Organic foods

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Key points

- The chemical composition of organic foods is not significantly different from that of conventional foods for the main nutrients
- Higher levels of polyphenolic compounds in certain organic fruits and of omega-3 polyunsaturated fatty acids in organic milk from grass-fed cows do not contribute significantly to the total dietary intakes
- Pesticide residues in conventional plant products are almost always lower than the allowed maximum limit
- Organic foods also contain natural toxins and residues of allowed pesticides
- Some beneficial associations observed between the consumption of an organic diet and several pathologies are not causal relationships but are due to the better hygiene of life and the dietary behavior of "organic eaters"
- Better nutritional and health values should therefore no longer be claimed for choosing to consume organic foods
- Organic farming cannot be sustainable, especially for cereals, without the proximity of animal husbandry to provide the essential organic fertilizers.
- The lower productivity of organic agriculture require more land, at the expense of biodiversity and carbon storage, and is not sufficient to feed the future world population.

Introduction

Organic farming, also known as biological or ecological agriculture, should follow a well-defined regulation and the mode of production must be controlled by a certification body. Its main constraints are a minimal use of off-farm inputs, the ban of synthetic chemicals including fertilizers, pesticides, drugs, the use of organic fertilizers and natural pesticides, long crop rotations, the maintenance of organic matter and microbial life in the soil, the ban of genetically modified plants. For organic husbandry, regulations concern welfare, use of organic feeds and limitation of therapeutic interventions (especially antibiotics and hormones). When necessary, derogations are granted. The conversion time from conventional to organic farming varies from 2 to 3 years. Organic farming involves obligations in relation to means of production but not to results with respect to nutritional, health, or sensory properties of the products. Foods marketed under the label "organic" must contain at least 95% ingredients from organic agriculture, with possible food additives from a restrictive list. For processed foods, only biological and physical treatments, except irradiation, are allowed.

Certified organic agriculture represents currently approximately 1.5% of agricultural land worldwide, over two-thirds are grassland-grazing areas. This average hides large variations between continents and countries: for example, 0.3% in Africa and Asia, 1% in North America, 3.3% in Europe (8% in the European Union) with a maximum of 25% in Austria. In the last case, the mountain regions with predominance of grazing livestock are more conducive to organic farming. About half of the world organic land is in Australia but 97% is extensive pasture. In contrast, in sub-Saharan Africa, farmers who have no access to chemical fertilizers and pesticides unknowingly practice a form of non-certified organic farming.

The organic market is increasing everywhere. The demand is mainly motivated by health maintenance, protection of the environment, including water resources, but also for ethical reasons. Thus, fear of "chemical" and attraction to the "natural" are the main reasons for choosing organic foods. Productivity is much lower in organic agriculture, the yields being 20–50% lower than in conventional farming, especially in the case of cereals. As costs of production are higher, selling prices are also significantly higher (30–100% more in stores). The market for organic foods ranges from 1% to 8% of food purchased, according to country, but demand is growing and most of the major consuming countries are dependent on imports.

Although motivations of consumers' choice, whether ethical or ideological, are not discussed in this article, it is important to know whether the widespread belief of better nutritional and health quality for organic foods is supported by scientific studies.

Scientific bases for the comparisons of food quality

The chemical composition of foods varies depending on many factors which are not all directly linked to the mode of production. These are, for crops, species and variety, ripeness at time of harvest, yield, climate, season, and for animal products, breed, age, fat content, growth rate and feed intake. It is obvious that when these conditions are comparable, it is unlikely that tissue composition is different. The clearest example is that of milk, whose lipid composition depends strongly on the consumption of grass or fresh forage, regardless of the production system, being organic or conventional.

The differences between organic and conventional products have been the matter of numerous studies and reviews. Several studies failed to demonstrate a significant change in product composition attributable to the mode of production, either because the experimental design or characterization of food were not suitable or well defined, or because statistical interpretation was missing or impossible. This resulted in a lack of useable compositional results, particularly for some vitamins.

