Organic food and farming: Scientific facts and consumer perceptions

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1. Introduction

Organic farming in the EU is a system of agriculture and food production that combines favourable environmental and animal welfare standards and is supported by EU law (Regulations (EC) No 834/2007 (1) and 889/2008/EC (2)). The organic production system strives for minimal disruption of the natural equilibrium while ensuring the production of high-quality food. To ensure that organic farmers and processors produce or process foods in accordance with organic legislation, designated control bodies and authorities certify and inspect each organic practitioner (cf. list of EU control bodies and authorities). Compliant produce is required to carry the EU organic logo (Figure 1).

Figure 1: EU Organic logo

Organic farming has become one of the fastest growing sectors in agriculture.(3) In the period 2005-2011, the total land area used for organic farming (i.e. the area fully converted and the area under conversion) increased from 3.6 % to 5.5 % of the total utilised agricultural area (UAA) within the EU-27 (data provided by Eurostat). In the ten year period 2000 – 2010, the global market for organic products increased over three-fold (estimated at 14 billion euros in 2000 compared to 45 billion euros in 2010). Growing consumer demand for organic food emerged mainly out of health and environmental concerns, which were intensified by food scandals and scares.(4-7) Organic food proponents in the media also played a role.(8) However, since the start of the financial crisis in 2008, growth has declined.(9) This may be explained by the higher prices for organic foods which mean they are no longer affordable to some consumers.

Interest in organic food has increased worldwide in response to concerns about conventional agricultural practices, food safety, human health, animal welfare and the environment.(7) Consumers make a range of positive inferences, e.g. inferences relating to human health, the environment and animal welfare, from the label ‘organic’.(10) Other inferences relate to the naturalness of the food, its taste, local production, purity (i.e. fully or nearly additive free) and cleanliness (i.e. pesticide free and free from other pollutants).(11,12)

This review examines consumer perceptions towards organic foods and examines the scientific basis for them.

2. Nutritional value

Consumers perceive organically produced food to contain more nutrients, including vitamins and minerals, than conventionally produced food.(13)

Dangour et al. conducted a systematic review of studies published between 1958 and 2008 on the nutritional quality of organic foods and concluded that the nutritional quality of organic and conventionally produced food was comparable.(14) For 10 nutrients and nutritionally relevant components (including vitamin C, magnesium and phenolic compounds), no significant differences were found between organic and conventionally produced food. There were three exceptions, i.e. nitrogen (higher in conventional foods), phosphorus and titratable acid (both higher in organic foods). Nitrogen is a constituent of amino acids and thus proteins, while phosphorus is needed for bone development, growth, maintenance, and repair of all tissues and cells. Titratable acid relates to the ripeness of the plant food, a higher titratable acid indicates a lower ripeness. Ripeness may influence the nutritional value, particularly the starch-sugar ratio which decreases as ripening progresses. The effect of ripening on the micronutrient level of plant foods is less clear. Studies have found both negative and positive correlations between ripening stage and antioxidant level, depending on the type of antioxidant.(15,16)

The findings of the review conducted by Dangour et al.(14) agree to a large extent with findings of other reviews.(17,24) However, some indicated that differences in nutrient content between organic and conventional foods vary considerably and depend on both the type of nutrient and food under examination.(17,19) More recently, the systematic review of Smith-Spangler et al.(25) concluded that with the exception of phosphorus, differences in nutrient content between organic and conventional foods vary considerably. However, the significantly higher phosphorus levels in organic foods emerged not to be biologically significant.

Factors other than production methods are also important determinants of the nutrient composition of foods. The genotype (i.e. variety or cultivar) is generally accepted as an important pre-harvest factor determining yield and nutritional quality of plant foods, in particular minerals, vitamins and secondary plant metabolites. The nutrient composition of some crops can also vary depending on growing conditions (air, water, soil, climate), pesticide and fertiliser regime, pest and disease incidence, time and method of harvesting, and post-harvest practices (e.g. storage, transportation and home preparation).(14, 26-28) The nutrient composition of livestock products can similarly be affected by factors such as the age and the breed of the animal, feeding regimen and season.(14)

In summary, it can be concluded that to date there is no evidence suggesting significant nutritional differences between organic and conventionally produced food.

