low input and/or conventional groups in diet intervention studies.

Also, virtually all existing cohort studies were designed primarily to quantify the effect of dietary composition on health, and not to identify the impact of foods produced by different production systems. The difficulties of identifying the effect of organic and conventional food consumption on human health in cohort type studies was shown by the recent EU-Parcival study which compared the incidence of allergies in children from families following an anthroposophical lifestyle (which involves a higher level of organic food consumption) and standard lifestyle (which involved a significantly lower level of organic food consumption (Alm et al., 1999). While the incidence of allergies was significantly (around 50%) lower in children from families following an anthroposophical lifestyle, this could not be clearly linked to organic food consumption, due to a wide range of other lifestyle differences between the 2 groups (e.g. lower levels of antibiotic, aspirin/paracetamol and MMR vaccination use, higher incidences of measles, and longer breast feeding in the anthroposophical group) (Alm et al., 1999) In another study the reproductive health of members of an organic farmers' association was found to be better than that of 3 control groups, but it remained unclear to what extent this was due to organic food consumption (Abel et al. 1994; Jensen et al. 1996).

Clearly, to address the fundamental question of whether consumption of food from organic and/or other 'low input' systems has a positive effect on health will require the establishment of new, well designed animal model or human dietary intervention studies (that test well defined hypotheses with respect to the effect of specific food compounds on specific health parameters) and/or long-term cohort studies.

In the QLIF IP further knowledge in this area was generated by **WP2.3.2**. Initial results are described in detail in two papers in these proceedings (see papers Baranska et al. and Rembialkowska et al. in these proceedings). They indicate some differences in immune system activity between rats provided with diets based on organic, low input and conventional crops from the field experiments established under WP2.1. However, there also appear to be interactions with both animal age and sex with respect to the effect of different feeds on immunological status.

Conclusions

While clear benefits from producing foods under organic and/or low input production standards have been identified for certain commodities (e.g. wheat and dairy products) further investigations are required to confirm these results and trends can currently not be generalised to all crop and livestock commodities.

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References

Abel A et al. 1994. High sperm density amongst members of organic farmers' association. *Lancet*; 343:1498.

Alavanja M C R et al. 2003. Use of agricultural pesticides and prostate cancer risks in the agricultural health study cohort. *American Journal of Epidemiology*; 157 (9): 800-814.

Alm J S, Swartz J, Lilja G, Scheynius A, Pershagen G. 1999. Atopy in children of families with an anthroposophic lifestyle. *Lancet*; 353:1485-1488.

Anonymous (1998). Organic and Ethical Foods, Market Intelligence. Mintel International Group Ltd

Anonymous 2002. Organic farming, food quality and human health; a review of the evidence. Bristol: The Soil Association

Anonymous. 2002b. Project report on EU-project QLK5-2000-00593. *Development of Origen Labelled Products: Humanity, Innovation and Sustainability (DOLPHINS)*. submitted

Asami et al. 2003. Comparison on the Total Phenolic and Ascorbic Acid content of freeze-dried and Air Dried Marionberry, Strawberry and Corn Using Conventional, Organic, and Sustainable Agricultural Practices. *Journal of Agricultural and Food Chemistry*; 51:1237-1241.

Avery D T. 1998. The hidden dangers of organic food. *American Outlook;* Fall.19-22.

Baker B P, Benbrook, C M, Groth, E, Benbrook, K L. 2002. Pesticide residues in conventional, IPM-grown and organic foods: Insights from three U.S. data sets. *Food Additives and Contaminants*; 19(5):427-446.

Basker D. 1992. *American Journal of Alternative Agriculture*; 7:129-136.

Benbrook C. 2002. Organochlorine residues pose surprisingly high dietary risks. *Journal of Epidemiology and Community Health*; 56:822-823.

Benbrook C. 2007 Dietary exposure to pesticides from organic and conventional food products. in *Handbook of organic food quality and safety.* In press Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Bengtsson J, Ahnström J, Weibull A. 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. *Journal of Applied Ecology*; 42:261-269.

Bergamo, P., Fedele, E., Iannibeli, L. and Marzillo, G. 2003 Fat soluble vitamin contents and fatty acid composition in organic and conventional Italian dairy products. Food Chemistry 82: 625-631

Bernart M W, Cardellina I I J H, Balaschak M S, Alexander M, Shoemaker R H Boyd M R. 1996. Cytotoxic falcarinol oxylipins from Dendropanax arboreus. *Journal of National. Prodceedings*; 59:748 -753.

Berry P, Ogilvy S, Gardner S. 2004. Integrated farming and biodiversity. *English Nature Report 634*; English Nature, Agriculture Unit, Peterborough.

