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ISSUES PAPER: ORGANIC AGRICULTURE AND FOOD UTILIZATION

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I. INTRODUCTION

1. Food utilization means achieving an adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. On the one hand, this means minimizing health risks by protecting consumers from risks of food-borne diseases or harmful levels of toxic substances, ensuring safe drinking water and protecting workers in agriculture and other food-related industries from occupational health risks. On the other hand, it means maximizing food benefits relating to the well-known requirement of providing adequate levels of essential dietary nutrients and the more complex food quality topics related to consumer choice, disease prevention, and ethical issues such as animal welfare.

2. Organic agriculture defines its basic principles as health, ecology, fairness and care (IFOAM 2005). While the minimum standards for organic systems are similar across the world, the differences in actual practices between production systems can vary substantially in different regions.

3. Many of the benefits of organic agriculture depend on establishing an ecological balance among soil, plants and animals, not just on substituting organic pesticides and fertilizers for synthetic ones. This fundamental difference is particularly important for farmers who have little experience in organic agriculture. Inadequate advice jeopardizes not just the farmers' livelihoods, but also the quality and even the safety of the products. Therefore, when possible, this review will relate each aspect of food utilization to the relevant practices such as soil fertility management or animal feeding strategies. Since most of the methods used in organic agriculture are not exclusive to this system, this can support enhancement of benefits and prevention of risks both within and outside organic agriculture.

4. The present report covers organic agriculture's effect on food safety, food quality and consumer health and the impact of production factors (fertilizers and pesticides) and food composition. It does not cover health issues, such as under-nutrition.

A. COMPLYING WITH FOOD SAFETY REGULATIONS

5. Food safety is defined as the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. It is regulated by national and international legislation.

6. The principles of organic agriculture emphasize strengthening the health of animals and plants, rather than waiting for disease to appear and then treating it. However, this requires fundamental changes in farmers' perception of their roles. They are now managers supporting and guiding a semi-autonomous ecological system, rather than workers in a factory using soil, sunshine and animals as machines to convert minerals and water into food. These changes, which enable them to move from a treatment strategy to a prevention strategy, can take several years, even with qualified support (Vaarst, *et al.*, 2006a). Often, without support, little change will take place (Vaarst, *et al.,* 2003).

7. Food safety problems can and should be solved by helping organic producers achieve the necessary skills. This requires that food safety authorities understand this issue and do not interpret every problem on an organic farm as a consequence of the organic status *per se*. It also requires

organic inspectors and advisors to recognize and live up to their responsibilities to advise organic producers to follow the spirit as well as the letter of the organic standards and regulations, emphasizing the benefits to the farmer of using more careful, ecological methods than required for certification (van Elzakker, 2006).

8. Pathogens are harmful biological agents such as bacteria, fungi, vira or prions that can cause disease in humans. Toxins are biologically active chemicals that can damage human health when ingested. They can be contaminants (defined as any substance not intentionally added to food) that are present in food as a result of production (crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding or as the result of environmental contamination. The term does not include insect fragments, rodent hairs and other extraneous matter.

Organic agriculture and pathogens

9. The safety situation for pathogens in organic agriculture has been reviewed many times (e.g. Magkos, *et al.*, 2006; Winter and Davis, 2006). Studies conclude that organic agriculture is either more safe, less safe or the same as conventional agriculture, depending on the design of the studies and local traditions regarding the methods used in organic as well as in conventional farming. For example, organic farming does not allow feeding animals the remains of the same species. Thus, in countries where bovine spongiform encephalopathy (BSE) or "mad cow disease" has been a problem, this has proven a major safety advantage, since no cows born in organic herds have been found to suffer from this disease (BMVEL 2003). Of course this makes no difference in countries where BSE is only known from spontaneous cases.

10. For zoonotic bacteria, such as salmonella and enterohemorrhagic E. coli, food safety can be protected at many steps of the supply chain. Animals can be protected against disease while on the farm through such steps as: i) eliminating sources of contamination, ii) improving the animals' ability resist an infection; iii) designing slaughtering and butchering processes to minimize cross-contamination, and iii) ensuring that food processing eliminates live bacteria before the food is consumed.

11. The organic preferences for outdoor rearing, using manure as fertilizer, and on-farm slaughtering (although not a requirement) often raise concern about potential risks for contamination from a range of zoonotic bacteria, parasites and vira. In fact, after an outbreak of H5N1 bird flu on a large commercial turkey farm in the UK, a government official told journalists that "We always expected it would start in an outdoor flock such as an organic farm, not like this" (BBC Radio 4, 2007). Yet, all studies comparing actual contamination rates of organic and conventional animal herds or food products show that they are often just as high in conventional systems as organic systems (Hovi, *et al.,* 2003). Still, problems that arise because of bad decisions or incompetence affect organic farms as much as conventional farms. The current rapid increase in the number of organic producers inevitably means that many farms are managed by people with relatively little experience in organic farming methods.

12. Factory farming systems with extensive bio-security measures, such as sealed production units that only use sterilized feed and filtered air, certainly reduce the rate of pathogen introduction. Yet surveys do not find consistently higher levels of zoonotic disease in organic animals. This means that

there are other factors in organic farming that protect animals against disease as efficiently as the conventional use of medication and biosecurity. For example, with organic there is the possible explanation that:

- early exposure to a variety of micro-organisms may improve general immunity;
- early exposure to specific pathogens and/or slower growth rates allow infected animals to recover and thereby become pathogen-free before the age when they enter the food chain;
- movement of animals between farms (which is less common in organic farming) can be a source of infection more than contact with local communities of wild animals (Hovi, *et al.*, 2003);
- a diet containing roughage inhibits the proliferation of pathogens in guts of ruminants (Gilbert *et al.* 2005)
- a diet containing a variety of fresh herbs can support the animals' immune system; and
- more severe economic consequences of disease will increase the farmers' priority for selection of resistant stock and intensive monitoring for early signs of disease.

13. The risk of transmission of zoonotic pathogens to plant foods via the use of animal manure as fertilizer seems to depend more on geography (including farm management culture, climate, etc.) and the design of the studies than on the farming system. While the bacteria can survive in manure and soil for long periods, and irrigation with contaminated water clearly can cause disease in humans, most studies show no significant difference in the rate of contamination of end products when comparing systems (Winter and Davis, 2006). Most enteric bacteria in surface water seem to originate from wildlife rather than farm runoff (Somarelli, *et al.*, 2007), presumably causing identical problems for organic and conventional farmers. While the manure is a more important aspect of fertilization on organic farms than in conventional farming, composting methods also tend to be better managed on organic farms (Winter and Davis, 2006). Additionally, high-roughage feeding regimes seem to both reduce the initial level of pathogens in the fresh manure and accelerate the rate of elimination during composting (Franz, *et al.*, 2005).

14. The widespread use of antibiotics in conventional farming has led to the appearance and spread of resistance to antibiotics in zoonotic pathogens, thus substantially increasing the risk of serious disease or death in humans, in particular in developing countries (Padungtod, *et al.*, 2006). Studies of bacterial pathogens in animals on organic farms tend to find lower levels of resistance to antibiotics than on conventional farms (e.g. Halbert, *et al.*, 2006), although in most studies, the differences were not significant.

Organic agriculture and toxins

15. Most toxins are only a safety risk when the dose exceeds a level that may cause harm to human health. In some cases, moderate levels in food are beneficial to health, even if a high content is harmful (e.g. selenium), so the level of intake is a crucial aspect of all assessments of food safety in relation to toxins.

16. For some chemical contaminants, the type of production systems does not influence the occurrence. This is the case with compounds that only occur in food due to negligence, accidents or sabotage, such as cleaning agents or asbestos. Industrial pollutants that occur in soil, such as dioxins, PCBs and heavy metals, will be equally distributed on organic and conventional land, but they may

accumulate more in organic foods, because animals in organic flocks or herds have direct contact with soil, in contrast to conventional indoor production (these pollutants do not accumulate in crops).

17. Dioxin pollution in eggs from commercial organic units tends to be similar to commercial conventional farms. However, problems occur in small flocks owned by private households in peri-urban areas (Pussemier, *et al.*, 2004), sometimes creating substantial health hazards, particularly for members of the owner's family. Harnly, *et al.* (2000) showed that among outdoor flocks kept in polluted areas, free-ranging chickens (allowed to roam freely during the day) had significantly higher levels of dioxins than flocks kept in a confined, fenced area. Additionally, dioxins accumulate in body fats throughout the animal's life and, thus, some cases with high levels of contamination have been linked to the presence of old hens up to four years of age (Food Safety Authority of Ireland, 2004). Previously, pollution by dioxins was localized in highly industrialized areas found mainly in developed countries. Now, however, open-air burning of plastics and other chlorine-containing waste is a serious and increasing source of pollution in developing countries, particularly in and near larger cities (Tanabe, 2006).

