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Conventional and Organic Farming – Does Organic Farming Benefit Plant Composition, Phenolic Diversity and Antioxidant Properties?

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Additional information is available at the end of the chapter

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Abstract

The growing demanding from consumers for healthier foods, produced using environmentally friendly farming practices has resulted in the rapid expansion of organic farming. There are numerous studies about the importance of organic farming but the majority of the results are sometimes contradictory, inconsistent and show no clear link between organic farming practices and enhancement of the nutritional quality of plant-derived foods. As such, ongoing research into the effects of organic farming and cultivation practices in comparison with intensive farming, is very important. The objective of this chapter is to discuss the most recent data and variation in the responses of plants to farming regimes in order to better understand the relationship between agricultural practices and high levels of valuable compounds (glucosinolates, phenolics, minerals, vitamins, antioxidants), as well as low levels of undesirable components such as nitrates, nitrites and microorganisms.

Keywords: Organic farming, conventional farming, nutrient diversity, phytochemicals, quality, safety

1. Introduction

Research studies continue to show that the desire of consumers to be able to purchase healthier fruits and vegetables, produced by a more sustainable and environmental friendly agricultural system, is increasing day-by-day. The majority of these studies attempt to show how safe and nutritious organic foods are for humans [1] and animals [2]. According to European regulations

[3] organic farming is defined as an overall system of farm management and food production that combines the best environmental practices, high levels of biodiversity, the preservation of natural resources, the application of high animal welfare standards and utilises production methods in line with the preference of consumers for products produced using natural substances and processes. The aim of an organic farming system is to provide to the consumer with fresh, tasty and natural food, while respecting natural systems and the environment. To achieve this, several principles and rules are followed in order to minimize human impact on the environment, while at the same time ensuring the agricultural system operates as naturally as possible [4]. Several different approaches are employed, but all of them are guided by strict rules [3] aimed at protecting the integrity of the environment, plants, animals and biodiversity.

A fundamental aim of organic farming is the provision of healthy, high quality plant and animal-derived foods. The concept of food quality can be defined in many different ways. Often, the quality of food is based on visual characters such as shape, size and colour, but can also be described as containing fewer pesticides, or more nutrients, or even containing specific functional properties due to elevated levels of phytochemicals [1, 5]. Thus, there is no one sole concept of quality. Nonetheless, countless studies of quality always refer to at least one or more of the following criteria: (i) food safety (absence of undesirable components like nitrites and pathogenic microorganisms); (ii) primary nutrients (minerals and vitamins, for example); (iii) secondary metabolites and phytochemicals that are closely associated with the beneficial health properties of plant and animal-derived foods; and (iv) observed health effects. However, research studies using these criteria vary widely, with investigative topics ranging from the taste of the food to how the food in question benefits health. Despite this diversity, the link between organic products and their nutritional, functional, and biological values is far from being fully understood. Therefore, in this chapter, we discuss recent advances in organic farming, particularly its differences from conventional farming, highlighting the differences in vitamins, minerals, phytochemicals, antioxidant activity and sensorial properties.

2. Factors and constraints affecting crop and plant-derived food composition

Growing crops in any part of the world is affected by many variables, including environmental, agronomical, social and economic factors, among others. These factors can affect not which particular type of agricultural system is employed, or which type of crop produced, but also and more importantly, the quality of the crop. Both conventional and organic farming systems are always heavily influenced by such factors. These factors can be grouped into 4 main types (Figure 1): a) socio-economic; b) pre-harvest; c) harvest; and d) post-harvest.

A recent study [6] showed that the choice between an organic or conventional farming system is primarily dependent on socio-economic factors, secondarily dependent on social aspects and then all of the remaining factors follow on. In fact, when farmers implement any production system or crop, their first question is: How profitable is it to produce? The answer will depend on the choices the farmer makes about what crops to grow, where to grow them, and