Biavati B, Santini, C 2007. Alternative therapies to reduce enteric bacterial infections and improve the microbiological safety of pig and poultry production systems. in *Handbook of organic food quality and safety*. In press Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Birzele B, Meier A, Hindorf H, Kramer J, Dehne H W. 2002. Epidemiology of Fusarium infection and deoxynivalenol content in winter wheat in the Rhineland, Germany. *European Journal of Plant Pathology*; 108:667-673.

Borojevic K. 2005. The transfer and history of 'reduced height genes' (Rht) in wheat from Japan to Europe. *Journal of Heredity*; 96:455-459.

Bourn D, Prescott J. 2002. A comparison of the Nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. *Critical Reviews in Food Science and Nutrition*; 42:1-34.

Boyd et al. 1990. Behavioral and neurochemical changes associated with chronic exposure to low level concentrations of pesticide mixtures. *Journal of Toxicology and Environmental Health*; 30:209-221.

Brandt K, Molgaard J P. 2001. Organic Agriculture: Does it enhance or reduce the nutritional value of food plants. *Journal of Science in Food and Agriculture*; 81:924-931.

Briggs W H, Folts J D, Osman H E, Goldman I L. 2001. Administration of raw onion inhibits platelet-mediated thrombosis in dogs. *Journal of Nutrition*; 131:10, 2619-2622.

Brunsgaard, G. (1998). Effects of cereal type and feed particle size on morphological characteristics, epithelial cell proliferation, and lectin binding patterns in the large intestine of pigs. Journal of Animal Science, 76, 2787-2798.

Butler J H. 2002. Methyl Bromide Under Scrutiny. *Nature*; 376:469-470.

Butler G, Stergiadis S, Eyre M, Leifert C. 2006 Effect of production system and geographic location on milk quality parameters. *Aspects of Applied Biology* 80:189-193.

Chilliard, Y, Ferlay, A.& Doreau, M. (2001) Effects of different types of forages, animal fat or marine oils in cow's diet on milk fat secretion and composition, especially conjugated linoleic acid (CLA) and polyunsaturated fatty acids. Livestock Production Science, 70, 31-48.

Dewhurst, R.J., Scollan, N.D., Lee, M.R.F., Ougham, H.J. & Humphreys, M.O. (2003). Forage breeding and management to increase rge beneficial fatty acid content of ruminant products. Proceedings of the Nutrition Society 62, 1-8.

Carbonaro M et al. 2002. Modulation of Antioxidant Compounds in Organic vs Conventional Fruit (Peach, Prunus persica L., and Pear, Pyrus Communis L.) *Journal of Agricultural and Food Chemistry*; 50:5458-5462.

Caris-Veyrat C, Amiot M J, Tyssandier V, Grasselly D, Buret M, Mikolajczak M, Guilland J C, Bouteloup-Demange C, Borel P. 2004. Influence of Organic versus Conventional Agricultural Practice on the Antioxidant Microconstituent Content of Tomatoes and Derived Purees; Consequences on Antioxidant Plasma Status in Humans. *Journal of Agriculture and Food Chemistry*; 52:6503-6509.

Charlier G et al. 2003. Breast Cancer and serum organochlorine residues. *Occupational and Environmental Medicine*; 60 (5):348-351.

Cormack W F. 2000. Energy use in organic farming systems (OF0182) http://orgprints.org/8169

Cooper J, Schmidt C S, Wilkinson A, Lueck L, Hall C M, Shotton P N, Leifert C. 2006 Effect of organic, 'low input' and conventional production systems on disease incidence and severity in winter wheat. *Aspects of Applied Biology* 80: 121-127.

Cooper J, Niggli U, Leifert C. 2007 *Handbook of organic food quality and safety.* In press Woodhead Publishing Ltd. London.

Critchley C N R, Allen D S, Fowbert J A, Mole A C, Gundrey A L. 2004. Habitat establishment on arable land: assessment of an agri-environment scheme in England, UK. *Biological Conservation*; 119:429-442.

Critchley C N R, Fowbert J A, Sherwood A J. 2006. The effects of annual cultivation on plant community composition of uncropped arable field boundary strips. *Agriculture, Ecosystems and Environment*; 113:196-205.

Curl C L, Fenske R A, Elgethun K. 2003. Organophosphorus pesticide exposure of urban and suburban pre-school children with organic and conventional diets. *Environmental Health Perspectives*; 111 (3):377-382.