It is significant that most reviews published by organizations or associations of organic farming drew a positive balance in favor of organic foods (Soil Association, 2000; Worthington, 2001; Organic Trade Association, 2008; Leifert and Niggli, 2009), whereas independent academic publications claimed that there was an overall lack of significant differences (Williams, 2002; Winter and Davis, 2006; Magkos et al., 2006; Williamson, 2007). The data summarized below result mainly from several reviews published before 2010 in Germany (Woëse et al., 1997), in UK by the Food Standards Agency (Dangour et al., 2009, 2010), in France in 2003 by the French Agency for Food Safety (Afssa, now Anses) with a 2010 update (Guéguen and Pascal, approximately 100 new references added), an US systematic review (Smith-Spangler et al., 2012), two Danish critical reviews (Jensen et al., 2012, 2013) and, more recently, three European comprehensive systematic reviews and meta-analyses (Baranski et al., 2014; Średnicka-Tober et al., 2016; STOA, 2016; Mie et al., 2017) and a French critical review (Guéguen, 2018).

Essential or beneficial nutrients

Plant products

A trend toward higher dry matter content in some organic vegetables has sometimes been reported. This difference is not systematic and depends greatly on the cultivar and stage of ripeness at harvest. No significant differences were observed for carbohydrate, protein, and total lipids of vegetables and fruits, particularly when expressed on a dry matter basis.

Organic cereals are generally poorer in protein, which raises, in the case of wheat, technological problems for bread production and requires the choice of adapted varieties. However, it seems that the balance of essential amino acids is sometimes better in organic compared to conventional wheat.

For minerals and trace elements, it can be concluded, from a large number of individual results on approximately 15 species of fruits and vegetables, that overall there is a lack of differences in levels. Occasionally, magnesium and iron contents have a trend to be somewhat higher in some organic vegetables, but no differences were observed for most minerals (calcium, potassium, sodium, copper, zinc, or selenium). Some extremely high levels of copper were found in potatoes, tomatoes, and grapes, due to repeated treatments with copper sulfate. The mineral composition of seeds is almost constant and no difference was recorded. Mineral and trace element contents of bread depend on the proportion of bran in the flour and not on the mode of production of wheat.

Too few studies have been done on vitamins A, E, and B group in vegetables and fruits, but the differences between organic and conventional products seem small. However, many studies have examined vitamin C, especially in tomatoes (Dangour et al., 2009), and a trend toward higher levels in some organic fruits and vegetables was confirmed but not systematically: for 43 individual comparisons, 19 (44%) were higher, 18 (42%) were equal, and 6 (14%) were lower (Guéguen and Pascal, 2010). This trend must be tempered by taking into account other factors that affect even more the level of vitamin C, especially the freshness of the product.

Several studies have shown the presence of larger amounts of phytomicrocomponents such as polyphenols and other phenolic compounds in organic plants. In the absence of phytopharmaceutical treatment, this increase can be explained by an increased defense reaction of the plant unprotected against attacks from insects or fungi. The production of secondary metabolites, including molecules with beneficial antioxidant properties, is then promoted. Low availability of soil nitrogen could also have the same effect. Thus, the levels of polyphenols, especially flavonoids, are sometimes 20–40% greater in organic vegetables and fruits, as mostly shown for tomato. However, this observation is not systematic because among 70 individual validated data across all products, 31 (54%) were higher in organic agriculture, 23 (40%) were equal, and three (5%) were lower (Guéguen and Pascal, 2010). In contrast, levels of carotenoids in organic fruits and vegetables are essentially lower or equal, especially for lycopene in tomatoes.

Several studies have shown that the antioxidant power of organic apples is 10–15% greater than that of conventional apples, but it remains to show that these small differences have any nutritional significance.

A systematic review (Baranski et al., 2014) on nutritional quality of conventional vs. organic foods, supported by the UK Food Standards Agency, has found significant differences only for nitrogen (protein in grains and nitrate in vegetables), being lower in organic products, and phosphorus, being lower in conventional products. However, it is important to remind that phosphorus is not a limiting factor in the human diets. Despite the use of very strict criteria for exclusion of publications, this review is currently the most comprehensive.