18. Certified organic producers will normally receive and follow advice from the certifying organization on how to prevent such problems. For example, they would be told to test their soil for contamination. If contamination is found, they would either abstain from organic poultry production or replace the topsoil. This is a case where certified and non-certified organic agriculture would result in a difference for food safety.

19. Pesticides can contaminate food through legal use on crops or through accidents anywhere in the supply chain. The use of pesticides is a very serious health issue for farm workers and others exposed to the compounds in concentrated form, and the levels allowed in food and water quite often are exceeded. Some 3.3 percent of samples reported in the EU exceed allowed levels (European Commission, 2005). Regulated use on crops been found to pose an intoxication risk to consumers in only exceptional cases and the concerns are mainly based on epidemiological studies showing links between pesticide exposure and some diseases (Carvalho, 2006). This risk and the intake of pesticides will be reduced by consuming organic food. Several survey types found the frequency of measurable residues in organic food is 3-4 times lower than for comparable conventional products (Winter and Davis, 2006). There are no published reports of health risks for consumers related to the types of pesticides allowed in (some forms of) organic agriculture, such as copper chloride or plant extracts.

20. Plants themselves produce toxins that are an important component of their self defense or resistance to pests and diseases. These chemical compounds are a crucial element in plant protection, particularly in organic agriculture. Most natural toxins in food made from crop plants occur in levels that do not pose any risk to humans, because the body can metabolize or excrete them without ill effects. Often the processing of plant food reduces high toxin levels in the raw material to below the threshold that can have negative effects on health such as lectins in beans, oleuropein in olives and linamarin in cassava. From a biochemical viewpoint, the toxicity of these natural pesticides is similar to synthetic pesticides, which has lead many authors to believe that natural toxins constitute a serious risk to human health (Ames, *et al*,. 1990).

21. However, considering our primarily herbivorous primate ancestors, it is not surprising that humans possess a range of effective mechanisms that allow us to eat plant foods without risk of poisoning. Most plant foods induce a range of detoxification mechanisms (e.g. Friedman, 2006) in our bodies. Conditioned taste aversion (Scalera, 2002) ensures that continued ingestion of foods with a

toxin content above the detoxification capacity is avoided (apart from psychoactive substances, which are not normally seen as a food safety issue).

22. For example, because the natural toxins phytoalexins can rise to much higher than normal level if the plant tissue is damaged (Harborne and Labadie, 1999), they intermittently occur in food in unusually high levels that can cause discomfort such as diarrhoea from one meal, and which would seriously damage health if consumed for long periods. Many cases of such acute intoxication are known, and a few fatalities have been recorded (Friedman, 2006; Kaiser, 2002). These reports contain little, if any, information about production systems and most cases occurred before 1960 or during periods of war when farmers were unlikely to have had access to pesticides, synthetic fertilizers or advice about organic production methods. However, reports of more than a few days of discomfort are very rare, and all reported serious cases have been related to food availability problems when consumers had no choice but to eat the toxic food (Friedman, 2006; Kaiser, 2002).

23. Comparative studies of organically and conventionally produced vegetables tend to show moderately higher median values in organic plants, while exceptionally high values tend to occur more often in conventional material (Brandt and Mølgaard, 2006). The biological mechanism behind this has to do with how plants grow. In nature, plants depend on nutrients released from decomposition of organic matter. If plants grow relatively slowly, they build up their chemical defenses to a level that prevents most diseases and pests. For edible crops, this normal level would not pose a human health threat after normal processing. However, if a plant is allowed to grow unusually fast by providing it with an abundance of nutrients, the accumulation of defense compounds is reduced, as has been shown in many studies (Stamp, 2003). The occurrence of very high levels of phytoalexins in some conventionally grown plants might indicate that plants with lower levels of this constitutive defense would react more strongly to the types of damage that result in production of phytoalexins, just as sunburn is more severe on skin that has previously been protected against the sun. However, experimental assessments of this hypothesis have not yet been published.

24. Contamination from natural toxins produced by micro-organisms can be prevented by: i) eliminating the micro-organisms before they produce any toxins, both in the field and after harvest; or ii) avoiding keeping food under conditions where these organisms produce toxins after harvest/slaughter. In addition, in the field, plant foods may be contaminated with toxin-producing fungi, and some formation of toxins may take place before harvest. Some fungicides reduce the number of toxin-forming fungi but other aspects of conventional farming, such as greater availability of nitrogen, reduce the plants' ability to fight these pathogens. In organic food, the overall outcome, as reviewed by Benbrook (2005), is a 50 percent lower frequency of toxic levels of mycotoxins across a large variability of climates, etc.

25. In some cases, organic products have been heavily contaminated as an indirect effect of converting to organic agriculture because if only a few farmers in a region convert, they have to store their grain on-farm, rather than in the commercial or cooperative silos available in the region that are used for storing non-organic grain of conventional farmers. Although inadequately controlled storage conditions pose a major risk for formation of mycotoxins (Elmholt, 2003), appropriate advice on improvement of the storage facilities was shown to be sufficient to eliminate this problem (Elmholt, 2003). In areas where the quality of the management of storage and processing is similar for conventional and organic products, the higher disease resistance of plants will reduce the risk of contamination. After harvest, when pesticide treatments are banned in conventional farming, the

increased resistance to fungi due to the plants' natural defense mechanisms will continue during storage.

26. Bacterial toxins are mainly a problem in processed meat or vegetables, where spores of *Clostridium botulinum* may germinate and cause formation of the very dangerous botulinus toxin. The bacteria will only grow under anoxic conditions at neutral pH, and a range of traditional preservation methods such as fermentation or curing will inhibit the growth of the bacterium as well as anti-bacterials used in conventional processing. *Bacillus cereus* causes similar problems in, for example, re-heated rice, where it is more common but less deadly, with diarrhoea or vomiting as typical symptoms. The limitations on the types and concentrations of additives allowed in organic food processing sometimes cause concerns that organic or other minimally processed foods will pose a specific health hazard (Food Standards Agency, 2006), and it attracts special attention when an organic product is shown to be contaminated with such toxins (Moore, 2006). However, no published data has been found to document any particular difference in risk between production systems, apart from the general risk factors associated with relatively inexperienced managers, as described above which, per definition, is a transient effect of rapid expansion.

B. IMPROVING FOOD QUALITY AND NUTRITIONAL EFFICIENCY

Organic agriculture and food quality

27. It is a fundamental aspect of the organic philosophy that consistent adherence to the organic principles of ecology, heath, care and fairness will lead to food of high quality for the consumer. However, because the rules and regulations defining when a product can be marketed as "organic" focus almost exclusively on which inputs and procedures are *not* allowed, organic agriculture often is misinterpreted as comprising any form of agriculture without external inputs (van Elzakker, 2006).

28. When representatives of organic organizations express their view that a healthy soil will support healthy plants that will nourish healthy animals and humans (e.g. Soil Association, 2002; IFOAM, 2005), people with another background may perceive such a statement as a clever, but unsubstantiated marketing gimmick (e.g. Avery, 1998) since this concept fundamentally contradicts their own understanding of the laws of nature. Both views express deeply felt convictions, and differences in vocabulary and underlying assumptions make communication difficult or impossible.

29. It is not uncommon for representatives from either side to appear to present scientific data in ways that support their convictions rather than contribute to a consensus. For example, when defining food quality, conventional food science, in general, tends to focus on organoleptic characteristics such as standardized size and shape and sensory properties, as well as contents of compounds defined as desirable or undesirable, even when no actual benefit or harm of varying the content of each of these compounds in the relevant range can be expected (e.g. Magkos, *et al.*, 2006; Winter and Davis, 2006), while proponents of alternative methods are exploring a different set of concepts, such as vitality and coherence (Meier-Ploeger, 2004).

30. Most publications on quality of organic food (including this review), written by people of either viewpoint/background, tend to cite general observations such as "most consumers of organic

food rank their own health as the primary motive for purchase" and then proceed with the assumption that the author's own definition of "good for health" is shared by those consumers.

31. From a more practical marketing perspective, quality of food (and other products) is defined as the degree of match with consumer expectations (Teas and Agarval, 2000), as expressed in the catchphrase "the customer is always right". This pragmatic definition has the advantage of being testable, at least within well-defined groups of consumers, and there are clear economic advantages for those producers, retailers, etc., who best understand the consumer expectations and are able to meet or exceed them.

32. Studies of consumer perceptions of the quality of organic food show that the main concerns are authenticity, trust and fairness (Torjusen, *et al.,* 2004), and that most consumers assume that food produced with authentic methods by fair and trustworthy producers will also be best for their own health and the environment. This means that consumer expectations correspond quite well with the principles behind the organic rules and regulations, a fact that causes substantial frustration among those conventional scientists who would prefer that consumers take a more analytical view of the issue (Trevawas, 2004).