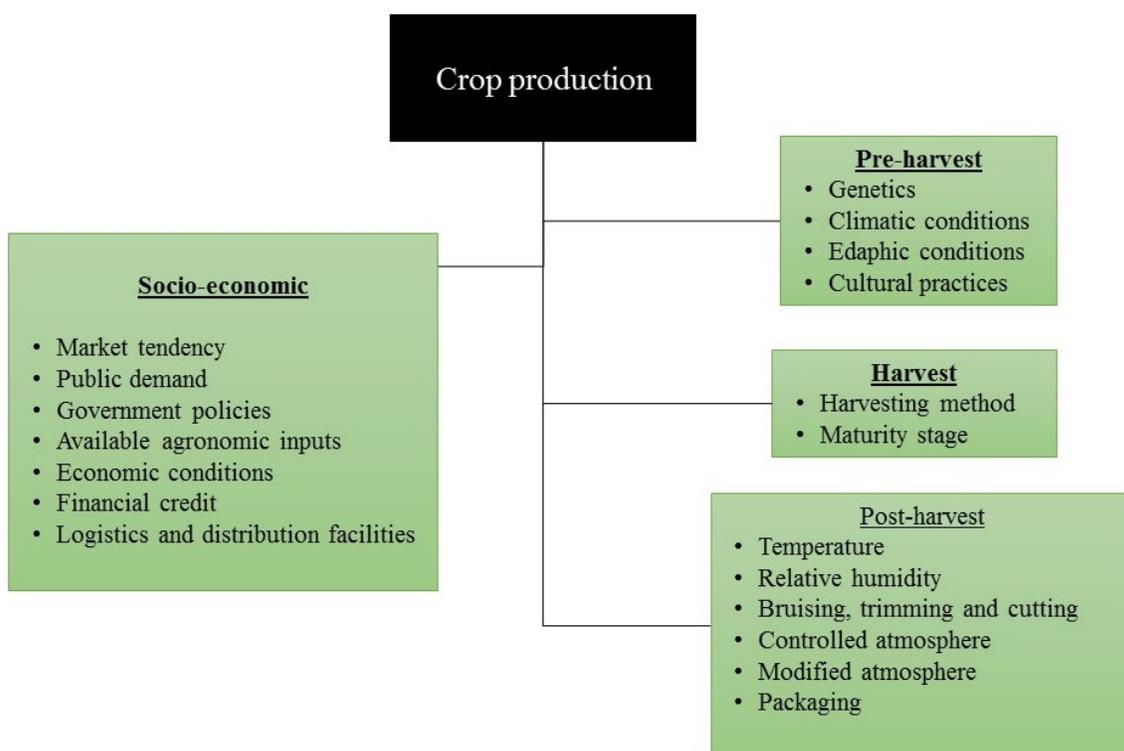


Figure 1. Constraint factors of any crop yield and production.

what technologies he uses. In addition, farmers tend to follow the system producing a higher financial income, lower financial risks, lower labour requirements, and if possible, the greatest pleasure [7]. The ability to obtain credit will also influence the choice of crops, farming systems and technologies [8]. The level of technical and scientific knowledge of production will also affect a farmer's propensity to choose a particular crop or production system [9, 10]. Moreover, the capital requirement for any crop development is always present, but can vary seasonally and is often far higher during harvesting than at other times during the production period. Any financial or labour constraint can negatively affect negatively the farmer's productivity and, therefore, income [11].

Another social aspect of decision to farm organically or conventionally is public demand [12]. If a farmer wants to succeed, then there must be a demand for their products, to generate an income, otherwise the farmer will switch to another, more profitable crop, whether it is organic or not.

Production is also affected by pre-harvest factors. In general, these factors include all physical factors, such as genetics, geology, soil and climatic conditions and cultural practices [13, 14, 15]. In other words, after a specific crop has been chosen, its success will depend on the outcome of the complex interaction between numerous elements such as the biology of the plant, interaction between plant and soil, crop management techniques, mineral and organic nutrition, chemical or biochemical treatments, and the watering regime employed, among other factors. Climatic parameters such temperature, humidity, altitude, rainfall and wind, are

all fundamental factors affecting the variation of plant and crop success [16, 17] and thus their nutritional quality as food. Temperatures can limit the growth of crops; water is a key factor in plant growth with different crops requiring water at different times; altitude primarily affects the average temperatures and consequently the type of farming; wind can have a destructive effect on crops physically, as well as increasing the dryness of soils, reducing moisture and increasing the potential for soil erosion. The soil type will influence crop cultivation because different crops prefer different soils, e.g., clay soils with their high levels of water retention are widely used to produce rice, as rice requires a lot of water to grow successfully [18, 19], whilst sandy soils are more suited to roots, tubers and vegetables, due to their need for better drainage, which is a requirement for good development of their roots [20]. Thus, selecting the right crop for the given specific conditions is fundamental to increasing yield and quality.

