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Invited review

Review on the main differences between organic and conventional plant-based foods

Giuseppina P. P. Lima[1]* & Fabio Vianello[2]

1 Department of Chemistry and Biochemistry, I.B., Universidade Estadual Paulista, CP 510, CEP 18618-000, Botucatu, SP, Brazil
2 Department of Biological Chemistry, University of Padova, Padova, Italy

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Summary The present review reports on the main characteristics and properties of plants cultivated following organic and conventional procedures, in the attempt to clarify give a deeper insight into some possible differences and to compare the two cultivation procedures. Here, we summarise research results regarding nutritional and safety properties of vegetable foods, evidencing qualitative differences observed between the two cultivation methods. It appears that the intake of organic foods leads to some advantages, such as the ingestion of a higher content of phenolic compounds and some vitamins, such as vitamin C, and a lower content of nitrates and pesticides. From literature, it appears that a special care should be taken about the ingestion of foods in relation to the content of some substances, e.g. polyamines, substances stimulating cellular division, because some foods coming from organic origin present a higher content of these compounds, which could explain some of the effect of the diet on patients affected by certain syndromes.

Keywords Nutritional value, organic crops, pesticide residues, phenolic compounds, polyamines, safety issue.

Introduction

Organic agriculture is an alternative cultivation model involving the practice of vegetable production without chemical additives or even growth hormones. This cultivation method is aimed to encourage the respect towards the biological cycles of the production system to maintain and to increase soil fertility, to minimise any form of pollution, to avoid the use of synthetic fertilizers and pesticides, to maintain the genetic diversity, to consider the wide social and ecological impact of the food production system and to produce good quality foods in enough amount (INFOAM, 1998). Furthermore, organic agriculture aims to enhance biodiversity and soil biological activity to achieve an optimal natural system, which is aimed to social, ecological and economical sustainability (Samman *et al.*, 2009). Food and Agricultural Organization of the United Nations (FAO/WHO, 1999) defined 'organic' the process whereby natural inputs in the field are approved and synthetic inputs are prohibited. The organic production system has been growing in recent years and it is considered that 31 million hectares, in 120 different countries, are dedicated to this kind of family farm agriculture (Willer & Yussefi, 2006).

*Correspondent: Fax: +55 14 38116255;
e-mail: gpplima@ibb.unesp.br

Current trade volume of organic food is estimated to be about 23.5 billion Dollars, growing between 20% and 30% per year. Main examples are represented by the Japanese market of 'agro-ecological' products, which is increasing 30% per year, with a value of about 2 billion USD. In the United States, this business segment is developing 20% per year, involving a market of about 10 billion USD and, in Europe, 25% per year, with a revenue of 10.5 billion USD (SOEL, 2003).

The importance of organic agriculture depends not only on the absence of pesticides but also on the effect on environmental quality, because the indiscriminate use of pesticides contaminates soil and water, provoking a generalised pollution in the ecosystem. Other problems can be observed by the use of conventional agriculture, such as an increase in soil erosion and pollution and a higher energy cost of the overall production (Azadi & Ho, 2010). Obviously, it should be mentioned that the most important advantage of conventional cultivation is attributed to the higher food production (Wisniewski *et al.*, 2002).

A problem observed all over the world related to the consumption of organic foods is their higher final price to the costumer, because of several factors, they cite a lower production, higher plant health care, lack of

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pesticides, among others. On the other side, the consumer buys a product free from pesticides, possibly characterised by a better flavour, not genetically modified (Batte *et al.*, 2007) and, frequently, produced in areas close to the consumption site. Furthermore, it is supposed to contain a higher content of beneficial and health promoting (Robinson-O'Brien *et al.*, 2009). In relation to sensorial quality, some studies suggest the superiority of organic products. Evers (1989) verified that carrot roots coming from organic cultivation subjected to sensorial analysis received a score of 6.9 and 8.3 for taste and texture, respectively, where the scale ranged from 1 (unacceptable) to 9 (excellent). While plants from conventional cultivation received 8.1 for both the attributes. Roots originating from organic system, after storage under low-temperature conditions, presented marks 25% and 18% higher, for taste and texture, when compared with nonstored products. Similar results were described by Hogstad *et al.* (1997). On the other hand, trained panelists consistently rated, over to 2-year period, conventionally grown carrots having a better taste than ecologically grown ones (Haglund *et al.*, 1999).

Several factors can influence the flavour and the aroma of a food product such as, for instance, the cultivar used the soil type and climate, the climatic year and the production procedure. Weibel *et al.* (1999) compared Golden Delicious apples produced in organic and conventional way, and they observed no differences in vitamin contents. Nevertheless, organic apples showed a higher content of some substances, such as +31.9% phosphorus, +14.1% firmness, +8.5% fibres, +18.6% phenolic compounds, a value +15.4% in the test of sensorial quality (flavour and aroma, firmness of the pulp and peel).

According to Zhao *et al.* (2007), consumer sensory analysis of a number of different types of vegetables produced in carefully managed replicated plots did not show significant differences in between organically and conventionally grown vegetables tested. Significant results occurred only in tomatoes about flavour, which appeared to be related to differences in ripeness between organic and conventional fruits.