33. So from the viewpoint of consumers and producers of organic food, quality of organic food is about i) ethically justifiable methods such as care for animal welfare, ii) documentation that food is produced with care and authenticity such as the absence of pesticide residues, food additives, irradiation and modified genes, and iii) and sensory quality. This is assumed to indicate superior food safety (described above), nutritional adequacy and other health benefits (described below), irrespective of whether such benefits can actually be measured.

34. Regarding animal welfare, IFOAM (2005) clearly specifies in its Principles that "animals should be provided with the conditions and opportunities of life that accord with their physiology, natural behaviour and well-being", so all organic rules, standards and regulations include measures to promote this aim. While some aspects of such rules can still be improved (Vaarst, *et al.,* 2006b), consumers recognize that the farmers take special precautions to support the welfare of their animals, and this self-imposed restriction is seen as an indication of trustworthiness and fairness (Torjusen, *et al.,* 2004) and thus an important aspect of the quality of organic food.

35. Regarding pesticide residues, food additives, irradiation and materials from genetically modified organisms (GMOs), the scientific community generally agrees that the forms and amounts of these substances presently found in food pose no measurable health risk (Magkos, *et al.*, 2006; Winter and Davis, 2006; Low, *et al.,* 2004). As is typical for many scientists in life sciences (Frewer, *et al.*, 2003), such reviews tend to present the consumer's rejection as illogical and uninformed. Clearly, certified organic food does have a 3-4 times lower risk of containing pesticide residues than conventional food (Winter and Davis, 2006). However, surveys in Europe show that 57 percent of the relevant conventional food materials are free from any measurable pesticide residues (European Commission, 2005).

36. Even in figures on imports from countries where pesticide use is completely unregulated, such as potato production in Ecuador, contamination of the food products can be insignificant (Yanggen, *et al.,* 2003). It is stated that consumption of the recorded levels in food pose no health risk of any significance (Low, *et al.*, 2004), and while mixtures of different pesticides may have different toxicity than similar total doses of individual compounds. Thus, the relative effect is small and it can just as

often reduce as enhance the toxicity of the mixture relative to a pure substance, so this also excludes the possibility of direct harm to consumer health (McCarthy and Borgert, 2006).

37. The focus of the dispute around pesticide residues relates to whether a substantial reduction of an already very small risk justifies the premium paid for organic food. However, much of this apparent conundrum can be explained by recent research on consumer views (McCarthy, *et al.*, 2006), which shows that consumers assess risks by a hierarchy of attributes, where the consumer focuses more on the acceptability of risks than on the odds that harm will occur. The least acceptable risks are those that i) could be avoided (e.g. by using organic methods), ii) are not directly detectable at the point of use, and iii) are seen as associated with a careless, inconsiderate attitude among producers ("more interested in profits than in quality"). From this point of view, it is easy to understand why most consumers prefer food without pesticides, and are only minimally impressed by what is seen as "half-hearted" measures such as integrated pest management.

38. For GMOs, food additives and irradiation of food, the situation from the consumer's point of view is similar to that of pesticide residues. Some concern about possible health risks (Union of Concerned Scientists, 2007) is related to distrust of those scientists who declare that everything is safe. However, the main point of outrage is that the technologies are seen as industry's attempts to increase profits at the expense of consumer choice. For example, Anonymous (2007) described views about irradiation, including the word "dutching", which refers to irradiation of food that has been rejected as unfit for human consumption due to bacterial contamination (based on an incident where food rejected by UK authorities was sent to the Netherlands for such "restorative" treatment).

39. With these types of "quality deficiencies", the issue becomes further muddled by differences in cultures and interpretation of data within the scientific community (Boeschen, 2006). Activists and journalists always can find a scientist who supports the opposite view of any other scientist. For GMOs, the main scientific problem is that most consequences are theoretical because it is not known what will happen to consumers and the planet in one or the other scenario (Union of Concerned Scientists, 2007). Food additives are much more familiar because consumers have long-term experience with the concept and the products. Thus, the differences in opinion among consumers and experts are smaller than for GMOs, although still significant (Haukenes, 2004).

40. Interestingly, discussions of harm or benefits to health tend to focus on the effect of the agent itself, be it pesticide residue, an additive, radiation or a modified gene product. If their availability promotes the attractiveness of foods normally seen as indicative of diets with low nutritional quality (such as carbonated drinks, cured meats and candy) compared to the foods that we should eat more of (fruits, vegetables and whole grain products), then their use could substantially exacerbate very serious public health problems such as obesity, even if the agents have no harmful direct effects (Brandt, 2007).

41. This is, thus, another example, similar to BSE, in which the precautionary principle in organic agriculture may be able to prevent a type of food-related health problem long before conventional science catches up, in terms of understanding the underlying causes of the problem. On the other hand, it is also an area where some organic producers and their organizations are pushing hard to move the boundaries, to allow them to produce "conventional-identical" products, e.g. using natural plant extracts as colorants (Weisman, 2006) and sweeteners (Footprint Choices, 2007). In the worst-case scenario, such a trend may dissipate an important health advantage of organic food, even before it has been properly documented.

42. Regarding sensory quality, for most products the quality is determined by other factors than those regulated by organic certification rules. Blind testing tends to show variable and inconsistent results, so it is not possible to say that the production system has a general influence on the food's taste and flavour (Hajslova, *et al*., 2005;, Sinesio, *et al.*, 2000; Thybo, *et al.*, 2000; Wszelaki, *et al.*, 2005). For example, when grown in the Czech Republic, organic potatoes contain higher levels of starch and are more mealy than conventional potatoes (Hajslova *et al.*, 2005), while the opposite is the case in Denmark (Thybo *et al.*, 2000) and, in both countries, the differences between varieties are larger than between cultivation systems (Hajslova *et al.*, 2005; Thybo *et al.*, 2000). In each country these differences can be explained by relative differences in physiological maturation between organic and conventional potato plants at harvest. The differences between countries can also be explained by differences in climate (relative risk of disease), in practice in organic farming (use of copper sprays or not) and in practice in conventional farming practice (use of manure, amount of synthetic fertilizer applied). However, this type of interaction between place and farming system means that it is impossible, and even irrelevant, to try to define any particular organic flavour for a product.

43. Fortunately, due to the way sensory preferences develop, consumers of organic products can (and often will) experience, recognize and cherish the typical flavour of the organic foods in their habitual diet. If consumers are informed that a sample is organic, they then perceive it as better tasting than if the same sample is being served with information that it is conventional (Johansson, *et al.*, 1999). This provides positive feedback to develop and sustain a consumer preference based on whatever difference may occur for the foods available to each individual consumer.

44. This is the same mechanism that creates and sustains sensory preferences between socially more or less desirable food production systems and other "brands", whether organic, fair trade or just generally fashionable. One notable exception to this is organic poultry (broilers). Organic regulations specify a substantially later age of slaughter (e.g. 81 days in the EU) than conventional farming (Castellini, *et al.*, 2002). The greater physiological maturity of the organic broilers at slaughter results in substantially and consistently better sensory meat quality and smaller loss during preparation and cooking than with conventionally reared birds (Castellini, *et al.*, 2002).

Organic agriculture and nutritional efficiency

45. Nutritional efficiency relates to the ability of a food to contribute to a nutritious diet. In low-income populations, nutritional efficiency corresponds to a high content of vitamins, minerals and high-quality proteins, and provides an increased levels of those nutrients most in short supply in the population's diet. In high-income populations, nutritional efficiency means low levels of fat and sugar and high content of phytochemicals, to best contribute to a balanced diet.

46. Many studies have compared contents of nutritionally relevant compounds in foods produced using organic and conventional methods (reviewed several times e.g. Magkos, *et al.*, 2003). While a few systematic differences in composition have been found (Magkos, *et al.*, 2003), very few of these studies assessed the relevance of these differences for population health.

47. Compared with conventional high-input production, organic plant foods tend to show higher levels of vitamin C, less nitrate, less total protein, higher levels of plant secondary metabolites (phytochemicals) and a higher proportion of essential amino acids in the protein. In developed

countries, almost everyone obtains more than sufficient amounts of vitamin C and essential amino acids from their diets while vitamin C deficiency is common in some developing countries (Ali and Tsou, 2000). However, no studies seem to have been published comparing the vitamin C content in organically produced vegetables with the content in vegetables from the low-input "subsistence" agriculture typical of poor areas, where yields are substantially lower than on comparable organic farms.

48. While an increasing body of evidence indicates that plant-derived nitrate benefits health (McKnight, *et al.*, 1999; Lundberg, *et al.*, 2004; 2006), no studies have assessed if differences in nitrate concentration within one type of vegetable (as opposed to differences in intake of one or more types of vegetables) have any consequences for health. Regarding plant secondary metabolites, Brandt and Mølgaard (2001) have argued that on a fresh weight basis, organic foods consistently contain 10 to 50 percent higher concentrations than comparable conventional foods, due to the mechanisms explained above for natural plant toxins.