Another set of factors are related to the harvest period. It is widely accepted that stage of maturity at harvest can have a critical influence on the nutritional content of the crop. Zaro et al. [21], observed marked changes in the level of bioactive compounds present (anthocyanins, carotenoids, ascorbic acid, phenolics) and in antioxidant activity of purple eggplants at the fruiting stage. They found a decrease of such compounds and beneficial properties when plants were harvested at earlier stages (I and II). The same tendency was recently observed [22] in carrots, where a relatively high amount of falcarindiol, an important antioxidant compound, was present during very early harvest (i.e. 103 to 104 days after sowing) compared with a later harvest (i.e. 117 to 118 days after sowing). The same trend was also recently noted [23] for anthocyanin content in blueberries when harvested earlier, but not when harvested at full maturity. Thus, correct choice of harvesting time is crucial in preserving the quality of fresh produce during storage. This way, it is possible to provide the consumer with high quality fresh food products.

After harvesting, several factors (identified here as post-harvest factors) can interfere with the quality of fruit and vegetables. Among them are temperature regime of storage, relative humidity of storage, type of atmosphere used if any, and packaging [24, 25]. Temperature management during shelf-life is one of the most important means of preserving the quality of fresh roots, fruits and vegetables. After harvest, any delay in cooling, or choosing the wrong temperature regime, can result in losses in nutritional quality, flavour, taste and saleability. Tano et al. [26], found that the quality of mushrooms, tomatoes and cabbages stored under a fluctuating temperature regime was severely affected by extensive browning, loss of firmness, increased weight loss, increased level of ethanol in plant tissues, and fungal infections due to physiological damage and excessive condensation, when compared with products stored at a constant temperature. Similar observations were recently made [27] for mandarins, when low storage temperatures (2, 5 and 8 °C) resulted in a loss of orange peel colour, volatile compounds, and flavour. Thus, storage temperature is a fundamental factor affecting nutrients, colour and flavour [27]. In addition, particular attention should be paid post-harvest procedures such as cleaning, bruising, trimming and cutting, which may also affect the quality of products if they are conducted in inappropriate conditions or improperly performed [28]. Thus, the quality and stability of plant-derived food products will be strongly dependent on

the interaction of several different factors and, therefore, an understanding of the physiological and biochemical process in plants and foods during the period of shelf-life, is crucial to maximising their nutritional quality and bioactive composition, and thereby their properties beneficial to health.

3. Conventional versus organic

Organic farming has increased in popularity in recent decades due to the public's perception that health problems may arise from the consumption of plant-derived foods produced under intensive farming practices. This growing concern lead to a considerable number of studies into the effect of organic production on nutrients (mineral, vitamins) and phytochemicals such as polyphenols, antioxidant vitamins (A, C, E), glucosinolates, carotenoids and isoflavones, among others. Although a large number of studies about the differences between plants produced under conventional and organic farming systems is now available, most of the studies present contradictory facts, inconsistent results and the differences are often reported as negligible. Consequently, it is important to study the variation in nutritional quality and safety of plant-derived food produced under both organic and conventional farming methods. In the following paragraphs we discuss recent findings about the effect of the two different agricultural systems on the variation in nutrients and phytochemicals in plant-derived food, focusing on the major differences already discovered.

3.1. Variations in vitamin, mineral, amino-acid and nitrate content

The nutritional value of food is essentially a function of its vitamin and mineral content, particularly those related to important beneficial functions in animals and humans [29]. Essential minerals required in the human diet include, among others, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), sulphur (S), boron (B), chromium (Cr), cobalt (Co), copper (Cu), iodine (I), manganese (Mn), molybdenum (Mo), selenium (Se), tin (Sn), and zinc (Zn) [30, 31] and the essential vitamins include mainly A, B (all vitamins of the B complex), C, E and K [30]. Compared with conventional farming, organic production relies on sustainable management practices, which include crop rotations, cover cropping, nutrient recycling, integrated pest management, and use of organic fertilisation [32], among other practices. All these practices, according to the majority of consumers have indeed had a positive impact on food quality, enhancing the levels of beneficial minerals and vitamins [33]. However, from a scientific point of view, the question of whether organic plant-derived foods are more nutritious than conventional ones remains.