DEFRA. 2006a. Assurance Schemes and Standards. http://www.defra.gov.uk/farm/trade/assurance/index.htm

DEFRA. 2006b. Countryside stewardship scheme (CSS) http://www.defra.gov.uk/erdp/schemes/css/default.htm

DEFRA. 2006c. Organic farming and the Environment.

http://www.defra.gov.uk/farm/organic/policy/actionplan/annex3.htm

De Meeus C, Eduljee G H, Hutton M. 2002. Assessment and management of risks arising from exposure to cadmium in fertilisers. *Science of the total* Environment; 291:167-187.

Diaz-Gonzalez, F. 2007. Organic livestock husbandry methods and the microbiological safety of ruminants. in *Handbook of organic food quality and safety.* In press. Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Drinkwater L E, Wagoner P, Sarrantonio M. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature*; 396: 262-264.

Dubois D, Gunst L, Fried P M, Stauffer W, Spiess E, Alföldi T, Fliessbach A, Frei R, Niggli U. 1999. DOC-trial: yields and energy use efficiency. *Agrarforschung*; 6(08):293-296.

EFSIS. 2006. Farm assured standard. www.fabbl.co.uk.

Eggers T. 1984. Changes in arable weed vegetation. Mitteilungen aus der Biologischen Bundesanstalt fur Land- und Forstwirtschaft Berlin-Dahlem 223:62.

Ellis, K.A., Innocent, D., Grove-White, D., Cripps, P. and McLean, W.G. 2006 Comparing the fatty acid composition of organic and conventional milk. Journal Dairy Science 89: 1938-1950

Ernst M, Feldheim W. 2000. Fructans in higher plants and in human nutrition. *Journal of Applied Botany – Angewandte Botanik*; 74:1-2, 5-9.

Esjberg Peter, Petersen Bo Svenning. 2002. *Effects of reduced pesticide use on flora and fauna in the agricultural fields*; Pesticides research 58, Danish Environmental Protection Agency.

Eskenazi B, Bradman A, Castorina R. 2000. Exposures of children to organophosphate pesticides and their potential adverse health effects. *Environmental Health Perspectives*; 107:409-418.

EU. 1991. Council Regulation (EEC) No. 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs as amended.

EU. 1997. Council Regulation (EEC) No. 1488/97 of 29 July 1997 amending Council Regulation (EEC) No. 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs as amended.

Eurepgap. 2006. Eurepgap standards. http://www.blik.be/Engels/e-eurep.html

Faustini A. 1996. Immunosuppressive effects of Chlorophenoxy herbicides. *Food and Chemical Toxicology*; 34:1190-1191.

Fedele, E., Iannibelli, L., Marzillo G., & Bergamo P. (2001). Comparison between conjugated Linoleic Acid and fat-soluble vitamins content in organic and conventional dairy products. Food and Nutrition for better health. (HEALFO Conference), Italy http://www.cmns.mnegri.it/en/congres/healfo/selected/files28.htm

Finamore A, Britti M S, Roselli M, Bellovino D, Gaetani S, Mengheri E. 2004. Novel Approach for Food Safety Evaluation. Results of a Pilot Experiment To Evaluate Organic and Conventional Foods. *Journal of Agricultural and Food Chemistry*; 52: 7425-7431.

Fließbach A, Mäder P. 1997. Carbon Source Utilization by Microbial Communities in Soils under Organic and Conventional Farming Practice. *In Microbial Communities – Functional versus Structural Approaches*. Pp 109-120. Ed Insam A. Rangger, Springer-verlag Berlin, Germany.

Fließbach A, Mäder P. 2000. Microbial biomass and size-density fractions differ between soils of organic and conventional agricultural systems. *Soil Biology and Biochemistry*; 32:757-768.

Fluck R C. 1992. Energy Analysis of Agricultural Systems. In *Energy in World Agriculture,* Vol 6 pp.45-52. Ed. R C Fluck, Elsevier Science Publishing.

Fjelkner-Modig S, Bengtsson H, Stegmark R, Nystrom S. 2001. The influence of organic and integrated production on nutritional, sensory and agricultural aspects of vegetable raw materials for food production. *ACTA Agriculturae Scandinavica Section B-Soil and Plant Science*; 50:102-113.

Frankel E N, Waterhouse A L, Kinsella J E. 1993. Inhibition of human LDL oxidation by resveratrol. *Lancet*; 341:1103-1104.

Fuglsang G, Madsen C, Saval P 1993. Prevalence of intolerance to food additives among Danish school children. *Pediatrics Allergy and Immunology* 4:123-129.

Fuller R J, Norton L R, Feber R E, Johnson P J, Chamberlain D E, Joys AC, Mathews F, Steward R C, Townsend M C, Manley W J, Wolfe M S, Macdonald D W, Firbank L G. 2006. Benefits of organic farming to biodiversity vary among taxa. *Biology Letters*; 1:431-434.