3. Food safety

Consumers perceive organic food to be safer than conventional food (i.e. they perceive organic food to have less synthetic chemical contaminants).(13) In addition, a study of Belgian consumers' perception of the nutritional and toxicological value of organic vegetables, found that consumers place a higher value on the health benefit of 'less contaminants' rather than 'more nutrients'.(13)

In the EU, both organic and conventional foods are subject to stringent food safety requirements. Commission Regulation (EC) No 178/2002(29)stipulates that the primary responsibility for ensuring compliance with food law rests with the food business operator and that food cannot be placed on the

market if it is unsafe. Article 14 of that Regulation defines unsafe food as food which is injurious to health or unfit for human consumption. Other EU legislation lays down specific requirements for contaminants such as heavy metals, microorganisms, mycotoxins, GMOs etc.

In terms of food safety, three areas are discussed below: i) Pesticides, nitrates and heavy metals, ii) microorganisms and mycotoxins and iii) foods or ingredients from genetically modified organisms (GMOs).

3.1 Pesticides, nitrates and heavy metals

In general, consumers believe that organic farming involves little to no use of pesticides.(7, 30) With respect to nitrates, no information is currently available on consumers' perceptions. However, given the prohibition of synthetic pesticides and synthetic fertilisers (containing nitrogen) in organic farming, it is reasonable to assume that consumers would expect residues of synthetic pesticides and nitrates to be lower in organic food.

Although few data are available in the scientific literature on pesticide residues in organic foods, evidence indicates that conventional foods are more likely than organic foods to contain (single and multiple) synthetic pesticide residues.(23, 25, 30-34) Furthermore, the residue levels in conventional foods are consistently higher than in organic foods. However, these findings do not mean that organic and conventional foods necessarily contain pesticide residues at concentrations that are a safety concern or at concentrations which can even be measured in the laboratory.(35,36) The presence of synthetic pesticides in organic food may arise from environmental pollution. Although organic farming does not permit the use of synthetic pesticides, it can involve the use of a limited number of biopesticides, which are types of pest management interventions based on micro-organisms or natural products (e.g. copper, sulphur). (37)Biopesticides generally tend to have a lower overall impact on the environment than conventional chemical pesticides.(38) A list of all authorised plant protection products is included in the European Directive 91/414/EEC(39), while Annex II of the Regulation (EC) No 889/2008(2)provides a list of products permitted for use in organic farming.

Given these data, it can be concluded that consumers' beliefs about the absence or limited presence of synthetic pesticide residues is to a large extent supported by scientific evidence. It does not support the perception that organic foods are safer or do not contain any pesticide residues at all.

Another relatively consistent finding is that organic food tends to have lower nitrate levels than conventional food.(17, 23, 33) The prohibition of synthetic fertilisers (containing nitrogen) and the use of natural fertilisers (e.g. compost) is likely to be the underlying reason. However, for some crops with a lower nitrate accumulating capacity such as seed and bulb vegetables, the fertilisation practice does not have a significant impact on nitrate content. Consequently, the nitrate level does not vary significantly between these crops whether they are produced organically or conventionally.(23) Although nitrate is classified as a contaminant, recent research suggests that nitrate may also have beneficial effects on health such as lowering blood pressure among adults.(40, 41)

Little evidence exists regarding differences in heavy metals (e.g. cadmium, lead) between organically and

conventionally produced crops. The possibility for heavy metals to be absorbed from the soil remains the same irrespective of cultivation technique; therefore, no significant differences would be expected. Cadmium could be an exception. Since the use of sewage sludge is allowed in conventional farming, conventional crops might contain higher cadmium levels. However, no significant differences have been reported in comparative studies.(23, 42-44)