Conventional farming usually relies on massive doses of readily soluble forms of mineral fertilisers (mainly in N, P, K form), whilst organic farming relies on the incorporation of organic material into the soil, normally through the use of animal manure as fertiliser [34]. Composted manure is the most commonly used fertiliser in organic farming [35] and thus the general consumer perception is that organic foods are better because they are produced using natural and safe agronomical inputs [33], and thus they are more nutritious.

Throughout the past 15 years, several comparative studies have demonstrated significant differences in the content of vitamins, minerals and free amino-acids (Table 1). However, several authors claim that no major or significant differences are found in mineral and vitamin content in fruits and vegetables produced under organic or conventional farming systems, and several others report that for some specific nutrients, conventionally grown plant-derived foods usually contain higher average levels (Table 1).

Products tested	Nutrients analysed	Key-results	Reference
Lettuce, spinach, carrots, potato and cabbage	Iron, Mg, and P	Higher in organics	[36]
Chinese mustard, Chinese kale, lettuce, spinach	Vitamin C, β -carotene and riboflavin	Higher in organics	[37]
Wheat	Minerals (N, K, Mg, Ca, S, Fe,)	Similar in both	[38]
Red potatoes	Minerals (K, Mg, P, S and Cu)	Higher in organics	[39]
Wheat	Essential Amino acids	Lower in organics	[40]
Wheat	Minerals (P, K, Ca, Zn, Mo, Co)	Similar in both	[40]
Kiwi fruits	Minerals (N, P, K, S, B, Ca, Mg)	Higher in organics	[41]
Tomato	Vitamin C	Lower in organics	[42]
Broccoli	Vitamin C	Similar in both	[43]
Spinach	Nitrate	Lower in organics	[44]
Strawberry	Vitamin C	Similar content	[45]
Broadbean, bean, lettuce, pepper, watermelon.	Nitrates	Lower in organics	[46]
Acerola	Vitamin C and carotenoids	Higher in organics	[47]
Strawberries	Vitamin C and carotenoids	Similar in both	[47]
Cauliflower	Vitamin C	Higher in organics, but only when higher organic fertiliser levels were applied	[48]
Potatoes	Essential amino acids	Higher in organics	[49]
Strawberries	Ascorbic acid	Higher in organics	[50]
Cauliflower	Soluble solids, nitrates, P and K	Similar in both	[51]
Green pepper	Weight, firmness, thickness, N and P	Lower in organics	[52]
Tomatoes	Vitamin C	Higher in organics	[53]
Apple	Aromatic volatiles, organic acids and sugars	Higher in organics	[54]

Table 1. Differences in the content of nutrients in organic and conventional fruit and vegetables

Some research studies have claimed that organic amendments can have a positive effect on the content of antioxidant vitamins such as vitamin C [47], but others claims that the effect is negative [42], whilst others still, claim no significant difference [43, 45, 55]. Thus, there is a discrepancy in the results, and external factors such as crop variety, crop location, climate and growing conditions [56] can all exert an effect. Moreover, it is unlikely that mineral fertilisers or manure alone can affect the nutritional content of fruits and vegetables. Nonetheless, the majority of authors seems to agree that an organic production system is friendlier than an intensive or conventional farming system and the choice of organic system as an alternative to conventional practice can be justified by its lower environmental impact [57].

Another important issue related to the nutritional quality and safety of organic food is nitrate content, particularly in fresh vegetables. Nitrates are a natural consequence of the mechanism by which plants absorb the element nitrogen, in the form of NO_3^- , from fertilisers or organic material [58]. Although nitrate is an important component of plants, it has the potential to accumulate in tissues, particularly in green leafy vegetables [59] and thus, nitrate from fertilizers could accumulate in vegetables on a large scale. The danger of this, lies in the fact that nitrates can be reduced to nitrites, which can react with amines and amides to produce “N-nitroso” compounds, responsible for gastric cancer [60]. In order to maximize the health benefits from eating vegetables, measures should be taken to reduce levels of nitrates and nitrites [59]. This is particularly true in organic farming due to the large quantities of manure used as natural fertiliser, which is sometimes reported as having the potential to elevate levels of nitrates and nitrites up to, or above, maximum residue levels (MRLs), which is dangerous. However, some studies report that manure fertilisers have no significant effect on nitrate levels because organic products should always contain fewer nitrates than their counterparts produced by conventional methods, due to their lower concentration of nitrogen-based fertilisers [61, 62]. Furthermore, several other authors have reported that nitrate content is more closely related to genotype, soil conditions, growth conditions (i.e., nitrate uptake, nitrate reductase activity, and growth rate), storage and transport conditions, than to mineral or organic amendments [63]. More recently [64] it was shown that that nitrate accumulation in vegetables is more closely related to the quality of water and water accumulation in vegetable tissues. Thus, the results available until now from various different studies are sometimes contradictory and doubts still remain. Nonetheless, based on the fact that organic farming enhances specific nutrients and is less aggressive to the environment, it is more beneficial than conventional farming, which is seen as more aggressive to the environment, fauna and flora, and ultimately, to animals and humans.