Furst, A. (2002). Can nutrition affect chemical toxicity? International Journal of Toxicology. 21, 419-424.

Garry V F, Schreinemachers D, Harkers M E, Griffith J. 1996. Pesticide applicators, biocides and birth defects in rural Minnesota. *Environmental Health Perspectives*; 104: 394-399.

Giotis C, Toufexi E, Theodoropoulou A, Dafermos N, Markelou E, Kasselaki A, Malathrakis N, 2006 Effect of soil steaming, amendments and resistant rootstocks on soil borne disease incidence and yields in organic tomato production systems *Aspects of Applied Biology* 80: 127-135.

Goodman D, DuPuis E M. 2002. Knowing food and growing food: beyond the production-consumptiondebate in the sociology of agriculture. *Sociologia Ruralis*; 42:5-15.

Grinder-Pedersen L, Rasmussen S E, Bügel S, Jørgensen L V, Dragsted L O, Gundersen V, Sandström B. 2003. Effect of Diets Based on Foods from Conventional versus Organic Production on Intake and Excretion of Flavonoids and Markers of Antioxidative Defense in Humans. *Journal of Agricultural and Food Chemistry*; 51:5671-5676.

Greenvald P, Clifford C K, Milner J A. 2001. Diet and cancer prevention. *European Journal of Cancer*; 37:948–965.

Gundgaard J, Nielsen J N, Olsen J, Sørensen J. 2002. Vurdering af de sundhedsøkonomiske konsekvenser ved øget indtag af frugt og grøntsager. (Evaluation of the consequences for health economy of increased intake of fruits and vegetables). Centre for Applied Health Service Research and Technology Evaluation, University of Southern Denmark. http://www.6omdagen.dk/dokumentation/sundhed/teknisk_rapport.pdf

Hald, T., Lo Fo Wong, D.M.A., & Wingstrand, A. (1999). Zoonotiske Salmonella i alternativ husdyrproduktion (In Danish). In: Den Danske Dyrlægeforenings Årsmøde 1999. Klinisk Mikrobiologi sektionen, 5 .

Hamm U, Gronefeld F, Halpin D. 2002. *The European Market for Organic Food*, Vol. 1., *Organic Marketing Initiatives and Rural Development.* School of Management and Business University of Wales, Aberystwyth.

Hannum S M. 2004. Potential Impact of Strawberries on Human Health: A Review of the Science. *Food Science and Nutrition*; 44:1-17.

Hartmann M, Fliessbach A, Oberholzer H R, Widmer F. 2006. Ranking the magnitude of crop and farming system effects on soil microbial biomass and genetic structure of bacterial communities. *FEMS Microbiology Ecology*; 57:378.

HDRA Consultants. 2006. http://www.compost-uk.org.uk/projects.htm

Hecht S S. 1999. Chemoprevention of cancer by isothiocyanates, modifiers of carcinogen metabolism. *Journal of Nutrition*; 129:768–774.

Helsel Z R. 1992. Energy and Alternatives for Fertiliser and Pesticide Use. In *Energy in World Agriculture*, Vol 6 pp.177-210. Ed. R C Fluck, Elsevier Science Publishing.

Hemingway, R.G. (1999) The influences of dietary selenium and vitamin E intakes on milk somatic cell counts and mastitis in cows. Veterinary Research Communications 23, 481-499.

Hirt H, Zeltner E, Leifert C. 2007. Effects of organic husbandry methods and feeding regimes on poultry quality. in *Handbook of organic food quality and safety*. In press Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Høgh-Jensen H, Schjørring, J K. 1997. Interactions between white clover and ryegrass under contrasting nitrogen availability: N_2 fixation, N fertilizer recovery, N transfer, and water use efficiency. *Plant Soil*; 197:187-199.

Holsapple M P. 2002. Autoimmunity by pesticides: a critical review of the state of the science. *Toxicology Letters*; 127:101-109.

Horticultural Development Council. 2006. Pesticide Gap Analysis. http://www.hdc.org.uk/sectors/gapanalysis_01.asp?sectorID=M

Hoyle D V, Shaw D J, Knight H I, Davison H C, Pearce M C, LowJ C, Gunn G J and Woolhouse, M E J. 2004. Age-Related Decline in Carriage of Ampicillin-Resistant *Escherichia coli* in Young Calves. *Applied and Environmental Microbiology* 70: 6927–6930.

Høyer A, Grandjean P, Jørgensen T, Brock J, Helle B. 1998. Organochlorine exposure and risk of breast cancer. *The Lancet*; 352:1816-1820.