The data of this last meta-analysis were utilized by an international group of experts in a Science and Technology Options Assessment (STOA) report submitted in 2016 to the European Parliament (report condensed in the review of Mie et al., 2017), the conclusions of which are as follows: "In summary, collectively the published meta-analyses indicate a modestly higher content of phenolic compounds in organic crops, which is plausible. These compounds are believed to play a role in preventing several non communicable diseases in humans, although the detailed mechanisms are not generally well understood. It is important to bear in mind that in many cases the variation in the concentration of phenolic compounds is greater between different types and varieties of crops and between years, climates, soils, etc. than between production systems".

For all the very many other constituents analyzed (dry matter, fibers, minerals, trace elements, vitamins, nitrate, etc.), the differences are not significant or have no nutritional impact. The lower protein content of organic cereals, which affects the baking value of wheat, is confirmed by all systematic reviews. A better protein (e.g., amino acid balance) quality of organic cereals, in particular slightly higher contents of threonine and leucine in wheat and more globulin and albumin in triticale have sometimes been observed. However, these differences are not always significant and have not been confirmed by all recent reviews. As for mineral and trace elements, it is well known that their contents are not very variable in the grain and do not depend on fertilization.

Here is the general conclusion of the STOA European report on organic plants: "Most aspects of crop composition, including vitamins and minerals, are not affected by the agricultural management system. If they are it is only to a limited extent. From the perspective of nutritional guidelines, which are generally concerned with macronutrients, vitamins and minerals, there is no reason to prefer organic over conventional plant foods or vice versa".

Animal products

The diet of organically farmed animals is not very different from that of conventional animals, particularly for pigs and poultry, which eat mainly grains and oil-seed cakes. The only difference is that most feeds (95–100%) must come from organic farms. However, the chemical composition of these feeds, mainly seeds, depends little on production mode. A supplement of minerals, trace elements, and vitamins in organic diets is allowed.

For most constituents, the composition of meat depends little on the mode of production. Only lipid composition varies according to animal's breed and age. Thus, comparisons must be made on animals of the same age because the degree of adiposity varies accordingly. For example, an "industrial" 40-day-old chicken cannot be compared to an 80-day-old organic chicken. Feed can affect fatty acid composition, especially of unsaturated fatty acids in meat, and more in pigs and poultry than in ruminants. Thus, the meat of cattle mainly fed with grass or fresh forage, preferred in organic husbandry, is richer in polyunsaturated fatty acids (PUFA) omega-3 and sometimes in conjugated linoleic acid (CLA) than the meat of cattle fed with corn silage and concentrate. It is the same for the composition of eggs. However, similar compositions are obtained for extensive grazing livestock or for hens with an outdoor run.

Several recent and validated studies have focused on the composition of milk which, for most of its constituents (protein, lactose, minerals, and trace elements), is fairly constant. Only vary omega-3 PUFA levels and CLAs that depend heavily on the season and the proportion of grass in the diet (Butler et al., 2008). Similar results, even better, can be obtained by extensive livestock grazing or by incorporation of clover or flaxseed. Only two trace elements from milk, iodine and selenium, are influenced by dietary intake and their levels are increased by the use of a mineral supplement. Selenium content of feed strongly depends on soil concentration.

Modeling was done in the recent STOA report. Based on results from the meta-analysis by Średnicka-Tober et al. (2016), the increase in PUFA content of organic meat is not clearly demonstrated. Even under the high assumption of the all-organic food scenario, the maximum nutritional impact would be less than 7% of the requirement. Here are excerpts from the findings of this report on omega-3 in humans …"On average, replacing conventional with organic dairy products while keeping the diet constant will increase the intake of omega-3 PUFA by approximately 4%. Replacing conventional meat products with organic meat products may increase the omega-3 PUFA intake by an additional 6% … Accordingly, at this point, there is no strong evidence available that would support the existence of health benefits of a higher ruminant fatty acid content in organic compared to conventional milk … It is therefore not possible to conclude any specific health benefit offered by a modest increase in omega-3 PUFA intake from a change from conventional to organic milk and meat."

The desirable increase in the intake of omega-3 fatty acids in the diet is much more effective by using certain vegetable oils (flaxseed, rapeseed) or fatty fish, which simultaneously leads to a decrease in intake of saturated fatty acids.

Another conclusion of all the reviews is that organic milk is always poorer in iodine and selenium, two essential trace elements added to the mineral supplement in intensive conventional breeding.