3.2. Influence on bioactive compounds and functional properties of foods

3.2.1. Glucosinolates, phenolics, carotenoids and pigments

Recent scientific advances in plant-derived foods studies have mainly focused on the potential health effects of phytochemicals in plant foods. Phytochemicals, also known as bioactive compounds, are naturally occurring substances in plants, functioning mainly as secondary metabolites [65]. Their distribution in plants is considered to be the result of the natural

adaptation of plants to environmental stress, pathogen infection, insects and other pests [66]. According Harbone [66], phytochemicals can be divided into different classes: phenolics (e.g. phenolic acids, flavonoids, anthocyanin), terpenoids (e.g., carotenoids, xanthophylls and other pigments), alkaloids (e.g., indole compounds), and sulphur-containing compounds (e.g., glucosinolates). Table 2 gives a brief summary of phytochemicals commonly found in fruits and vegetables, and the potential health benefits associated with them. To date, studies have shown that phytochemicals can have a protective effect on human health (Table 2 and Table 3), including mopping-up free radicals, reduction of oxidative stress, inhibition of cell proliferation, induction of cell differentiation, inhibition of oncogene expression, suppression of gene expression in carcinogenic processes, modulation of detoxification enzymes, stimulation of the immune system, regulation of hormone metabolism, and antibacterial and antiviral effects [67]. Strong associations have been also found between disease risk reduction and consumption of foods with a high content of glucosinolates (anti-cancer), tocopherols (cardiovascular), phenolics and carotenoids (eye-health) [68].

Phytochemicals		Example of food sources	Proposed health benefits found in literature
Class	Example		
Phenolic acids	Gallic acid, caffeic acid,	Tea, kiwi fruit, strawberries, pineapple, coffee	Antioxidant and anti-inflammatory
Flavonols	Quercetin	Red and yellow onions, tea, wine, apples, cranberries, beans	Antioxidant, anti-inflammatory, enzyme inhibitor and immune modulation
Flavanols	Catechins	Chocolate, tea, grapes, wine, apples, cocoa, black-eyed peas	Antioxidant, anti-hypertensive, anti-inflammatory, anti-proliferative, anti-thrombogenic, and lipid lowering effects
Flavones	Apigenin	Chamomile, celery, parsley	Lowers high blood pressure, antioxidant and anti-inflammatory
Anthocyanins	Cyanindin	Blackberry, blueberries, red wine, strawberries	Improvement of vision, and neuroprotective effects
Isoflavones	Genistein	Soy, alfalfa sprouts, red clover, chickpeas other legumes	Reduction in blood pressure, antioxidant activity
Lignans	Secoisolariciresinol	Linseed, sunflower seeds, sesame seeds, pumpkin seeds	Improves glucose control, prevents pre-cancerous cellular changes, decreases the incidence of several chronic diseases
Stilbenes	Resveratrol	Grape skins and seeds, wine, nuts and peanuts	Antioxidant, anti-inflammatory, protects the body against nitric oxide, keeps the blood vessels optimally dilated