3.2 Microorganisms and mycotoxins

Foods may be contaminated by microorganisms (e.g. bacteria, fungi) at any time during cultivation, harvest, storage, processing, distribution, or preparation. The primary sources of microbial contamination include soil, air, water, untreated animal manure used as fertiliser, animal hides and intestines and food processing machinery or utensils. Regarding microbial contaminants, consumers' perceptions are that organic food is less contaminated than conventional food.(13)

Several studies indicate that contamination with bacterial pathogens is higher in organic compared to conventionally grown crops, while others show no difference.(45-47) Some authors have suggested that, given the use of animal manure and the prohibition of fungicides and some food additives in organic production practices, organically produced foods may have an increased risk of microbiological contamination.(45, 48) Regarding the use of animal manure, some research has reported that most pathogens were destroyed due to the high temperature during the composting process.(49, 50) On the other hand, others argue that composting may destroy the vegetative cells but not the spores which can germinate under appropriate conditions.(51) Good management of animal manure plays an important role in the prevention of microbiological food contamination.(52) Therefore, many countries have developed guidelines for best manure management practices throughout the food chain (including consumers) to ensure food safety.

Regarding food, a recent systematic review concluded that bacterial contamination of retail chicken and pork was common but unrelated to the farming method. However, the risk for isolating antibiotic-resistant bacteria was higher in conventional than in organic chicken and pork.(25)

Mycotoxins are another food safety issue. They are produced under certain conditions by some fungi growing as contaminants on food crops (this can occur during cultivation and/or storage). The presence of mycotoxins in crops and in foods and animal feeds produced from them is undesirable, as they are toxic and have adverse effects on both animal and human health. Conflicting studies have been published on the occurrence of mycotoxins in organic and conventional foods. Some studies have reported significantly higher levels of mycotoxins in organic food,(53,54) other studies have reported higher levels of mycotoxins in conventional foods; (55,-59) while, other studies have reported no differences.(44, 60-62)

These data show that conclusive evidence is lacking on whether organic or conventionally produced foods are more prone to microbiological or mycotoxin contamination.

3.3 Genetically Modified Organisms and organic foods

Although genetic modification has many potential benefits, some consumers consider it unnatural(63) and consumer tolerance for the accidental presence of GMOs in organic crops is limited.(64)

By regulation, the use of GMOs in organic food production is prohibited (Article 9, Regulation (EC) No 834/2007/EC(1)). The EU regulation states that organic farming should maintain the genetic diversity of the agricultural system and its surroundings. Organic food producers may rely on the labels or any other accompanying document to ensure that GMO ingredients are not included in the organic products. However, it is worth noting that under GM food and feed legislation, GM-labelling is not required if a food contains or is produced from a GMO in a proportion < 0.9 %. Organic production legislation requires that the organic label cannot be used on a food that requires a GM label. As a consequence, food with a GM ingredient could be labelled as organic if the GM percentage of that ingredient was less than 0.9%.

4. Healthfulness

Some consumers are motivated to buy organic food for its perceived health benefits (i.e. nutritional and safety value).(4) Based on the evidence presented, there is no reason to support the selection of organic over conventional food to increase the intake of specific nutrients or to decrease the intake of contaminants. However, a study that performed nutrient and contaminant intake assessments based on the consumption of organic and conventional vegetables, found that vegetable intake was higher among organic consumers.(65) In most cases, the amount of vegetables consumed was found to be more important in determining the intake of nutrients and contaminants than differences, if present, in nutrient and contaminant concentrations between organic and conventional vegetables.