Undesirable components

Nitrate is abundant in vegetables but not in fruits, cereals, milk, or meat. Nitrate levels in vegetables vary according to several factors, including sunlight, rainfall, and especially nitrogen fertilization. Nitrate levels are lower in greenhouse production, and in autumn compared to spring and summer for field production. They increase when nitrogen is provided by rapidly available soluble fertilizers. Organic farming uses mostly organic fertilizers such as guano, meat or blood meals, which are rapidly assimilated by the plant and thus also lead to high levels of nitrate. Nevertheless, the published comparisons show that organic vegetables (lettuce, spinach, rucola, carrot, beet, etc.) have usually lower nitrate levels than conventional vegetables.

Nitrate does not have a good reputation because of past accidents of methemoglobinemia in infants with poor food hygiene, notably contaminated feeding bottles in which microorganisms accelerated the reduction of nitrate to nitrite. Improvement of hygiene leads to a very low risk nowadays. In adults, the formation of carcinogenic nitrosamines has long been suspected. In fact, many studies have shown that nitrate of vegetables, which represent approximately 75% of ingested nitrate, have no negative effect on health in adults and their carcinogenic effect has not been demonstrated (European Food Safety Authority, 2008). It is noteworthy that water is also a vector of nitrate in the diet but the maximum limit (usually 50 mg L-1) is not a threshold of toxicity for adults. In addition, several studies (Katan, 2009; Hord et al., 2009) emphasize the beneficial effects of nitrate, thanks to the formation of nitrogen monoxide (NO), especially in the immune protection of the mouth and stomach, in the prevention of hypertension and cardiovascular disorders.

The fear of residues of synthetic pesticides in conventional plant products is by far the main reason for the choice of organic foods by consumers. It is true that the ban of their use in organic agriculture should logically lead to the absence of residues in food. Many surveys have been conducted on these residues in the US, UK, New Zealand, Netherlands, France, and elsewhere. For example, an annual report of the European Food Safety Authority (EFSA) compiles the results of legal controls in the Member States on a large number of plant products. For 2018, no detectable traces of synthetic pesticide residues were found in 58% of samples (all origins confounded), traces were detected in 40.5% but at levels below the maximum residue level (MRL), and only 1.5% samples exceeded the MRL. These results overlap well with those of other national studies. It is noteworthy that the tests are done on raw, unwashed, unpeeled products.

MRL is the pesticide residue level in a particular food following its production according to Good Agricultural Practice (GAP). There is an MRL for each pesticide and each plant species, and values adopted have been harmonized in the UE in 2008. Taking into account food habits of consumers, the sum of residues of a given pesticide from all food respecting MRL must not from a regulatory point of view exceed its acceptable daily intake (ADI). However, when a residue of one food is found above the MRL, the result does not automatically mean the levels of residue found are a risk to people's health. What matters is the sum on all residues in the total diet. ADI itself is calculated with a safety factor of at least 100, from the highest dose without effect observed in laboratory animals.

These assessments are based on a calculation of risk, taking into account the possible cumulative effects of several molecules of the same chemical group having the same mechanism of action, and leading to a "reasonable certainty of no harm".

If synthetic pesticides raise a distinct risk to health (e.g., skin disorders and hematopoietic cancers) for the farmer highly exposed and poorly protected, this should not be amalgamated with the negligible risk to consumers who ingest doses of residues of the order of one million times lower. Based on studies published by international bodies, residues of synthetic pesticides are without any risk to the consumer and the expected marginal benefit of eating more organic products is insignificant. Thus, according to an UE study, individual chronic exposure to pesticides would be between 0 and 0.2% of the acceptable daily intake (ADI). Other studies done in the US by the FDA also show pesticide exposures below 1% of ADI, or approximately 10,000 fold lower than the highest dose having no effect on the animal. A study from the University of Oxford found no difference in overall cancer risk when comparing 180,000 women aged 50 years or over who reported never eating organic food with around 45,000 women usually or always eating organic food.