Phytochemicals		Example of food sources	Proposed health benefits found in literature
Class	Example		
Carotenoids	Lycopene, beta-carotene and other types of carotenes	Carrots, spinach, tomato and several other types of fruits and vegetables	Neutralisation of free radicals that cause cell damage
Monoterpenes	Limonene	Citrus oils, cherries, spearmint, garlic, maize, rosemary, basil	Antioxidant, anti-inflammatory, anti-cancer, helps with weight management (“fat cleanser”) and helps clear cholesterol
Diterpenes	Gingkolides	Gingko biloba	Protects neurons against Abeta1-42-induced synapse damage and cognitive loss
Triterpenes	Ginsenosides	Ginseng	Boosts the immune system and may lower blood sugar levels
Phytosterols	Sitosterol	Sunflower oil, avocados, rice bran, peanuts, soybeans	Inhibits 5-alpha reductase in prostate tissue
Alkaloids	Capsaicin	Chili pepper	Reduces the expression of proteins that control growth genes that cause malignant cells to grow
Glucosinolates, isothiocyanates	Sulforaphane, allyl-isothiocyanate, phenethyl-isothiocyanate,	Broccoli, mustard, cress, cabbages and all Cruciferae family plants	Neutralisation of free radicals that causes cell damage. Protection against some cancers
Indoles	Alliin, allicin	Onions, garlic, leeks	Antimicrobial agents and decreases LDL cholesterol

Table 2. Examples of some important phytochemicals commonly found in foods

<ul style="list-style-type: none"> • antioxidant activity • neutralises free radicals and reduces oxidative stress • inhibition of cell proliferation • induction of cell differentiation • inhibition of oncogene expression • inhibition of tumour gene expression • induction of cell cycle arrest • induction of apoptosis • inhibition of signal transduction pathways 	<ul style="list-style-type: none"> • phase II enzyme • glutathione peroxidase (GPX) • catalase • superoxide dismutase (SOD) • enzyme inhibition • phase I enzyme (block activation of carcinogens) • cyclooxygenase-2 (COX-2) • inducible nitric oxide synthase (iNOS) • xanthine oxide 	<ul style="list-style-type: none"> • enhancement of immune functions and surveillance • anti-angiogenesis • inhibition of cell adhesion and invasion • inhibition of nitrosation and nitration • prevention of DNA binding • antibacterial and antiviral effects
--	--	--

- enzyme induction and enhancing detoxification

¹ Adapted from Liu and Finley [67].

Table 3. Proposed health protective mechanisms of dietary phytochemicals¹

Glucosinolates are sulphur-containing compounds mainly present in the Cruciferae family. When consumed, they are hydrolysed via myrosinase (EC 3.2.1.147, thioglucoside glucohydrolase) into isothiocyanates (ITCs) and other derivative products [69], that up-regulate genes associated with carcinogen detoxification cellular mechanisms [70]. Clinical studies have shown that the products of glucosinolate hydrolysis can reduce the incidence of certain forms of cancer [71].

Other compounds such as carotenoids lutein, β -carotene and tocopherols in addition to their role as vitamins, are also powerful antioxidants [72]. Tocopherols and carotenoids have been associated with the decrease of certain forms of cancer [73] and with a reduction in risk of cardiovascular diseases [74], whilst lutein protects against the development of cataracts and age-related macular degeneration [75], even if according Trumbo and Ellwood [76] there is no credible scientific evidence to support a health claim that lutein or zeaxanthin intake can reduce the risk of age-related macular degeneration or cataracts.

Phenolic compounds are a large group of secondary metabolites, categorised according to their chemical structure, into different classes, with phenolic acids, flavonoids, stilbenes and lignans being the most relevant ones [77]. They all have in common the presence of labile hydrogen able to neutralise or mop-up free radicals, and as such they are recognised as powerful antioxidants. Fruits and vegetables are the richest potential sources of these substances [78].

As mentioned above, the diversity of the chemical composition of plants, and thus by extension of phytochemicals is determined by a number of factors, including genotype, ontogeny, growth conditions, management practices and the environment. Thus, it might be expected that differences caused by organic vs. conventional growing practices may cause associated differences in phytochemical levels and diversity. Increasing organic food consumption is partially as a result of consumer perception that organic foods are healthier, but do organic foods actually contain more phytochemicals than conventional foods? Are the levels of phytochemicals in organic production relevant? Is the diversity of phytochemicals in foods affected by agronomical practices?

Table 4 summarises some of the results from different studies conducted over the last 15 years into the difference in phytochemical content in fruits and vegetables produced under organic and conventional farming practices. This is not an exhaustive list, but unsurprisingly several different conclusions are drawn. Recent studies [79, 80, 53] have indicated that organic produce contains higher concentrations of certain phytochemicals associated with health, than those produced under conventional farming systems. In addition, some studies [81, 82] reinforce this idea, stating that the abiotic and biotic stress induced by organic farming practices seems to overcome the variability among samples and consequently, the use of organic practices may

be a means of increasing the levels of phytochemicals. However, according a recent observation [83] there is little evidence for any differences in the health benefits of organic and conventional produce. The differences often found may in fact be due to cultivar genotype influence and climatic variation rather than agricultural practices. The same observations was made by Oh et al. [84] and Lv et al. [85].