Reliable research investigating the effect of organic food consumption on animal and human health is scarce. Few animal studies suggested a positive association of organic feeds with the immune status of animals,(66, 67) while in human studies indications were found for a beneficial influence of organic diets on reproductive health, growth and weight development,(22)plasma antioxidant status(22, 68-70) or the risk of eczema.(71) However, three recent reviews concluded that evidence is presently lacking for nutrition-related health benefits from the consumption of organic compared to conventional foods.(25, 72, 73)

5. Processing of conventional and organic food

When organic farming was still in its infancy, consumers interested in organic food were looking for fresh or minimally processed food without synthetic chemicals. They mostly purchased organic foods directly from growers, from whom they developed first-hand knowledge and awareness about organic food ("Know your farmer, know your food”). Nowadays, organic food sales through mass outlets such as supermarkets have rapidly replaced the direct farmer contact(74) and competition with processed conventional food is likely to increase the availability of processed organic food. Nevertheless, consumers consider that food processing is not appropriate for organic foods. Organic foods are associated with purity and small-scale production, more than locally produced food(11) or home-grown production.(75)

By law, processing of organic food is allowed once the food maintains it organic integrity and vital qualities.

Compared to conventional processing methods, organic food processing is even more restricted in its use of food additives (cf. positive list in Annex VIII of the Regulation 889/2008/EC(2)), non-organic ingredients with mainly technological and sensory functions, and micronutrients and processing aids. They can only be used in the event of essential technological needs or for particular nutritional purposes.

6. Sensory Qualities

Whilst consumers commonly believe that organic foods have a better taste, colour and flavour(22), there is no convincing evidence to suggest organic foods have superior sensory qualities.(17, 76) Blind sensory tests have shown little or no differences between organic and conventional foods.(77-79) In spite of this, many chefs choose organic foods for perceived sensory superiority.(80) It is worth noting that taste, colour, flavour, etc. of a crop plant may vary by cultivar, stage of ripeness, freshness or length of storage.

7. Environmental issues

After health, environmental protection is the next most important factor motivating consumers to buy organic food.(4) Four main indicators of environmental state are discussed below: i) soil and water quality, ii) greenhouse gas emissions, iii) biodiversity and iv) resource use efficiency.

7.1 Soil and water quality

A high organic matter content in soil leads to good agricultural and environmental conditions because of a reduction in soil erosion, a high buffering and filtering capacity of the soil and a rich habitat for living organisms. Organic farming positively influences the organic matter content in agricultural soils and carbon sequestration.(81) This is mainly explained by the use of only organic fertilisers (compost and manure), crop rotation, recycling of crop residues, and a higher percentage of grass land compared to the common use of synthetic fertilisers in conventional farming.

The leaching of nitrates and phosphates from agricultural sources influences the quality of ground and surface water (i.e. it stimulates algal growth and reduces the available oxygen concentrations, hampering the growth of water plants and animals). Research has shown that nitrate leaching levels vary considerably between organic and conventional farming, indicating that factors other than agricultural practices (e.g. climate and soil type) play an important role. On average, conventional agriculture shows higher leaching per unit of area compared to organic agriculture, which is explained by a higher application of fertiliser, a lower use of green cover crops, a lower carbon (C) to nitrogen (N) ratio and a higher stocking rate (i.e. number of animals on a given amount of land over a certain period of time).(81) However, when nitrate leaching is expressed per unit of product (per kg) both systems do not differ. Regarding phosphate, there are indications that leaching is lower on organic than conventional farms;(81) however, further studies are required to support this hypothesis. The most likely explanation is again the lower fertiliser application in organic farming.

7.2 Greenhouse gas emissions

Greenhouse gas (carbon dioxide, methane, nitrous oxide and chlorofluorocarbons) emissions into the atmosphere are considered a significant factor contributing to global climate change. Agricultural production is part-responsible for the emission of the three most important greenhouse gases, namely carbon dioxide, methane and nitrous oxide. A meta-analysis of research indicated that organic farming has a lower emission of these gases per hectare compared to conventional farming.(81)When the emission is expressed per unit of product, there is no difference between both systems. When focused on the two gases that predominantly originate from agricultural production, methane and nitrous oxide, lower emissions per hectare are reported for organic farming.(81)

7.3 Biodiversity

Both for species diversity and abundance within species, organic farming seems to score better than conventional farming per hectare.(82-84) The general absence of synthetic fertilisers and synthetic pesticides, the active management of non-cropped habitats and field borders, and the higher occurrence of mixed cropping are the most important management practices contributing to diversity.