49. Based on data from Van't Veer, *et al.* (2000), Gundgaard, *et al.* (2003) calculated that a 60 percent increase in intake of mostly conventionally grown vegetables and fruit (from 250 g per day to 400 g per day) would increase average life expectancy by 0.8 year by reducing the incidence of cancer and, less pronounced, by reducing the risk of cardiovascular disease. If the plant secondary metabolites really are the main health- promoting compounds in vegetables (Brandt, *et al.*,. 2004), and taking into account the uncertainty intervals in the cited publications, linear interpolations of these figures indicate that a total switch from conventional to organic vegetables throughout life would result in 1-12 months increase in life expectancy. Ongoing and future research will provide more precise data to refine this estimate. It must be emphasised that future changes in practice in organic or conventional agriculture may also change the magnitude of this difference (Brandt and Mølgaard, 2001), so as new data become available, old data will become obsolete.

50. For animal foods, a higher proportion of roughage eaten by organic animals, in particular fresh grass, as is typical but not exclusive to organic production (Vaarst, 2006b) results in different composition of the lipids, with more unsaturated and conjugated fatty acids in organic meat and milk, as well as more vitamin E (Soil Association, 2007). A recent survey in the Netherlands, where fresh grass is only a minor proportion of the diet of average conventional cows, showed that milk from breastfeeding mothers whose diets contain a large proportion of organic food also have a significantly higher content of conjugated linoleic acids (CLA) than from mothers who eat mostly conventional food: 0.34 percent versus 0.25 percent (Rist, *et al.*, 2007). Several studies show significant correlation between CLA content of the diet and health measurements. If future controlled studies confirm a causal relationship between this group of compounds and the health benefits, then this result is a very strong indication of direct benefits of organic agriculture for health in areas with comparable dietary and agricultural practices. It also will allow calculations of consequences for health, as above, for vegetables and fruit. However, at present, it is not known if these differences are large enough to have any consequences for health (Magkos, *et al.*, 2003).

51. When evaluating differences in nutrient content between organic and conventional food, it is important to take into account the absolute content in the food and the recommended daily intake of different nutrients in the diet, if known. For example, the recommended daily intake of vitamin E is 15 mg per day, the recommended upper limit for total intake of (full-fat) milk and milk products is 1 kg per day, corresponding to 30 g of milk fat. The vitamin E of organic milk is consistently and significantly higher than conventional milk by 0.1 to 0.2 mg per kg milk (Soil Association, 2007). So

if a diet is deficient in vitamin E, changing to organic milk from conventional will as compared with other changes to the diet. For example, 10 conventional peanuts contain 0.8 mg of vitamin E (USDA, 2005) and only approx. 5 g of fat.

52. Very few published studies have relevance for the typical conditions of developing countries, where lower food availability makes the nutrient content of each part of the diet particularly important. Comparisons of Zn and phytate contents of cereals grown on tropical, P-deficient soil consistently show better Zn/phytate ratios in material fertilized with plant residues or on organic farms, to a degree that might have nutritional relevance in Zn-deficient populations (Brandt and Mølgaard 2006).

53. Most studies have focused on the composition of individual foods, although it is clear that increasing the diversity of crop and animal species produced in an agricultural system will also increase the nutritional adequacy. This is simply because a food rich in any one nutrient normally will be low in at least one other nutrient, so a combination of different species as raw materials gives a more balanced diet than any one species can provide. Brandt and Kidmose (2002) made some calculations based on published tables of nutrient contents in various foods, and Johns, *et al.* (2006) also described the potential nutritional benefits of increasing diversity of crops and food animals. However, no actual experimental surveys seem to have been published on this crucial aspect of organic agriculture.

54. Even the connection with organic agriculture is, at present, primarily theoretical rather than documented, although there are some mutually supportive aspects:

- diversity is directly promoted in organic agriculture as being in line with the philosophy of the origins of the organic movements and specifically mentioned in its principles (IFOAM, 2005),
- the need for crop rotation and/or fallow land to conserve and regenerate soil fertility provides a direct incentive for organic farmers to introduce crops and/or animals that can optimize production on land that cannot be used for the main crop; and
- the emphasis on the values of traditional, locally adapted resources, where improving the status, (e.g. indigenous and under-utilized seeds and breeds), can provide valuable sources of nutrients (van Rensburg, *et al.*, 2004).

C. IMPROVING HEALTH AND IMMUNOLOGICAL PARAMETERS

55. While it is clear that improving a nutritionally unbalanced diet or eliminating safety hazards will improve health and nutrition, some studies indicate that even in well-nourished populations with effective safety regulation systems, organic lifestyle is still associated with better than average health, particularly for dealing with allergies. This could be due to either a tendency for consumers of organic food to make a greater effort of health promotion than non-consumers, or to some compositional difference between organic and conventional food that could cause a difference in health.

Organic agriculture and a healthy lifestyle

56. Epidemiological studies have compared school children in Rudolf Steiner schools, which belong to the anthroposphic movement and consume biodynamic foods. One study in Sweden (Alm, *et al.*, 1999) and the PARSIFAL study (Alfvén, *et al.*, 2006) in four countries across Europe, found

that children from families with an anthroposophic lifestyle, which includes a preference for organic/biodynamic food, had significantly lower incidence of a range of allergic symptoms than the children in control groups. The PARSIFAL study also recorded a tendency for lower Body Mass Index (BMI) among the anthroposophic children. In such observational studies, it is not possible to distinguish if it is the effect of the organic food, or if people who join an organic lifestyle generally are more health-conscious and therefore eat healthier, exercise more regularly, etc. In fact, surveys of shoppers (Williams and Hammitt, 2000) indicate that those who bought organic food also appear to be more health-conscious in other regards.

Physiological impact of organic food

57. The only way to separate the effects of lifestyle and diet is to use controlled intervention studies, either with human volunteers or with animals. Since it is extremely difficult to control human diets for extended periods of time, it is not surprising that, until now, no human controlled intervention study has shown any definitive difference in physiological characteristics with clear implications for health that unequivocally was caused by differences in production systems (Magkos, *et al.*, 2006). When differences were found (Grinder-Petersen, *et al.*, 2003), they could have been due to different varieties as well as to the production method as such (Magkos, *et al.*, 2006). A true reflection of the impact of differences in the content of actual shopping baskets is interesting in the time and place it was done, but cannot be generalized to other times and places, when the precise causal factors are not known.

58. In contrast to the situation with humans, studies of controlled diets are relatively easy to perform in animals. As reviewed by Magkos, *et al.* (2003), reports of early studies (before 1950) of organic food and feed emphasized positive effects on general well-being and resistance to diseases in people, animals and plants. However, the design and reporting of these studies did not meet today's standards for scientific evidence. A recent study on rats fed conventional or organic wheat showed a higher level of lymphocyte function in the organic treatment (Finamore, *et al.*, 2004). However, this study was designed to test a very sensitive method for detection of food-induced immune deficiency, not to compare food production systems, so it used a model (young rats deliberately malnourished by a protein-deficient diet) that has little relevance for most human consumers of organic food.

59. In a recent study of rats fed controlled diets from different production systems (Lauridsen, *et al.*, 2005), those fed with feed from a model of an organic production system showed increased amount of IgG as well as lower accumulation of adipose tissue and less activity during the day (indicating more uninterrupted sleep) than in other treatments. While data from such model studies cannot be directly extrapolated to humans, it is intriguing how well they reflect the data from the above-mentioned human epidemiological studies – which did not include sleep quality in their questionnaires.

D. MINIMIZING LOSSES OF POST-HARVEST OPERATIONS

60. Generally, the quality of food materials deteriorates after production, in particular fresh materials such as vegetables, eggs, fruits and milk. However, most foods are produced only or mainly in certain seasons or areas, and therefore must be stored and/or transported before reaching the consumer, in spite of most consumers' preference for freshly produced food.

61. Three aspects of organic agriculture affect post-harvest losses of plant foods: i) the susceptibility of the plant material to disease, ii) the time spent in transport from producer to consumer and iii) the time seasonal products spend in storage.

62. Regarding susceptibility to disease, the above-mentioned mechanisms for promoting increased resistance to disease in organically grown plants also reduce storage losses caused by rot and moulds. For example, organic cereals have a lower content of mycotoxins (Benbrook, 2005) and organic Swiss chard has a longer shelf life (Moreira, *et al.*, 2003).

63. Researchers studying storage diseases have found that unsprayed control treatments suffer the greatest losses in storage experiments that compare different conventional pesticide treatments. Thus, they often assume that the losses in organic crops are the same as in unsprayed conventional crops. However, in the few cases where different fertilization regimes have been compared under unsprayed conditions, the moderate nutrient supply typical of organic agriculture has consistently lead to significantly lower disease scores after harvest than intensively fertilized crops such as wheat (Birzele, *et al.*, 2002) and apples (Pedersen and Bertelsen, 2002).