Crops & products	Bioactive substances	Key-results	Reference
Apple	Polyphenols	Higher in organic production	[86]
Chinese cabbage	Flavonoids	Higher in organic production	[87]
Spinach	Flavonoids	Higher in organic production	[87]
Green pepper	Flavonoids	Higher in organic production	[87]
Pear	Polyphenols	Higher in organic production	[88]
Yellow plum	Quercetin	Lower in organic production	[89]
Apple	Anthocyanins	Higher in organic production	[90]
Tomato	Lycopene	Similar content in both systems	[91]
Broccoli	Total glucosinolates	Lower in organic production	[92]
Strawberry	Polyphenols	Similar content in both systems	[93]
Tomato	Carotenes	Higher in organic production	[94]
Tomato	Polyphenols	Lower in organic production	[95]
Blueberry	Polyphenols	Higher in organic production	[96]
Tomato	β -carotene	Higher in organic production	[42]
Tomato	Lycopene	Lower in organic production	[42]
Carrot	Carotenoids	Similar content in both systems	[97]
Egg-plant pulp	Phenolics	Similar content in both systems	[98]
Cauliflower	Glucosinolates	Similar content in both systems	[48]
Strawberry	Anthocyanins	Higher in organic production	[79]
Soybeans	Isoflavones	Lower in organic production	[99]
Broccoli and collard greens	Glucosinolates	Higher in organic production	[100]
Watercress	Glucosinolates	Lower in organic production	[100]
Broccoli	Glucosinolates	Lower in organic production	[80]
Tomato	Polyphenols and lycopene	Higher in organic production	[53]
Pepper	Higher	Lower in organic production	[101]
Broccoli	Polyphenols	Similar content in both systems	[102]
Broccoli	Glucosinolates	Higher in organic production	[102]

Table 4. Summary of studies comparing phytochemical contents in fruits and vegetables from organic and conventional production

These authors stated that the most important factor affecting the phytochemical composition of plants is the interaction between genotype, environment and agronomical practices. Therefore, it is crucial to select the optimal environment conditions, genotype and best agronomical practices, in order to maximise the levels of a components beneficial to health.

In order to accurately evaluate the differences between organic and conventional farming systems, all the factors affecting quality of produce must be controlled, which is a major limitation of some studies through their poor experimental design. So, an accurate evaluation of all these aspects should be made over a substantial period of time (more than one year at least) in order to assess the eventual changes related to the year, seasonal effect, genotype or agronomical practices employed. A multi-year sampling study to evaluate farming systems with the necessary consistency to draw valid conclusions, is a minimum requirement [103].

3.2.2. Antioxidant activity

Closely linked to phytochemical content is the variation in antioxidants. Antioxidants, by definition, are any substance that reduce or inhibit oxidation or other reactions caused by oxygen and peroxides and free radicals, and which protect the body from the deleterious effects of free radicals [104]. Well-known antioxidants includes enzymes, vitamins (C and E), carotenes, polyphenols and others capable of counteracting the damaging effects of oxidation. They are important, because to date, epidemiological studies have shown their preventive effect against several infectious processes such as cancer, and neurodegenerative and cardiovascular diseases [105, 106, 62, 81]. As with primary nutrients and phytochemicals, the effect of organic farming practices on the antioxidant properties of plant-derived foods is controversial. It is common to find an association between organic farming practices and an increase in antioxidant content, and the converse is also true (Table 5).

Wang [81] found that organic practices result in an increase antioxidant activity in blueberries (measured by the ORAC) due to the increase of phenolic acids and anthocyanin content when compared with a conventional system, whilst Garuso and Nardini [107], didn't find any substantial difference in antioxidant activity in wines produced under organic and conventional farming practices. Similar observations were made by Unal et al. [108] for Brassicacea vegetables. They didn't detect any significant difference in antioxidant activity in brassicas produced under organic and conventional practices. However, Stracke et al. [97], when comparing the organic and conventional cultivation of apples over three years, observed that organic apples presented on average 15% higher antioxidant content, as determined by FRAP, TEAC and ORAC than conventionally produced fruits, but these authors also observed that inter-annual climatic variations were more critical to the antioxidant capacity than the type of farming. Despite these inconsistencies, the majority of authors seem to agree that the type of farming system may affect the phytochemical composition and thus by extension the amount of antioxidant activity. Since organic farming does not provide as much nitrogen as conventional fertilizers [56], as well as causing more stress to the plants (Straus et al., 2012)[109] than conventional farming, it has the potential to influence the synthesis of antioxidants, increasing their levels and thus increasing antioxidant activity, as recently reported [110]. Therefore, at least theoretically, it can be concluded that organic farming has a tendency to produce foods with more nutritional value, based on their enhanced antioxidant content and activity.