To be on the safe side, it is advisable, especially for infant feeding, to wash and peel vegetables and, if possible, fruits. It should be noted that there is a consensus on the beneficial health effects of consumption of fruits and vegetables, whereas nearly half contain detectable residues of synthetic pesticides. Arguments based on pesticide residues (and nitrate in the case of vegetables) should not, therefore, be used as a pretext for decreasing the recommended consumption of fruits and vegetables.

It is true that organic plant products do not generally contain residues of synthetic pesticides. However, surveys sometimes reveal their presence at levels below the MRL, which is due to pollution, errors, faults, or derogations. Furthermore, organic products can contain residues of natural pesticides authorized as rotenone, pyrethrins, azadirachtin from neem oil (from *Azadiracta indica*), and particularly copper often heavily used. These residues are not taken into account in official inspections, although their safety is not guaranteed. Thus, rotenone is neurotoxic and is banned in the EU since 2008, whereas azadirachtin from neem oil, permitted in some countries (e.g., by derogation in France), is an endocrine disruptor. Copper in excess poisons the soil and is not without health consequences.

Like the beneficial antioxidants, toxic secondary metabolites can be formed as a defensive response to attacks by insects or fungi in untreated plants. The effects on human health of hundreds of natural toxins acting as insecticide or fungicide have not been well studied. Some such as cruciferous glucosinolates (sometimes beneficial), glyco-alkaloids in potatoes and tomatoes and celery furanocoumarins are well known. Others have not been identified or studied, and it may be important consider their effects on health.

Similarly, lipid transport proteins in Rosaceae (most edible fruits) are defense proteins responsible for severe allergies in children and adults. Studies have shown that they are more abundant in the skin of organic apples and plums whose consumption should not be recommended for allergic patients (Barré et al., 2009).

It would be logical to find higher levels of carcinogenic mycotoxins in organic cereals not protected by antifungal pesticides. In fact, if cases of severe contamination by mycotoxins have been found in organic cereals, the difference with the conventional grains is not systematic (Murphy et al., 2006). Thus, the presence of Fusarium mycotoxins in wheat depends on many factors and several recent studies in various UE countries (Germany, UK, Netherlands, Italy) showed that organic wheat is sometimes the least contaminated. The main factors of variation in mycotoxin levels are the year, the climate, and the storage conditions.

The risk of pollution by heavy metals, polychlorobiphenyls (PCBs), or dioxins is not different in the two modes of production but it depends on exposure to atmospheric deposition. All outdoor productions, animal or vegetable, are most at risk. This is usually the case for organic agriculture but also often for conventional agriculture, especially for the meat of grazing animals (Dervilly-Pinel et al., 2017). Thus, milk from cows on pasture, whether organic or conventional, is less well protected than the milk from cows in barn because the consumption of grass and soil may be an important vector of various pollutants. It is the same for eggs from hens with outdoor run, often more contaminated than eggs from hens reared in cages.

For similar reasons, the risk of bacterial or viral contamination is greatest in outdoor production, from hydrotelluric sources (e.g., *Clostridium botulinum*) or contact with wildlife fauna (e.g., *Campylobacter*).

Microbial contamination of plants can be enhanced by the use of organic fertilizers compared to mineral fertilizers. Thus, the use of manure, even composted, increases the risk of contamination of fruits and vegetables by *Escherichia coli*, *Salmonella*, or *Listeria monocytogenes*. On the one hand, poultry manure from organic livestock is often contaminated with *Campylobacter*, which may be an increased risk for eggs. However, according to several studies, these are only trends and, on the other hand, it appears that the resistance of these bacteria to various antibiotics is lower in organic farming.

Cases of mastitis in dairy cows are more frequent without that with antibiotic treatment. However, milk is not sold then and a limited use of antibiotics in livestock is also authorized in organic husbandry, if required. Internal parasites in sheep are conditions prevalent in organic farming, but the new UE regulation now allows the use of antiparasite treatments without limitation.