Isaacson, R.E., Firkins, L.D., Weigel, R.M., Zuckermann, F.A., Di Pietro, J.A. (1999). Effect of transportation and feed withdrawal on shedding of *Salmonella typhimurium* among experimentally infected pigs. American Journal of Veterinary Research, 60, 1155-1158

Jensen T K et al. 1996. Semen quality among members of organic food associations in Zealand, Denmark. *Lancet*; 347:1844.

Jones, P.H., Roe, J.M. & Miller, B.G. (2001). Effects of stressors on immune parameters and on the faecal shedding of enterotoxigenic Escherichia coli in piglets following experimental inoculation. Research in Veterinary Science 70, 9-17.

Jorhem L Slanina P. 2000. Does organic farming reduce the content of Cd and certain other trace metals in plant foods? A pilot study. *Journal of the Science of Food and Agriculture*; 80:43-48.

Karavoltsos S, Sakellari A, Dimopoulos M, Dasenakis M, Scoullos M. 2002. Cadmium content in foodstuffs from the Greek market. *Food additives and contaminants*; 19:954-962.

Kim J G, Yousef A E, Dave S. 1999. Application of ozone for enhancing the microbial safety and quality of food: a review. *Journal of Food Protection*; 62:1071-1087.

Klocke P, Walkenhorst M, Butler G. 2007. Reducing antibiotic use in organic dairy production systems. in *Handbook of organic food quality and safety.* In press Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Kuznesof S, Ritson C. 1996. Consumer Acceptability of Genetically Modified Foods. *British Food Journal*; 98:4-5.

Lampkin N. 1999. *Organic Farming*. Farning Press Miller Freeman, Tonbridge.

Laseter J, Rea W. 1983. Chlorinated hydrocarbon pesticides in environmentally sensitive patients. *Clinical Ecology*; 2:1.

LEAF. 2006. The LEAF marquee standard. http://www.leafuk.org/leaf/producers/join.asp?id=4030602

Leclerc J, Miller M L, Joliet E, Rocquelin G. 1991. *Biological Agriculture and Horticulture*; 7:339-348.

Ledgard S F, Steele K W. 1992. Biological nitrogen fixation in mixed legume/grass pastures. *Plant Soil*; 141:137-153.

Leifert C. 2000. A re-evaluation of the beneficial and other effects of dietary nitrate. *Proceedings of the International Fertiliser Society, No 456, 2000, London UK.*

Leifert C, Shiel R, Lueck L, Cooper J, Sanderson R J, Shotton P. 2007. Effect of organic, 'low input' and conventional crop production systems on crop yield, quality and health: the Nafferton Factorial Systems Comparison Experiments. *Annals of Applied Biology* in press.

Lehesranta S L, Koistinen K M, Massat N, Davies H V, Shepherd L V T, McNicol J W, Cakmak I, Cooper J, Lueck L, Kärenlampi S O, Leifert C. 2007. Effects of agricultural production systems and their components on protein profiles of potato tubers. *Proteomics* in press.

Locasio S J, Wiltbank W J, Gull D D, Maynard D N. 1984. Fruit and vegetable quality as affected by nitrogen nutrition. In *Nitrogen Crop Production*, pp 617-626. Hauck, R.D., Ed, American Society of Agronomy, Madison, WI,

Lockie S, Lyons K, Lawrence G, Mummery K. 2002. Eating 'green': motivations behind organic food consumption in Australia. *Sociologia Ruralis*; 42:23-35.

Lombardi-Boccia G, Lucarini M, Lanzi S, Aguzzi A Cappeloni M. 2004. *Journal of Agricultural and Food Chemistry*; 52:90-94.

Liu S M, Sesso H D, Manson J E, Willett W C, Buring J E. 2003. Is intake of breakfast cereals related to total and cause-specific mortality in men? *American Journal of Clinical Nutrition*; 77: 594-599.

Luebke B. 2002. Pesticide-induced immunotoxicity: Are humans at risk? *Human and Ecological Risk assessment*; 8:293-303.

Lueck L, Schmidt C S, Cooper J M, Hall C M, Shotton P, Leifert C. 2006. Effect of organic, low-input and conventional production systems on yield and quality of winter wheat. *Aspects of Applied Biology* 80: 127-135.

Lund, P. (1991). Characterization of alternatively produced milk. Milchwissenschaft – Milk Science International. 46, 166-169.

Mäder P, Fliessbach A, Dubois D, Gunst L, Fried P, Niggli U. 2002. Soil fertility and biodiversity in organic farming. *Science*; 296:1694-1697.