64. Transportation often affects food negatively and can accelerate deterioration and, ultimately, loss after harvest. In particular, this happens when a food cannot be kept under its optimal storage conditions, such as during transport from a supermarket distribution centre when different products are transported in the same truck.

65. Many consumers are concerned about unnecessary transport of food, both in relation to food quality and as a source of CO_2 and other pollutants. Transport for foods produced throughout much of the year, such as milk, greenhouse vegetables and eggs, can, in principle, be minimized if these foods are produced close to where the consumers live and consumers consistently buy products brought directly from the nearest producer. However, in industrialized countries, this situation is very rare, due to a variety of economic and historic reasons, most importantly the “economy of scale”.

66. Organic producers are more likely than corresponding conventional producers to market their products locally through farm shops, self-picking, farmers markets etc. (Torjusen, *et al.*, 2001). This is partly because consumers who are willing to pay a premium for organic products tend also to be interested in local products, and partly because organic producers often have strong views on this issue and see it as a civil obligation for them to offer their products to their community, even if they could get marginally higher profits by selling it all to wholesalers.

67. The Austrian concept of *Selbsternte* (self-harvest) is a particular form of local production with no transport to retailers involved (Vogl, *et al.;* 2004). Participating farmers situated near a city prepare one of their fields, sow a variety of vegetables, divide the sowed field into small plots and then rent out the plots to city dwellers who look after their plots during the summer and then harvest the vegetables. This system allows a landless family to participate in real local organic production and enjoy consumption of freshly harvested vegetables, while leaving crop rotation, fertilization, drainage, purchase of certified seeds, etc, to the expert, i.e. the farmer who owns the land. Similar schemes allow consumers to “adopt” or buy shares in apple trees, cows or other animals and then receive fresh fruit, milk or meat from their “own” animals or plants.

68. In most developing countries, it is still common for farmers to produce a variety of plant and animal foods, focused on the needs of their own families and communities, and sell most of their

surplus products directly to the consumers at markets, with the exception of cash crops intended for export to other regions or countries. These traditions are threatened by economic forces similar to those mentioned above, further exacerbated by unique problems such as inadequate transport infrastructure and subsidised imports.

69. In most cases, the establishment of organic agriculture in a region includes an element of empowerment by offering an alternative to the conventional way of doing things. It also requires some level of farmers' organization or cooperative, for example to manage the demands of certification and mutual advice (van Elzakker, 2006). Due to this, organic agriculture can provide means for farmers and consumers to support local products as opposed to imported ones, by organizing transport and local distribution chains, marketing and catering, focusing on the "local" as well as the organic (van Elzakker, 2006). However, few, if any, developing countries have so large organic agriculture movements that data are available to quantify this effect.

70. Some crops, such as cereals and many fruits and vegetables, are harvested only once a year, creating a demand to store them throughout the year. Greater diversity of crop choice, in a diverse crop rotation incorporating early and late varieties and different crops used for similar purposes, will reduce the time much of a crop needs to be stored before the next crop is harvested. In organic agriculture, diversity in the rotation is necessary to optimize the maintenance of soil fertility, so everything else being equal, this will both reduce post-harvest crop losses and improve the freshness of the food at the time of consumption. In addition, that the greater environmental and food quality awareness of consumers who demand organic products results in a conscious effort to select foods when they are in season, particularly for domestic fruits and vegetables.

E. REDUCING TOXIC EXPOSURE TO FARMERS AND POLLUTION OF DRINKING WATER AND THE ENVIRONMENT

71. The use of pesticides in conventional agriculture is a major health hazard for farm workers and their families. In addition, both pesticides and surplus fertilizer often leak from conventional fields, pens and depots, damaging the environment, particularly lakes, rivers and estuaries. Organic farms do not leak pesticides and fertilizer runoff is normally (but not always) much less than from conventional farms.

Organic agriculture and pesticide poisoning

72. Pesticide-related health hazards for farm workers and their families are very substantial, particularly in developing countries. Since Forget (1991) estimated more than 20 000 deaths per year related to pesticides, most of them in developing countries, global pesticide production has increased by 50 percent (Carvalho, 2006), mostly in developing countries. In developed countries legislation on health and safety, including bans on the most toxic and bio-accumulating pesticides, has reduced pesticide-related health problems to a level where precise data are difficult to obtain (Ritter, et al., 2006).

73. Studies of workers in the pesticide industry or those using pesticides on farms have indicated increased risk of infertility and Parkinson's disease (Ritter, *et al.*, 2006; Gorell, *et al.*, 2004).

However, studies also showed that, in addition to pesticides, working with copper and other heavy metals such as lead and manganese significantly increased the risk of Parkinson's disease (Gorell, *et al,*. 2004). So, in countries where copper salts are still allowed in organic farming, organic farmers may not achieve the full reduction in risk of Parkinson's. Studies of greenhouse workers have shown changes in blood biomarkers even when no acute symptoms were apparent (Hernández, *et al.,* 2006), indicating a risk of chronic disease, in particular among a subgroup with genetically determined increased sensitivity to certain pesticides.

74. In contrast, studies of farm workers or smallholder farmers in developing countries consistently find high incidences of readily measured intoxication symptoms, correlated with pesticide exposure (Konradsen, *et al,*. 2003; Ohayo-Mitoko, *et al.*, 2000; Yanggen, *et al.,* 2003). A study in Ecuador (Yanggen, *et al.*, 2003) showed that the average cost of farmers' sick days, medical bills and reduced work productivity caused by each case of pesticide poisoning corresponded to 11 day's wages and more than offset the additional income from increased yield. Farmers' children in developing countries are often poisoned due to accidental contact with pesticides kept in easily accessible containers in the home (Konradsen, *et al.*, 2003). Additionally, in many areas, pesticides are the most common means of suicide, often reaching double figures as a percentage of total deaths in rural areas (Konradsen, *et al.*, 2003)

75. The prospect of paying substantial fines and/or generous compensations to affected workers or bystanders provides powerful incentives for pesticide users in developing countries to adhere to most of the safety regulations most of the time, and has substantially reduced the number and severity of pesticide poisonings compared with the 1980s (California Deptartment of Pesticide Regulation, 2005). However, many developing countries do not yet have the necessary administrative and operational capacity to establish and enforce such rules (Konradsen, *et al.,* 2003; Yanggen, *et al.,* 2003). In these cases where bans or taxes tend to have little effect or are unrealistic to enforce, the only effective strategy for reduction of pesticide exposure is to introduce alternative methods to increase yield and income (Konradsen, *et al,*. 2003), such as organic farming methods.

Organic agriculture and pollution of water and the environment

76. The main agricultural pollutants affecting drinking water and the general environment are zoonotic or human pathogens, pesticides and plant nutrients. Contamination of drinking water with pathogens is a major cause of disease and mortality in large parts of developing or recently developed countries.

77. Most pathogens contaminating drinking water originate from animal or human wastes that enter wells or surface waters, through i) deliberate discharge, ii) carelessness, such as discharge of contaminated water used to clean toilet buckets or inadequately designed or maintained animal pens or landfill sites, or iii) accidental contamination caused by floods or collapse of slurry tanks (Ritter, *et al.,* 2002). In other words, for all except the worst floods, contamination can be prevented with careful planning and adequate investments at a fraction of the cost of the sewers and wastewater treatment facilities found in most developed areas. In this context, the regulations banning the use of synthetic fertilizer in organic farming and restricting import of organic materials provide a powerful economic incentive to farmers to invest in facilities to collect, compost and store all nutrient-containing organic material, and to keep the facilities in good repair to prevent any leakages, since the nutrients already present on the farm have a very high value.

78. In contrast, for a conventional farmer, the nutrients in farm wastes have little or no value, since the additional work and costs of spreading them on the fields are higher than the price of the corresponding amount of synthetic fertilizer. For them, there is little economic benefit of exceeding the absolute minimal standards accepted by the relevant authorities (if any). If the animal waste treatment is done using best practice, most pathogenic micro-organisms are eliminated (Bicudo and Goyal, 2003). This means that in areas without effective municipal sewer systems, where contamination of water with human and animal urine and excrement is a problem, these composting facilities can also provide safe disposal of human waste. Composting of human waste, as in the use of "composting toilets" in remote areas of industrialized countries (Langergraber and Muellegger, 2005), turns a problem into a resource. As for animal waste, organic farmers' economic incentive to collect and treat the waste will be higher than for conventional farmers in the same area.

79. However, in many cases such as annual food crops, recycling nutrients from human waste as fertilizer would be discouraged, for ethical reasons or food safety, to protect the consumers of the crops. The use of municipal sewage sludge is prohibited in many organic regulations. The reason for banning sewage sludge is that most existing sewage system designs allow the sludge to be contaminated with heavy metals and other toxins from other sources than the human waste, and these contaminants should not be re-introduced into the food chain.