In spite of the small, if significant, differences on sensorial quality between organic and conventional products, some authors stated that food of organic origin presents a better flavour, if compared with food produced in a conventional way (Carvalho *et al.*, 2005), and this opinion remains in organic product consumers.

Consequently, the market is going to move towards the consumption of organic products, and many studies have been driven to this aim. However, in spite of the great demand for organic products, the available information from the governmental organisations regarding the nutritional quality of these products is scarce. In this context, Williams (2002) affirmed that future studies that can evaluate effects of growing conditions on levels of protective phytochemicals are urgently required, and he commented the need to include studies relating organic products with human health. Among consumers, doubts raise in the choice between organic products and conventional ones, concerning nutritional quality. Like this, the study of the nutritional quality of organic foods is fundamental to confirm a possible superiority, as well as to test their functionality in animals, because epidemiologic studies have shown that diets rich in fruits and vegetables are associated with longer life expectancy, and these beneficial effects may be because of the high antioxidant content contained in these products (Brandt and Mølgaard, 2001).

Safety of organic products

In spite of the positive effects suggested in food chemistry literature of organic cultivation, it has not been fully elucidated whether significant differences exist between foods produced under organic and conventional cultivation, in particular if there are alterations in the chemical composition when foods are subjected to thermal processing, such as cooking or prolonged storage. Furthermore, organic production needs an excellent field handling, and the farmers need to pay attention mainly to the materials used for organic fertilizer (manure), because of the high probability of microbiological contaminations (mainly *Escherichia coli*, mycotoxins, coliforms, etc.) and parasites. Frequent contaminations can occur when the compost production process is not correctly carried out.

A problem of great importance that should be taken into account is the use of noncomposted bovine manure as fertilizer, which could be a possible route of vegetable contamination (Tauxe *et al.*, 1997). According to Williams (2002), it has been suggested that the application of manure and the reduced use of fungicides and antibiotics in organic farming could result in a greater contamination of organic foods by microorganisms or microbial products.

Manure may contribute to develop several pathologic agents into soil, and while some of them present a short environmental life-time, some others persist for long periods (Pell, 1997). The use of untreated manure to produce crops may carry a higher risk of contamination if compared to treated manure, which has markedly reduced levels of pathogens (Pell, 1997). To decrease the risk of manure-borne pathogens, such as *Salmonella enterica* or *Salmonella typhimurium* and *E. coli* O157:H7, it is necessary to establish appropriate time limits between the application of noncomposted manure and vegetable harvest (Natvig *et al.*, 2002). Accordingly to US Department of Agronomy regulation, it should be of 120 days. This should ensure that roots and leaves

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of vegetable crops should be free of *S. enteric* and *S. typhimurium*.

In literature, several studies have been concerned about plant pollution following the use of manure, in particular regarding human pathogens, such as *E. coli*, *Salmonella* spp. and *Listeria monocytogenes*. According to Loncarevic *et al*. (2005), Escherichia coli O157 and *Salmonella* spp. may be present in the intestinal tract of animals and, thus, in animal manure used as fertilizer. *Listeria monocytogenes* are ubiquitous bacteria, often found in decaying plants, soil and animal manure, and as a consequence, they may contaminate vegetables growing in the field. On the other hand, up to now, no studies definitively prove that vegetables produced following organic procedure contain harmful microorganisms to human health. Alternatives should be pursued with both a better management and a more extensive microbiological testing (Magkos *et al*., 2003). Loncarevic *et al*. (2005) showed that *E. coli* O157 and *Salmonella* were not detected in plant samples. However, organically produced lettuce was found contaminated by *E. coli* and *L. monocytogenes* (Oliveira *et al*., 2010). On the other hand, studies carried out by Sagoo *et al*. (2001) showed that vegetables may be easily contaminated by these bacteria and, the absence of pathogens (*L. monocytogenes*, *Salmonella, Campylobacter and E. coli* O157) or the low incidence (1–5%) of *E. coli* and *Listeria* spp. associated with organic vegetables, indicates that overall agricultural, hygiene, harvesting and production practices were good.

It is unknown, however, whether organic farming practices, *per se*, are to blame because product contamination can occur in the field or in the orchard during harvesting, postharvest handling, processing, shipping, marketing or at home (Beuchat & Ryu, 1997). In addition, caution should be warranted when interpreting the results from research studies (Magkos *et al*., 2003).

Another point that should be taken into account, besides the right time of manure application, is the vegetable cleaning procedure before the consumption. The results from studies on organic manure application show the potential importance of extensive washing of vegetables to reduce or even eliminate pathogenic bacteria. The correct washing procedure of vegetables may be critical for human safety even if vegetables are cooked prior to consumption, because handling of unwashed contaminated vegetables prior to cooking may initiate person-to-person transmission of pathogenic microorganisms (Natvig *et al*., 2002).