Mäder P, Pfiffner L, Niggli U, Balzer U, Balzer F, Plochberger K, Velimirov A, Besson, J-M. 1993. Effect of three farming systems (bio-dynamic, bio-organic, conventional) on yield and quality of beetroot (Beta vulgaris L., var. esculenta L.) in a seven year crop rotation. *Acta Horticulturae*; 339:11-31.

Mallarino A P, Wedin W F. 1990. Effect of species and proportion of legume on herbage yield and nitrogen concentration of legume-grass mixtures. *Grass Forage Science*; 45:393-402.

Malmauret L, Parent-Massin D, Hardy J L, Verger P. 2002. Contaminants in organic and conventional foodstuffs in France. *Food additives and contaminants*; 19:524-532.

Matson P A, Parton W J, Power A G, Swift M J. 1997. Agricultural Intensification and Ecosystem Properties. *Science*; 277 (5325):504-509.

Maurer V, Hördegen P, Hertzberg H. 2007. Reducing anthelmintic use for the control of internal parasites in organic livestock systems. in *Handbook of organic food quality and safety*. In press Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Mayer A M. 1997. Historical changes in the mineral content of fruits and vegetables. *British Food Journal*; 99:207-211.

Mensink R P, Katan M B. 1990. Effect of Dietary Trans-fatty acids on high-density and low-density Lipoprotein Cholesterol levels in healthy subjects. *New England Journal of Medicine*; 323:439-445.

McKnight G M, Duncan C W, Leifert C, Golden M H N. 1999. Dietary Nitrate in Man - friend or foe. *British Journal of Nutrition*; 81: 349-358.

Michels K B, Wolk A. 2002. A prospective study of variety of healthy foods and mortality in women. *International Journal of Epidemiology*; 31:847-854.

Ness A R, Powles JW. 1997. Fruit and vegetables, and cardiovascular disease: a review. *Int J. Epidemol*; 26:1–13.

Nielsen, J.H., Østdal H. & Andersen, H.J. (2002) The influence of ascorbic acid and uric acid on the oxidative stability of raw and pasteurized milk. Chapter 9 in Free Radicals in Foods: Chemistry, Nutrition, and Health Effects. American Chemical Society Symposium Series No. 807, 9, 126-137.

Niggli U. 2007. History and concepts of food quality and safety in organic food production and processing.

Obst A, Lepschy J, von Gleissenthall J, Beck R. 1998. Die Desoxynivalenol-Belastung von Weizen durch *Fusarium graminearum* in Abhängigkeit von Pflanzenbaufaktoren und Witterung, p.85, in *Mitteilungen aus der Biologischen Budesanstalt für Land – und Forstwirtschaft*. Berlin Dahlem (Hrsg., 1998) 51 Deutsche Pflanzenschutztagung in Halle/Saale. 5-8 Oktober 1998. Heft 357. Berlin. Parey Buchverlag.

Oehl F, Sieverding E, Ineichen K, Mader P, Boller T, Wiemken A. 2000. Impact of Land Use Intensity on the Species Diversity of Arbuscular Mycorrhizal Fungi in Agroecosystems of Central Europe. *Applied Environmental Microbiology*; 69:2816-2824.

Ohlo G. 1999. Endocrine disrupting chemicals and carcinogenicity. *Gan to Kagaku Ryoho*; 26:263-8.

Ougton E, Ritson C 2007. Food consumers and organic food. in *Handbook of organic food quality and safety*. In press Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Pesticide action network 2002. Pesticide Impacts in the environment. http://www.pan-europe.info/About%20pesticides/Impacts%20environment.shtm

Pinheiro J C, Bates D M. 2000. Mixed-effects models in S and S-plus. Springer, New York.

Pither R, Hall M N. 1990. *Technical Memorandum* 597. Maff Project 4350.

Pool-Zobel B L, Bub A, Muller H, Wollowski I, Rechkemmer G. 1997. Consumption of vegetables reduces genetic damage in humans: First results of a human intervention trial with carotenoid-rich foods. *Carcinogenesis;* 18:1847-1850.

Porter et al. 1993. Groundwater pesticides: interactive effects of low concentrations of carbamates aldicarb and methomyl and the triazine metribuzin on thyroxine and somatrophin levels in white rats. *Journal of Toxicology and Environmental Health*; 40:15-34.

Porter WP, Jaeger J W, Carlson I H. 1999. Endochrine immune and behavioural effects of aldicarb (carbamate), atrazine (triazine) and nitrate (fertiliser) mixtures at groundwater concentrations. *Toxicology and Industrial health*; 15:133-150.

Pretty J N, Ball A S, Xiaoyun Li, Ravindranath, N H. 2002. The role of sustainable agriculture and renewable-resource management in reducing greenhouse-gas emissions and increasing sinks in China and India. *Philosophical Transactions of the Royal Society A*; 360:1741-1761.