The use of hormones is universally prohibited in organic animal husbandry, but also in conventional husbandry in the UE. Several countries (USA, Canada, Australia, South Africa, New Zealand, Mexico, Chile) authorize steroid hormones (estradiol, progesterone, testosterone, zeranol, trenbolone acetate, and melengestrol acetate) to increase meat yield in beef cattle, or a protein hormone, rBST (recombinant bovine somatotropin) to increase milk production in dairy cows (prohibited in Canada based on concerns about health effects, including mastitis in treated animals). The Food Safety authorities of these countries ensure that the possible residues found in meat and milk do not present any health issue for the consumer (e.g., early puberty in girls, risk of breast cancer or allergy, endocrine disruption have been mentioned in countries where these treatments are not allowed) if the treatments are applied according to the regulation.

Health effects

Clinical trials

Given the many factors that determine the nutritional and health qualities of agricultural products, it is difficult to demonstrate significant differences resulting specifically from the production system, organic or conventional.

Ten controlled clinical studies comparing organic and conventional foods were included in the systematic review supported by the UK Food Standards Agency. Most were carried out on subjects consuming conventional or organic vegetables and fruits, and the antioxidant status of blood plasma was used as a biomarker. None of these studies could demonstrate a positive effect of diet on this blood parameter but this does not suffice, however, to characterize the health status. There is no published long-term study comparing the health effects of a diet exclusively organic or conventional, using several criteria relevant to health. This lack is unfortunate, but the small differences found in the composition of foods would leave little chance of finding a significant health effect.

In several trials, none of the numerous measured health biomarkers were affected by the cultivation system, particularly for the effect of organic fruits and vegetables on blood anti-oxidant status. In fact, the antioxidant capacity of the diet depends, for about half, on the polyphenolic compounds which are mostly provided, in Europe, by tea and coffee (50%), followed by cocoa and red wine, the contribution of fruits and vegetables being less than 10%. Therefore, an eventual increase of 15–30% of the content of polyphenolics in organic fruits cannot have a detectable effect on the blood anti-oxidant status.

Epidemiological studies

Observational epidemiological studies involving large cohorts of consumers receiving long-term organic or conventional food are scarce. This is primarily due to the fact that it is difficult to recruit participants who regularly consume a significant proportion of certified organic foods (which represent in France less than 5% of the foods) and that a fully organic diet is exceptional.

The largest prospective study was published by epidemiologists from Oxford University in 2014 (Bradbury et al., 2014). It was conducted over 9 years on more than 600,000 women older than 50 years. It showed that the consumption of organic food had no influence on the incidence of common cancers, except perhaps on non-Hodgkin lymphoma. This should, in this regard, exonerate the traces of residues of synthetic pesticides that can potentially be found in products from conventional agriculture.

A large French prospective study, NutriNet-Santé (and its BioNutriNet component), covers cohorts of 60,000 to 70,000 adult volunteers, 78% of whom are women, that are followed since 2009 and periodically respond to a questionnaire on their diet. This study first observed that the frequency of overweight, obesity and metabolic syndrome was lower in heavy organic consumers

(Kesse-Guyot et al., 2017). However, as the authors acknowledged, these are associations and not causal links. Many causes of bias and confounding factors, partially taken into account in the interpretation of the results, are involved in this study: on the one hand, the proportion of organic foods in the diet, evaluated by questionnaire, is imprecise and clearly overestimated and, on the other hand, it is well known that organic food eaters are more attentive to the balance of their diet and, more generally, to their lifestyle (tobacco, alcohol, physical exercise…).

The most publicized study (Baudry et al., 2018) concerned the association between organic food and cancer and its conclusions were translated in the medias by headlines such as "eating organic reduces cancer risk by 25%". This study was the subject of many critical reactions because, despite the precautions objectively taken by the authors of the article, this purported beneficial effect made public opinion. The study compared the 20% of the cohort who never consumed organic with the 20% for whom more than half of the food was organic. In fact, this association has only been observed in women and it is not for all types of cancers but only for postmenopausal breast cancer and some lymphomas. According to the authors, one explanation could be the lower ingestion of synthetic pesticide residues by organic consumers. The very low contribution of pesticide residues in conventional fruits and vegetables, not quantified in the study, certainly does not support such a hypothesis, especially since, when the statistical interpretation only takes into account the consumption of plant products, the only ones that may contain pesticide residues, the observed association is no longer significant for breast cancer. The statistical interpretation of data from NutriNet-Santé has also been severely criticized and therefore the conclusions of the studies strongly contested. In addition to the flaws in the statistical methodology, the poor evaluation of the share of organic in the diet does not allow any associations observed to be attributed to the differences between organic and conventional foods but to the behavior of the "organic eater", more vigilant about his hygiene of life and eating more balanced diets, including less meat and more fruits and vegetables. The noted associations concern, therefore, the effect of the lifestyle and eating behavior of organic eaters and not the favorable effect of organic foods alone. These would then be possible beneficial effects on the health of a flexitarian diet (less meat and more vegetable foods). This is objectively and clearly admitted by one of the co-authors of the article: "The main lesson is that going organic without reducing the share of meat in our consumption is useless, neither for health, nor for the environment".