Crops & products	Antioxidant activity in organic compared to conventional counterpart	Reference
Blueberries	Higher in organics	[81]
Apples	Similar in both	[111]
Fruits and vegetables	Similar in both and no consistent trends were found	[112]
Tomato	Higher in organic	[113]
Grapes and wines	Higher in organics	[114]
Lettuce	Similar in both	[115]
Tomato	Higher in organics	[110]
Tomato	Higher in organics	[116]
Brassicac	Lower in organics	[108]
Oranges	Similar in both	[117]

Table 5. Some examples of studies comparing antioxidant activity of fruits and vegetables produced under organic and conventional farming practices

3.3. Consumers’ sensory expectations and preferences related to variability of antioxidant activity and phytochemical content of organic foods

There is common belief that organic food is healthier and safer than conventional food. According to the vast amount of literature already published, some of which is reported in this chapter, organic food is free of chemical residues, contain fewer nitrates and more antioxidants. In respect of product quality, surveys in the last 10 years [118, 119, 120, 121, 122, 123] indicate that consumers consider organic foods to be more beneficial for human health than their conventional counterparts, even if those studies often assume a lack of knowledge on behalf of the consumers of the aims and production practices of organic farming. Moreover, consumers often buy organic foods based on an emotional view, such as a desire to preserve traditional products and processes [124]. According to a survey conducted in Turkey in 2012 [120] consumers indicated 4 main reasons to buy organic foods: they are healthier, they have higher quality, the price is normally acceptable, and the food is microbiologically safe. As Monk et al. reported in 2012 [125], for the majority of consumers, the idea of enhanced nutrition, being free from chemicals, and a better taste, are the major advantages of organic foods. Consumers often think that organic food is better because it tastes better, but apart from physical and sensorial qualities, the understanding of nutritional quality by consumers seems to be a question of the ability to find credible information [118], which they often can’t. A recent survey [126] showed that 78% of consumers when questioned about the quality of labelling information, responded that they didn’t believe that all food labelled ‘organic’ was, in fact, organic, and neither did they totally believe in their healthier effects. Often, consumers purchased organic food due to personal morals or beliefs such as: ‘I feel obliged to buy organic food to protect my health’ and ‘I feel obliged to buy organic food to protect the health of my family’ [126]. The same authors observed that consumers repeatedly reported that they

experience difficulty in getting more knowledge about a product's properties, certification bodies, and labels etc... Nonetheless, nowadays consumers tend to be more conscious and more aware about the positive effects of organic foods on health and the environment [127], and as a result are buying more organic foods.

4. Conclusions

Since the 1980s, organic farming has been increasing due to growing demand from consumers for high quality foods, with lower pesticide residues, less synthetic fertilisers and produced using environmentally friendly practices. Presumably, animal and plant derived foods have fewer chemical residues and veterinary drugs in them when compared with conventional ones. The growing perception from consumers that organic foods are healthier and safer, has to the rapid growth of this type of production seen over the last 20 years. Although the beneficial properties of these foods for human health have not been unequivocally proven, the accumulation of nutritional metabolites in organic cultivation has been well documented. Recent studies have shown that organic foods are, from a nutritional point of view, at least similar to conventional ones, if not slightly better. Also, recent epidemiological studies advocate that under organic farming practices, plants can accumulate nutrients and phytochemicals, enhancing their biological value and thus increasing the nutritional quality of foods. Moreover, the growing evidence of lower pesticide exposure to consumers of organic foods, is one of the main reasons for converting to organic farming. Although more and more well-documented studies are still required to improve our understanding of which factors contribute to differences between organic and conventional farming practices, the most recent findings provide evidence-based knowledge that organic farming is a sustainable way of producing healthier and safer plant-derived foods.

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