Pyšek P, Lepš J. 1991. Response of a weed community to nitrogen fertilization: a multivariate analysis. *Journal of Vegetation Science*; 2:237-244.

Pyšek P, Jarošik V, Kropáč Z, Chytrý M, Wild J, Tichý L. 2005. Effects of abiotic factors on species richness and cover in Central European weed communities. *Agriculture, Ecosystems & Environment*; 109:1-8.

Reganold J P, Elliott L F, Unger Y L. 1987. Long-term effects of organic and conventional farming on soil erosion. *Nature*; 330:370-372.

Reganold J, Glover J, Andrews P, Hinman H R. 2001. Sustainability of three apple production systems. *Nature*; 410: 926-930.

Ren H, Endo H, Hayashi T. 2001a. The superiority of organically cultivated vegetables to general ones regarding antimutagenic activities. *Mutation Research*; 496:83-88.

Ren H, Endo H, Hayashi T. 2001b. Antioxidative and antimutagenic activities and polyphenol content of pesticide-free and organically cultivated green vegetables using water-soluble chitosan as a soil modifier and leaf surface spray. *Journal of the Science of Food and Agriculture*; 81:1426-1432.

Rice-Evans C A, Miller N J, Paganga G. 1996. Structure-antioxidant activity relationships of flavonoids and phelonic acids. *Free Radical Biology and Medicine*; 20:933-956.

Riserus, U., Berglund, L. & Vessby, B. (2001) Conjugated linoleic acis (CLA) reduced abdominal adipose tissue in obese middle-aged men with signs of metabolic syndrome: A randomised controlled trial. International Journal of Obesity, 25, 1129-1135.

Rosa E, Rodrigues P. 1998. The effect of light and temperature on glucosinolate concentration in the leaves and roots of cabbage seedlings. *Journal of the Science of Food and Agriculture* 78:208-212.

Sanalidou E, Barouakis G, Siskos Y. 2002. Customers' Perspectives on the Quality of Organic Olive Oil in Greece. *British Food Journal*; 104:3-5.

Sattelmacher B, Reinhard S, Pomikalko A. 1991. Differences in Mycorrhizal Colonization of Rye (*Secale cereale* L.) Grown in Conventional or Organic (Biological-dynamic) Farming Systems. *Journal of Agronomy and Crop Science*; 167:350-355.

Schifferstein H N J, Ophuis P A M O. 1998. Health-related determinants of organic food consumption in the Netherlands. *Food Quality and Preference*; 9:119-133.

Schollenberger M, Suchy S, Jara H T, Drochner W, Muller H M. 1999. A survey of Fusarium toxins in cereal-based foods marketed in an area of southwest Germany. M*ycopathologia*; 147:49-57.

Schreinemachers D M. 2000. Cancer mortality in four Northern wheat producing states. *Environmental Health Perspectives*; 108 (9):873-881.

Seal C J 2006. Whole grains and CVD risk. *Proceedings of the Nutrition Society*; 65:24-34.

Seal C J, Brandt, K 2007. Nutritional quality of foods. in *Handbook of organic food quality and safety.* In press Ed. C Leifert, U Niggli, & J. Cooper, Woodhead Publishing Ltd. London.

Shimbo S, Zhang Z W, Watanabe T, Nakatsuka H, Matsuda-Inoguchi N, Higashikawa K, Ikeda M. 2001. Cadmium and lead contents in rice and other cereal products in Japan in 1998-2000. *Science of the total environment*; 1-3:165-175.

Sorensen M T, Danielsen V 2006. Effects of the plant growth regulator, chlormequat, on mammalian fertility. International Journal of Andrology 29:, 129-132.

Stephens R., Spurgeon A, Calvert I A et al. 1995. Neuropsychological effects of long term exposure to organophosphates in sheep dip. *Lancet*; 345:1135-1139.

Sterling T, Arundel A V. 1986. Health effects of Phenoxy herbicides. *Scandinavian Journal of Work and Environmental Health*; 12:161-173.

Stoate C, Boatman N D, Borralho R J, Rio Carvalho C, de Snoo G R, Eden P. 2001. Ecological impacts of arable intensification in Europe. *Journal of Environmental Management*; 63:337-365.

Stolze M, Piorr A, Häring, A Dabbert. 2000. The environmental Impacts of Organic Farming in Europe. University of Hohenheim, Stuttgart.