7.4 Resource use efficiency

Meta-analyses of research indicated lower land use efficiency and thus lower yields for organic farming compared with conventional farming per hectare.(81, 85)Regarding energy efficiency, organic farming is more efficient than conventional farming in terms of energy input/output ratio.(86) The main reasons are the prohibition of synthetic pesticides and fertilisers and the lower use of concentrated feed, resulting in a lower energy input. However, when expressed per product unit (per kg) the difference in efficiency is much smaller.

Overall, for the four aspects investigated, organic production is more environmentally friendly when the findings are expressed per area of production (hectare). The difference is smaller when the findings are expressed per product unit (Kg).

8. Animal Welfare

Consumers have become increasingly concerned about the welfare of animals used in food production.(87, 88) This is obvious from the increased demand for certain foods (e.g. free-range eggs), the increased number of vegetarians and the call for more stringent animal welfare legislation.(75)Although consumers' concerns for their health and the environment are important factors influencing their decision to buy organic foods, their concerns regarding animal welfare must not be ignored.(75) Consumers perceive organic food as food which is produced naturally (i.e. without synthetic chemicals and growth hormones) and non-intensively.(89) They believe that organic and 'animal-friendly food' are equivalent and use animal welfare as an indicator for food safety and food quality.(90)

While it is true that animal welfare is a key component of the organic principles, it is not necessarily true that the animal welfare requirements specified in the organic legislation exceed the animal welfare requirements of conventional farming (these animal welfare requirements are very strict in the EU and

refer not only to animal production but also to transport, stunning and killing practices). According to the regulation, organic farming should include high animal welfare standards and meet animals' species-specific behavioural needs. Animal health management should be based on disease prevention. The high animal welfare standards include larger housing areas (including outdoor access), obligatory straw bedding, organic feed, restricted use of antibiotics, longer waiting times before delivery of products after medical treatments, longer weaning periods (pigs), the prohibition of tail, teeth and beak clipping and the selection of appropriate breeds. Disease prevention in organic livestock production is based on the assumption that housing, feeding and care of the animals is undertaken in a manner which ensures animals develop optimal natural resistance to combat disease. There is, however, little scientific evidence today to support or refute this assumption.(87)

9. Food supply

Can organic food feed the world? Today this question remains open. Some evidence suggests that organic farming could produce enough food to sustain the current world population without increasing land occupation for agricultural purpose. Besides considering the resource degradation caused by conventional farming, this evidence is based on the assumption that the entire agricultural land base is converted to organic production.(85)Whether organic food production may feed the growing world population is less certain. Important factors in favour of the sustainability of organic farming are the ban of energy-intensive synthetic pesticides and fertilisers and environmental protection. However, opponents doubt that agriculture will be capable of feeding a growing population without maximising yields, greatly reducing pre-harvest and post-harvest losses and making use of new technologies such as genetic modification. A scenario study indicated that if 50% of the European and North-American agriculture was converted to organic, production would decrease and commodity prices would increase.(91) As such, hunger in this scenario would worsen slightly. However, if low-input areas in Sub-Saharan Africa are converted to organic, production would increase and prices would decrease. In this scenario food security would improve slightly. This illustrates the complexity of the question and calls for more evidence on whether the world can be fed organically.

10. Conclusion

In general, organic food and farming benefit from favourable consumer perceptions, some of which cannot be scientifically substantiated. Therefore, further research is needed to strengthen scientific evidence about the relative risks and benefits of organic compared to conventional foods and farming so that consumers can make decisions based on accurate and objective information. Because of the thorough regulatory framework, consumers can be confident that both organic and conventional foods are safe to be consumed as part of a healthy balanced diet. “Organic” should be considered as a production claim, indicating to consumers that a product was produced according to the organic regulation (EC Regulation 834/2007(1)), rather than a product claim (including nutrition and health claims).

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