Organoleptic quality

Organoleptic characteristics of organic foods have not been the subject of many comparative studies. Those that have been published do not highlight superior sensory qualities due to the production method, as results are variable and contradictory. For fruit and vegetables, sensory properties are mainly determined by the variety, ripeness and freshness. Organic farming often uses more hardy cultivars and, if production is local, the harvest can be later. For meat, taste properties depend mainly on breed, age, and degree of fatness. The mode of production, organic or conventional, is not a criterion of taste. For milk and eggs, no reproducible difference was obtained in the literature. In line with the nutritional values and health attributes, regulation of organic agriculture does not imply any better organoleptic quality of its products, but only an obligation of means of production.

Conclusions and prospects

Consumption of organic foods cannot have a nutritional effect in the overall diet. Even if we admit a slight superiority of organic foods for some nutrients in some foods, the difference would be insignificant in the global regime. For example, measures taken in France for "one organic meal per week in collective catering" cannot have significant influence on the quality of diet throughout the week. The health impact is also negligible because the effect of organic vegetables or fruits on blood antioxidant status could not be demonstrated, nitrate in vegetables are safe and chemical residues of conventional foods, including synthetic pesticides, are almost entirely below the allowed maximum limit and do not pose a risk to health. The few clinical or observational epidemiological studies have failed to attribute any beneficial effect to organic food on the incidence of various diseases, including cancer. Better nutritional and health values should therefore no longer be claimed for choosing to consume organic foods. The argument of preventing climate change or preserving biodiversity is also highly debatable. Indeed, the lower yields of organic farming (20–50%) lead to devoting more areas to the same production, at the expense of forests, fallows, wetlands and permanent meadows, and therefore biodiversity and carbon storage.

In most Western countries, organic foods account for less than 5% of foods consumed. Despite a strong trend of increasing demand, this share will be limited if a larger supply does not bring down the selling prices of organic foods. Significant imports from distant areas are not desirable because they are incompatible with the ecological spirit of organic agriculture. Organic production in industrialized and emerging countries will also be limited by local availability of organic fertilizers and especially by heavy yield losses (e.g., 50% for wheat in France). In developing countries, particularly in several parts of sub-Saharan Africa, food production could be increased through a wide application of the principles of organic agriculture for food crops associated with animal husbandry. However, this production will be self-consumed and may not be sufficient without recourse to a minimum of mineral fertilizers and plant protection products to reduce the very high crop losses. The increasing demand for organic foods, currently hampered by higher purchase prices, could explode if a large increase in local production or imports led to falling prices. However, this would be a vicious circle as farmers' income could drop and then discourage their conversion. In addition, throughout the world, intensive conventional farming will be subject to environmental constraints worldwide, including the use of pesticides.

Reductions of 30–50% of the amounts used presently are already planned in some countries. Under these conditions, the difference in food quality and ecological effects perceived by consumers will decrease and will not be market-friendly with organic foods.

Organic farming cannot be sustainable, especially for cereals, without the proximity of animal husbandry, including intensive breeding, to provide the essential organic fertilizers. An objective of the European "Green Deal project" to reach 25% of land in organic farming by 2030 seems paradoxical and unrealistic, while productivity is much lower and that, according to the FAO, it would be necessary to increase food production by 50–70% to feed the future world population.

Between the two extreme forms of agriculture, intensive conventional and organic farming, there are several intermediate modes of production that provide good quality food and preserve the environment, without sacrificing the high productivity required to maintain the food sovereignty of developed countries and to ensure, or even improve, global food security.

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