Sundrum A. 2007. Effect of organic husbandry and feeding regimes on pork quality. in *Handbook of organic food quality and safety.* In press Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Swiss Federal Office for Agriculture. 2006. Verordnung über die Direktzahlungen an die Landwirtshaft. 2. Kapitel: Extensive Produktion von Getreide und Raps. http://www.admin.ch/ch/d/as/1999/229.pdf

Tanaka Y, Taguchi S, Yoshida S, Hori S, Takagaki Y. 2001. Effects of organonitrogen, carbamate pesticides and others on ss-hexosaminidase release from rat basophilic leukemia cells (RBL-2H3). *Journal of the Food Hygienic Society of Japan*; 42:257-261.

TESCO. 2006. Environmental Detail website
http://www.tesco.com/everylittlehelps/environmentdetail.htm.

Thiruchelvam M et al. 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):9207-9214.

Toledo, P., Andren, A. & Bjorck. (2002). Composition of raw milk from sustainable productions systems. International Dairy Journal, 12, 75-80.

Trewavas A. 2001. Urban myths of organic farming. *Nature*; 410:409-410.

Trewavas A. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. *Crop Protection*; 23:757-781.

Vaarst M, Roderick S, Lund V, Lockeretz 2004. *Animal Health and welfare in Organic Farming*. CABI Publishing,Wallingford.

Van Poppel G, Verhoven D T H, Verhagen H, Goldbohm R A. 1999. *Brassica* vegetables and cancer prevention. Epidemiology and mechanisms. *Advances in nutrition and cancer*. Pp 159-168. 2. Kluwer Academic/Plenum Publishers, New York.

Veer P V, Jansen M C J F, Klerk M, Kok F J. 2000. Fruits and Vegetables in the Prevention of Cancer and Cardiovascular Disease. *Public Health Nutrition 2000*; 3:103-7.

Verhoog H, Matze M, Van Bueren E L, Baars T. 2003. The role of the concept of the natural (naturalness) in organic farming. *Journal of Agricultural & Environmental Ethics*; 16:29-49.

Verma V, Worland A J, Sayers E J, Fish L, Caligari P D S, Snape J W. 2005. Identification and characterization of quantitative trait loci related to lodging resistance and associated traits in bread wheat. *Plant Breeding*; 124:234-241.

Vogtmann H, Matthies K, Kehres B, Meier-Ploeger A. 1993. *Compost Science and Utilisation*; 1:82-100.

Wade M G, Parent S, Finnson K W, Foster W, Younglai E, McMahon A, Cyr D G, Hughes C. 2002. Thyroid toxicity due to subchronic exposure to a complex mixture of 16 organochlorines, lead, and cadmium. *Toxicological Sciences*; 67:207-218.

Waterhouse A L, Walzem R L. 1998. Nutrition of grape phenolics. In *Flavonoids in Health and Disease*. Pp 359-385. Rice-Evans, C.A., Packer, L., Eds., Dekker: New York.

Wattenberg L W, Coccia J B, Lam L K T. 1980. Inhibitory effects of phenolic-compounds on Bezo(a)pyrene-induced neoplasia. *Cancer Research*; 40:2820-2823.

Weller R F, Marley C L, Moorby J M. 2007. Effects of organic and conventional feeding regimes and husbandry methods on the quality of milk and dairy products. in *Handbook of organic food quality and safety.* In press Ed. J Cooper, U Niggli, & C Leifert, Woodhead Publishing Ltd. London.

Weir M, Calverly C. 2002. Potential for Organic Foods in Europe. *British Food Journal*; 104:23-26.

Whalen J K, Parmelee R W, Edwards C A. 1998. Population dynamics of earthworm communities in corn agroecosystems receiving organic or inorganic fertilizer amendments. *Biology and Fertility of Soils*; 27:400-407.

Wilkinson A, Young D, Cooper J M, Wilkockson S, Leifert C 2006. Effect of fertility management and variety choice on yield and baking quality of organic spring and winter wheat. *Aspects of Applied Biology* 80: 147-153.

Woese K, Lange D, Boess C, Bögl KW. 1997. A comparison of organically and conventionally grown foods- results of a review of the relevant literature. *Journal of the Science in Food and Agriculture*; 74:281-293.

Wszelaki A L, Delwiche J F, Walker S D, Liggett R E, Scheerens J C, Kleinhenz M D. 2005. Sensory quality and mineral and glycoalkaloid concentrations in organically grown redskin potatoes (Solanum tuberosum). *Journal of the Science of Food and Agriculture*; 85:720-726.

Younie D, Wilkinson J M 2001. *Organic Livestock Farming*. Chalcombe Publications, Lincoln.

Zanoli R, Naspetti S. 2002. Consumer Motivations in the Purchase of Organic Food. *British Food Journal;* 104:8-14.