80. Pesticides have caused a range of environmental problems that can only be solved by terminating their use, as in organic agriculture. The best documented examples are DDT and similar persistent bio-accumulating endocrine disruptors that caused egg shell thinning and other malformations that decimated many populations of carnivorous birds in the 1960s and 1970s (reviewed in Vos, *et al.*, 2000). Most of these bird populations subsequently recovered after DDT was banned in the developed countries, although the shell thickness has not yet reached the pre-1946 level (Vos, *et al.*, 2000).

81. However, due to their low price and low acute toxicity, these pesticides are still in widespread use in developing countries (Carvalho, 2006) where they have recently been linked to problems with human fertility (Weiss, *et al.*, 2006), although it is not known how much of the exposure is environmental or occupational. The particularly serious issue with these types of compounds is that they disrupt the normal development of foetuses (Vos, *et al*., 2000), so health problems will persist for at least one generation after their use has ceased. However, these compounds are fat-soluble and tend to bind strongly to surfaces, so they are not a pollutant of concern in relation to drinking water (Ritter, *et al.*, 2000). In contrast, water-soluble pesticides such as atrazine occur very often in drinking water (Ritter, *et al.*, 2000). However, the same chemical properties that make these compounds easily soluble in water also promote rapid excretion after ingestion, so potentially harmful concentrations are extremely rare, even in areas with widespread use (Ritter, *et al.*, 2000).

82. Plant nutrients leach into ground water when mineralization in soil is higher than the uptake by plants and precipitation is higher than evaporation, such as during winter/spring or the beginning of a rainy season. Nutrients can also be lost in surface runoff. In the United States, contamination by plant nutrients is the most widespread cause of water quality impairment (Ritter, *et al.*, 2002).

83. Studies comparing the leaching of nitrogen (N) from organic and conventional farms in developed countries tend to conclude that the differences are small, but generally in favour of organic farms (e.g. Knudsen, *et al.*, 2006). They found the type of products and the general quality of the farm

management to be more important factors than the type of production system. Still, due to the relatively high value of this material as a crop fertilizer the incentive to minimize runoff and leaching of nutrient-containing waste is greater than in comparable conventional farms, so it is reasonable to expect that a greater effort will be expended on nutrient management, and very good nutrient utilization efficiency is possible in organic agriculture. For example, a best practice demonstration rotation allowed the sustained production of crops of vegetables or cereals (without need to import manure or other fertilizer) five years out of a six-year-rotation by careful use of catch crops, legumes and optimal crop sequences (Thorup-Kristensen, 1999).

84. However, the accepted method for surveys of nitrate leaching is to calculate inputs of nutrients and outputs in sold products, and assume that the proportion of N lost to the atmosphere only depends on the soil type (Knudsen, *et al.,* 2006). Intriguingly, when comparing organic, conventional and integrated pest management fruit production systems on the same soil type, and actually measuring the nitrogen below the root zone and losses by emission into the air, it was shown that the conventional soil had a much lower denitrification activity (formation of gaseous N_2), resulting in more than four times higher leaching of nitrate to the groundwater, despite identical N inputs and similar outputs in all three systems. If this feature is typical of organically managed soils, then the balance will favour organic crop production compared with conventional, much more than previously expected.

85. The other nutrient that can occur as a major pollutant is phosphorus (P) (Ritter, *et al.,* 2002; Hart, *et al.,* 2004). However, for P, the literature shows substantially and systematically less leaching from organically fertilized soils than from soils treated with synthetic fertilizer (Hart, *et al.,* 2004), probably due to formation of complexes with organic molecules that facilitate immobilization by binding to soil particles.

86. Still, some organic farming practices pose particular problems in relation to nutrient leaching. Notably, outdoor pig production, whether organic or conventional, requires very qualified and intensive management to prevent substantial N-leaching (Quintern and Sundrum, 2006), while indoor pig production allows the farmer to collect all slurry and manure and spread it on the fields at a time of year when the crops are best able to utilize the nutrients.

87. Leaching of nutrients is a major threat to biodiversity due to eutrophication (Camargo and Alonso, 2006; Hart, *et al.,* 2004). In relation to human health, the proliferation of toxic cyanobacteria, dinoflagellates, etc., in eutrophied waters poses a substantial health risk to those who have to use such water for cooking or who eat seafood from the polluted water (Camargo and Alonso, 2006).

88. In contrast, even the highest levels of phosphorus that can realistically occur in drinking water are not considered any risk to human health (Hart, *et al.,* 2004). While some authors link intake of nitrate from drinking water with deaths of babies from methemoglobinemia (60 per year on average) as well as a host of other diseases (Camargo and Alonso, 2006), others question the methodology of this risk assessment and suggest that nitrate is positive for health (Lundberg, *et al.,* 2004) and that contamination with feces had caused high levels of both nitrate and the real culprit; pathogenic bacteria.

II. SUMMARY OF FINDINGS

89. The following summarizes the various issues discussed in this paper regarding benefits of organically produced food in terms of the food utilization and in comparison to conventionally produced food.

90. *Food safety*: Many aspects of organic agriculture reduce the risks of pathogens (zoonoses), mycotoxins, bacterial toxins and industrial toxic pollutants, compared to conventional agriculture. However, some other aspects potentially increase them. Reduced resistance to antibiotics in zoonotic pathogens indicates a better prognosis for patients if an infection does occur. For natural plant toxins, the content in plants appears to systematically be 10 to 50 percent higher than in conventional plants. However, this is in a range of concentrations where these compounds have no toxic effect and may even benefit human health.

91. *Pesticide poisoning*: This is an area where very substantial health problems have been documented, especially among farmers and their families. Pesticide poisoning causes some 20 000 deaths per year globally and an average of 11 days wages lost due to illness, per farmer per incidence, in some areas. Even symptom-free workers often exhibit biomarker changes indicating increased risk of diseases, including Parkinson's disease. With the present level of knowledge, elimination of such horrible conditions, which can be achieved on a short timescale, is the quantitatively single most important benefit of organic farming in terms of human health. Still, long-term occupational exposure to copper also increases the risk of Parkinson's disease, but not as much as exposure to synthetic pesticides.

92. *Pesticide residues:* The levels in organic products are consistently 4 to 5 times lower than in conventional products. However, no definitive causal connection with harm to consumers has ever been demonstrated for food produced in accordance with general (conventional) food safety rules. Errors and accidents can cause contamination with harmful levels of pesticides, but this risk is eliminated when no pesticides are present. Across the different safety risks in both systems, the best managers achieve much better standards than the average producers, and the occurrence of serious hazards is so low that no significant differences have been demonstrated between production systems.

93. *Food quality*: Consumers generally appreciate that food is authentic and trustworthy and produced with care for them and the environment. So reduced food additives and pesticide residues, good traceability and emphasis on animal welfare all support the perception of organic food as being of high-quality. Differences in taste between organic and conventional food products are strongly affected by interaction with local aspects and therefore show few general trends. Only poultry (broiler) produced according to the organic standards results in a clearly differentiated taste compared with mainstream conventional products.

94. *Nutritional adequacy*: In developing countries, organic agriculture has several advantages for the provision of nutrients, such as higher Zn/phytate ratio and better amino acid composition in cereals. Also, a more balanced diet due to the greater diversity of organic rotations, including legumes and various types of vegetables, and the need for animals on each farm provide important nutritional benefits. In developed countries, nutritional value is much more difficult to determine. However, the higher levels of plant secondary metabolites and conjugated fatty acids in milk may provide important protection against cardiovascular disease, cancer and other diseases known to be influenced by diet.

95. *Human health*: Epidemiological studies have shown better health scores among consumers of organic food for immunological characteristics and weight control, and similar benefits have been reproduced in animal studies, supporting a possible causal role of the food production system.

96. *Post-harvest operations*: Higher activity of plant defense mechanisms in organic plants reduces the losses during transport and storage. The preference for local products and short supply chains also reduce the loss of quality during transport.

97. *Pollution of drinking water*: Organic farmers have substantially higher economic incentives than conventional farmers to establish and maintain sufficient capacity for collection, composting and incorporation of animal and human wastes as valuable fertilizer. This is particularly important in areas where sanitation is not provided or standards not enforced by the authorities. Such measures will also substantially reduce contamination with nitrates and phosphorus. There is little evidence that these minerals have any harmful effects on humans, if the drinking water is free of pathogens, except by promoting blooms of toxic algae.

98. *Pollution of the environment:* Persistent pesticides (such as DDT) have damaged wildlife globally and are still being used in many developing countries. Organic agriculture protects the local environment against all types of pesticides and has potential to benefit the global situation if the proportion of land under organic management becomes large enough to reduce the total use. Pollution with nitrate and phosphorus are major causes of eutrophication. Organic farms leach lower levels of phosphorus into drainage water than conventional ones. For nitrate, the loss from organic farms tends to be slightly lower than conventional, except when comparing organic outdoor pig production with conventional indoor production. However, recent data indicate that organically managed soil may be more efficient at denitrification, releasing most of the nitrate into the atmosphere as harmless N_2. If this is a general trend, the benefits of organic farming are much larger than previously estimated.

III. CONCLUSIONS

99. Organic agriculture offers a wide range of benefits for food utilization, both in developing and developed countries. The greatest advantage that can be quantified today is the protection of farm workers and their families from exposure to pesticides, particularly in developing countries.

100. In developing countries, the greatest potential advantage for consumers of organic food is a more nutritionally balanced diet resulting from greater diversity of crops and animals. In developed countries, potential benefits are increased intake of compounds such as conjugated linoleic acids and plant secondary metabolites, which may play important roles in prevention of cancer and cardiovascular disease.

101. Some aspects of organic agriculture, such as requirements for outdoor rearing of animals and the use of manure for fertilizer, may pose potential food safety problems, while the increased awareness of standards and producer responsibility provides a vehicle for advice and education to improve food safety management. The increasing body of data on actual incidences of food poisoning show no significant differences between production systems, indicating that the better control compensates for the potential risks, except for some specific places and periods where the capacity for

advice and education has been overwhelmed by large numbers of conventional farmers converting to organic agriculture.

102. Important research needs are, among others, a better understanding of:

- consequences of organic agriculture on the nutritional quality of the diet, both in developing countries (focus on diversity) and in developed countries (focus on foods without additives and with different composition of the raw materials), in particular effects that are indirect consequences of the standards, for example a reduced proportion of refined starch in the diet;
- relations between the higher economic incentives for preserving fertilizer value of organic wastes and the actual behaviour of organic farmers, in particular for safeguarding of water quality;
- psychological and behavioural aspects for both farmers and consumers of self-reliance, ethical standards and personal responsibility as central features of the organic philosophy, and the effects on quality of life in a wider sense than just economy and health.
- Information from research into issues 1 and 2 will also be useful for improvements of conventional farming, in particular as rising energy prices make synthetic fertilizers less accessible.

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CASE STUDIES

Relocalizing Food Systems for Food Security: Successes and Challenges in Cuba

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Introduction

Organic agriculture in the South is frequently promoted as a means by which farmers may gain access to niche western markets. But concerns about yield performance and labour requirements limit the extent to which organic production is accepted as a mainstream approach to achieving global food security (Pinstrup-Anderson et al., 1999). Although there are many who do not share these concerns (Parrott and Marsden, 2002), examples of the nationwide practice of organic agriculture are scarce (Pretty, 1995).

Throughout the 1990s, anecdotal evidence emerging from Cuba suggested that this country might provide such an example (Carney, 1993; Rosset, 2000). With the dissolution of the Soviet block and the tightening of trade sanctions by the United States, Cuba was forced to undergo a major agricultural transformation as its imported supplies of agrochemicals, petroleum and food dwindled to 10–50% of previous levels. These events inspired a doctoral research project conducted at Wageningen University, the Netherlands[1]. The National Institute for Agricultural Sciences, Cuba hosted the fieldwork from 1999 to 2001.

Both quantitative and qualitative research methods were applied in this study and more than 350 farmers, researchers, extensionists and policy makers participated from the agriculture, health, education, civil society, environment and science sectors across three representative provinces of Cuba: Havana, Cienfuegos and Holguin (Wright, 2005). The research included an analysis of major cropping systems, coping strategies in the agricultural sector, changes in the food system and the development of organic agriculture. In order to capture the diverse nature of the topic, the research utilized a systems approach to examine not only food utilization but the overarching themes of organic agriculture and food security as well.

The research demonstrated that rural production in Cuba was not organic: 83 percent of farmers wished to use more chemical inputs when they became available and substituted with organic inputs only when availability of chemical inputs was limited. The State aimed at 70 percent high-input or integrated production of many staple crops, and the small quantity of chemicals available were allocated to specific crops and farms while others received none. This produced a patchwork of organic, integrated and industrialized approaches to agriculture at the field, farm and regional levels.

Cuba's reputation as an 'organic nation' could be attributed to its urban agriculture network. Urban dwellers had rapidly turned to organic production at the start of the country's food crisis and this

[1] This study was carried out at the School of Communication and Innovation Studies, Department of Social Sciences. The research was partly funded by a European Union Marie Curie Research Award and by the Netherlands Foundation for the Advancement of Tropical Research (WOTRO).

system proved viable in contributing to food security within a short time, attracting government support for its continuation. Rural production, however, had been slower to change.

Nevertheless, Cuban farmers, researchers and extension workers reported that based on empirical evidence, widespread organic production was technically and economically feasible, and conferred notable environmental and health benefits to both humans and livestock. Five major challenges to its wider uptake were identified: (i) lack of access to organic inputs and knowledge of organic agriculture (exacerbated by lack of fuel); (ii) lack of inclusive policy support; (iii) reluctance to face change; (iv) misperceptions about organic agriculture; and (v) fear of losing control.

Throughout the 1990s, Cuba remained somewhat dependent on food imports and aid while State agricultural subsidies fell by 50–90%. Nevertheless, production of major crops doubled toward the latter part of the decade and for some crops surpassed yields of the 1980s. These production increases were in part the result of organic production techniques but could also be attributed to pragmatic policy measures such as offering farmers incentives to diversify and increase production through higher prices and access to land, and decentralizing and downsizing monolithic State co-operative farms to encourage farmer ownership. Agricultural wages tripled and there was mass migration back to rural areas.

As a result, Cuba became more self reliant in its food production. More importantly, it succeeded throughout its food crisis to maintain a basic and equitable food ration for every citizen. By the end of the 1990s, the population was being weaned off this ration and into diversified market outlets; food availability increased by 25 percent. This was achieved not only by increasing production quantities, but by prioritizing fuel-saving food security measures. These included: an emphasis on self-provisioning at the household, farm, municipal and provincial levels; local and regional food processing, storage, access and distribution networks; and export restrictions on crops for which there was an unfulfilled domestic demand. The major outcome was the decentralization of the State food system towards a model that could be described as organic.

Experiences in Cuba indicate that the most important factor ensuring food security is a cohesive policy across all sectors of the food system, with agricultural strategies playing a crucial role within this. During the crisis, it was the small, diverse farmers that were able to maintain the domestic food supply; the large monocultural farms lacked such resilience.

In the new millennium, the degradation of Cuba's natural resource base through continued industrialized practices showed signs of exacerbation by climate change: one quarter of Cuba's agricultural soils had become uncultivable and water tables in the drought-stricken east of the country were turning saline. Human health was also becoming a major concern with a resurgence of obesity and diet-related diseases to pre-1990 levels.

Although the urban agriculture movement had provided sufficient fresh vegetables, knowledge gaps on the links between diet and health was meant low levels of consumption. In addition, the State ration continued to focus on bulky carbohydrates and feelings of food insecurity lingered among the population. At the same time, studies indicated that pesticide residues on some crops exceed the maximum permissible levels. To reverse these trends, a more holistic approach to agriculture is would be required.

Conclusions

While the rhetoric on organic agriculture in Cuba proved to be largely unsubstantiated, the country did develop its own brand of locally appropriate agriculture, and demonstrated the effectiveness of integrated policy measures to tackle food insecurity. Although it is arguable that Cuba's distinct style of centralized governance precludes its usefulness as a model, decisions regarding food resources and systems in other countries are centralized in a similar manner among a few corporations. In this sense, Cuba's achievements in moving from a highly vulnerable situation to one of relative food security within one decade show what can be achieved with a firm political commitment to prioritize the basic right to food and to re-localize the food system in the process.

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Impact of Organic Agriculture on Food Utilization in Egypt

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Introduction

Health is one of IFOAM's four principles of organic agriculture, along with ecology, fairness and care. Health is also one of the main components of food utilization. This indicates that health of individuals and communities cannot be separated from the health of ecosystems – healthy soils produce healthy crops that foster the health of animals and people.

Health is not simply the absence of illness, but the maintenance of physical, mental, social and ecological well-being. Immunity, resilience and regeneration are key characteristics of health. Thirty years ago, the SEKEM Initiative started its first farm on 24 ha in the desert, 60 km northeast of Cairo. This was the first farm in the country, perhaps in the Middle East, to introduce and adapt biodynamic systems. As a result, the organic certified area in Egypt has increased to almost 20 000 ha with another 20 000 ha in transition.

Although still a very limited area comprising less than 1 percent of Egypt's cultivated land, organic agriculture has made contributions to improving environmental parameters, preventive health care and reducing diseases. This paper discusses the influence of organic agriculture on the Egyptian health system.

Results

Less polluted air

To increase soil fertility of organic farms, microbial compost has replaced mineral fertilizers. Today, Egypt's annual compost production amounts to 1.6 million tons. The main ingredient of this compost is rice straw that farmers traditionally burned at the end of the harvest. Considering that burning 1 kg of rice straw produces 56 kg of carbon monoxide (El-Haddad, 2001), it can be noted that using 500 000 tons of rice straw to produce compost rather than burning it reduces the carbon monoxide by 32 500 tons. In Egypt, it is estimated that carbon dioxide emission has been reduced by some 26 000 tons as a result of cultivated organic areas and that emissions of nitrous dioxide and methane gasses have also been reduced. If the goal of increasing the cultivated area under organic agriculture to 10 percent in the next five years is met, its impact on air pollution will be noticeable.

Less polluted drinking water

One of the main causes of water pollution is heavy use of chemical fertilizers and pesticides. Recently, due to the economic liberalization policy and increased exports on the international market, farmers have had to reduce their use of chemical fertilizer and improve the fertilization methods through the use of biological fertilizers. The widespread use of organic agriculture in the farming community has helped farmers improve their practices. This, in addition to the impact of cultivating 20 ha organically, has reduced the amount of chemical fertilizers by 50 000 tons. Published research shows that nitrate leaching rates per ha are significantly lower in organic agriculture than in conventional systems. There is still a long way to go to solve the problem but, hopefully, with expected expansion of organic agriculture, the quality of drinking water will improve.

Reduction of pesticide use

Shame Heaton, a chemical nutritionist, in evaluating organic and non-organic food found that only seven of the 450 pesticides allowed in conventional farming are allowed, on non-routine basis, in organic farming. These seven degrade quickly and rarely leave any residue on organic food. In contrast, multiple pesticide residues can be found on many non-organic fruits and vegetables. Pesticide residues rank among the top three environmental cancer risks and are linked other health issues. In Egypt, as a result of the positive impact of the organic agriculture system, the amount of pesticide chemicals was reduced from 30 000 tons annually in the early 1990s to around 3 000 tons today.

Food quality

Organic food is of higher quality than conventional food. There are many well-known reasons for these advantages.

- It contains more nutrients. Nutrient levels in fruits, vegetables and grains are lower now than they were 60 years ago and multiple nutrient deficiencies are on the increase which, in the long-term, can increase susceptibility to more serious disease. However, in organic produce, levels of all nutrients, on average, are higher, particularly vitamin C, magnesium, iron and phosphorus.
- It contains more phytonutrients. These naturally occur in plants and protect them from disease and pests.
- It contains fewer food additives. Certain additives and ingredients that have been linked with such disorders as heart disease, osteoporosis, asthma and neurological disturbances are prohibited in organic processing. Around 30 additives are permitted in organic produce (only when necessary), compared with more than 500 in conventionally produced foods.
- It contains fewer nitrates. Nitrate can be converted into a more harmful substance that has been linked to cancer in animals. Mineral fertilization practices are known to result in much higher nitrate levels in non-organic vegetables crops.

For the above mentioned reasons, Egyptians are generally willing to pay more for organic food and the market is expanding. In the last three years, SEKEM products sold in Egypt increased by 15, 34 and 20 percent respectively. On the other hand, under a recent UNDP project, SEKEM organic products were introduced with 20-50 percent increase in prices and the results show that there is increasing awareness and health consciousness.

Reducing toxic exposure to farmers

The members of the Egyptian Biodynamic Association of SEKEM are mostly farmers who now cultivate an area of around 2000 ha. Experience and feedback from farmers indicate that they recognize the difference between organic and non organic farming, their health problems have been reduced significantly and they are happy about improving the safety for their children.

Conclusion

In Egypt, organic agriculture may be the only practical solution to control and reduce the pollution of air, food and water and produce better and more nutritious food.

Contribution of Organic Agriculture to Food Quality and Safety in Shandong, China

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Introduction

Chinese farmland covers 122 million ha and represents all climatic zones from tropical to cold. There are some 900 million people involved in agriculture in China, representing 70 percent of the Chinese population, yet agriculture only accounts for 13.2 percent of national GDP.

In China, the organic agriculture movement was initially pushed by environmentalists in the early 1980s. They sought ways to reduce rural environmental pollution and soil erosion, improve agricultural ecosystems and enhance biodiversity. In the early 1990s, external demand from developed countries was another driving force for organic production in China. In recent years, the living standard and, consequently, the consciousness of health and environmental protection have increased among the Chinese consumers, creating increased demand for healthy foods and organic foods in China.

Organically managed land increased from about 342 000 ha (0.28 percent of total land) in 2003 to about 978 000 ha in 2005. There are currently about 20 categories of certified organic and in-conversion products. Plant products such as cereals, beans and tea account represent most organic production, while vegetables, fruits and animals are still a minor part. The land area devoted to "green food" was about 6.4 million ha in 2005 which is about six times more than organic lands. Greenfoods was introduced in the late 1980's as an attempt to produce 'pollution free' foods and to reduce the demand for petrochemical products. Since 1995, green food standards have evolved to include 2 standards, the grade 'A' for transitional levels between conventional and organic and 'AA' for full organic status.

With respect to food safety, organic production not only benefits human health, it also influences all the stakeholders and markets involved in organic agriculture. Tai'an Taishan Asia Food Co., Ltd. is an organic vegetable production, processing and trading company in Shandong Province of China. The company has been engaged in the organic industry for ten years, has exported its products to Japan and North America and its operations are respected. The development of the company has proved that the organic industry can produce enough safe food products to meet the market demands.

Results

The company history

This company was certified by Organic Food Development Center of SEPA in 1997 and subsequently received international organic certifications from OCIA (1998), JONA (2000), ICS (2001), and BRC (2005). The company has 170 000 ha of organic farmland and six vegetable processing plants. The sales of the company increased by 384 percent from 1997 to 2006. It is the leading corporation in China's organic vegetable sector, covering organic production, processing and exporting. Chinese consumers are increasingly favouring fully organic food and they are prepared to pay higher prices for it and 'AA' foods are gaining emphasis over 'A' standard green food.

The market

Organic production helped the operator overcome the "green food barriers". People's Daily, an official newspaper of China, reported on 13 July, 2006, that the implementation of the Japanese Positive List System had led to an observable decrease in the amount of agricultural products exported from China. However, Tai'an Taishan was not influenced by this action, and its exports actually increased by 20 percent over the previous year. This illustrates that the development of organic agriculture not only can contribute to breaking trade barriers, it also increases the market share. While the export of conventional product was influenced significantly by trade barriers, organic products have had predominance in domestic and international markets.

The safety of organic products

The demand for organic food in China is constantly increasing, mainly due to consumer perception that organic food is healthier and safer than conventional foods. Yuan (2005) noted that the scientific connotation of food safety includes safety, nutritional balance and sustainable supply (food security).

Rembialkowska (1999) found health-quality factors were better for organic potatoes than for conventional potatoes. With regard to other food hazards, such as natural chemicals, microbial pathogens and mycotoxins, no clear conclusions can be drawn, although several interesting points can be highlighted. As certified farms have adopted proper agricultural practices and management, people think organic food is healthier and safer. Organic farming can be seen as an approach to agriculture where the aim is to create integrated, humane, environmentally and economically sustainable agricultural production systems (Thamsborg, 2001). Principles such as nutrient recycling, prevention rather than treatment, and the precautionary principle are included in its aims and standards. Tai'an Taishan has its own laboratory and has cooperated with experts of a local agricultural university for many years. The farm management and cultivation systems often have been optimized to adapt new situations. Therefore, their developing future is bright.

The management of agricultural practices

Organic integrity is most important to organic operators who must be aware of all the points in the processes of planting, harvest, handling, storage and transportation where contamination or commingling could occur. For example, finding organic alternatives for post-harvest decay control is critical to maintain food safety. Furthermore, the tracking system is also indispensable for organic operators. For example, "F01P1OSPN050411" is one of the lot numbers for the products of Tai'an Taishan, and, as shown below, the number reveals the history of its production.

F01	P1	O	SPN	050411
↓	↓	↓	↓	↓
Farm No.	Processor	Organic	Product	Date of harvest

The company maintains detailed records, so any product can be traced by lot number and its organic integrity can be insured.

The profit of organic operator

Profit, of course, is crucial to farmers. In this case, annual income of the local farmers working with this company has increased nine fold in the past ten years. Not only can organic vegetable planting lead to more profit than conventional corn-wheat planting, the economy and environment also benefit from the organic industry.

Conclusions

In investigating the ten-year history of Tai'an Taishan's development, it has been found that organic agriculture contributed greatly to i) improving food security in terms of nutrition and quantity, ii) optimizing the agricultural structure and iii) ensuring the profit of the farmers and the company.

Organic farming and organic food markets are growing fast. The consumers, due to health concerns, environmental consciousness, social status considerations and other reasons, are interested in products from organic farming. Therefore, research work should accompany the expansion of organic farming and organic food production. Research related to organic farming is important to both producers and processors and should be well supported. For instance, the questions of health benefits, although of great interest and importance to the public, are difficult to answer, necessitating collaborative studies by food and nutrition experts. In addition, effective pest control methods and soil fertility management should be studied and supported.

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