As regards fungal contamination, mycotoxins constitute a major health hazard, as their relative presence in organic or conventional foods has been the object of many studies. Considering the most recent reviews, however, it cannot be concluded that one particular type of agronomical or cultivation procedure leads to an increased risk of mycotoxin contamination, even if analytical results may vary greatly (Magkos *et al*., 2003). The comparison of the contaminant content in organic and conventionally grown raw materials showed no conclusive evidence whether conventional products are more or less safe than organic ones. Notwithstanding, it has to be noticed that contamination by deoxynivalenol (vomitoxin) of both conventional and organic wheat was observed, being higher in organic products Malmauret *et al*. (2002).

Another crucial point is represented by the safety of water used for irrigation, the deep cleaning of the equipment and the environmental conditions after harvest, because microbiological contamination can derive simply from water. Only good agricultural practices, which should be requested by national and international certified organisations, can guarantee the safety of the final product.

Vitamins, minerals and antioxidants

Winter & Davis (2006) reported that it is too early to affirm that organic food is better than a conventional one, as regards safety and nutritional quality. However, interest in organic products is growing worldwide principally because consumers are concerned about the amounts of agrochemicals, pesticides, synthetic growth stimulants and antibiotics in foods, as well as in genetic modifications (Torjusen *et al*., 2001). Bearing in mind the principle of 'health improvement', organic product consumers are looking for a product free from pesticides and characterised by a higher nutritional quality (Luthria *et al*., 2010), that is, with good content of substances, such as proteins, carbohydrates, lipids, vitamins (vitamin C, E and A) and other antioxidants.

Some research work has evidenced nutritional differences between organic and conventional products, where these differences involve basically vitamin C content and the amount of sulphur-containing compounds (Worthington, 2001). Furthermore, differences were also observed regarding some micronutrients, and a higher content of nitrate was observed in products coming from conventional cultivation (Williams, 2002; Siderer *et al*., 2005). Davis *et al*. (2004) compared forty-three products (garden crops grown following traditional agriculture production, without modern methods) between 1950 and 1999. They found significant differences among six nutritional principles (proteins, calcium, potassium, iron, riboflavin and ascorbic acid), reporting a lower content in cultures dated 1999. Authors attributed this difference (decrease in nutrients) mainly to cultivar selection by producers and not only to the cultivation procedures used in the field.

In relation to product quality, Barrett *et al*. (2007) reported on higher content of total soluble solids (SS), higher titrable acidity and firmness in organic tomatoes (*Lycopersicon esculentum*) when compared with conven-

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tional ones. Weibel *et al.* (2000) showed that internal fruit quality of organic apples was similar or slightly better than that of conventional. Other studies, as evidenced by Roussos & Gasparatos (2009), showed no differences in terms of food quality and no significant correlation between quality parameters regarding organic and conventional apples (*Malus domestica*), such as titratable acidity (TA), total soluble solids (TSS), pH, starch content and TSS/TA ratio. Similar results were reported by Juroszek *et al.* (2009) on tomato quality considering pH, ascorbic acid, SS and TA. They commented the results obtained following a 2- year study, suggesting that the cultivation procedure did not have significant effect on the quality of tomatoes. Authors reported that organic tomatoes presented a lower content of undesirable compounds, such as pesticides and nitrates, indicating a possible advantage of the use of organic products. In relation to vitamin C, authors did not observe significant differences between the cultivation procedures. Nevertheless, several researchers have reported a higher content of vitamin C in organic foods (Heaton, 2001; Worthington, 2001; Bourn & Prescott, 2002; Williams, 2002).

Research carried out by Borguini (2006) shows that tomatoes coming from organic cultivation procedures presented higher vitamin C content than the fruit by conventional cultivation. Chassy *et al.* (2006) reported, as well, a statistically significant higher content of ascorbic acid in organic tomatoes compared with conventional ones. Schuphan (1974) generalised stating that organic foods present, on average, vitamin C content 28% higher than that of conventional products. Moreover, other papers on the comparison between organic and conventional vegetables showed no difference on vitamin C content (Weibel *et al.*, 2000). Anyway, there are still controversies concerning the vitamin C contents in organic and conventional vegetables. In average, even if a tendency appears to find higher values of ascorbic acid in organically grown vegetables, studies already reported in literature are still not conclusive.

In a comparative study on sweet corn (*Zea mays* cv. *Sunnyvee* and cv. *Pride and Joy*) cultivated following organic and conventional procedures, Warman & Havard (1998) were not able to observe significant differences in vitamins C and E content between the two production producers. On the other hand, extractable P, Ca, Mg and Cu were present in higher amounts in organically fertilised potato plots; while only extractable Mg was affected by the treatments in the sweet corn, being higher in organic plots. Smith (1993) analysed mineral content in fruits (apples and pears), potatoes and corn, selected as organic and conventional food samples. Results showed that in organic foods, a higher content of calcium (+63%), iron (+59%), magnesium (+138%), phosphorus (+91%), potassium (+125%), zinc (+72.5%), sodium (+159%) and selenium (+390%) and a lower content of aluminium (−40%), lead (−29%) and mercury (−25%) were found. In Germany, Schuphan (1974) compared, over a 12- year period, the effect of the two fertilisation procedures on the production of spinach, potato, carrot and cabbage, observing that organic fertilisation led to an increase in dry matter (+27%) and in the content of iron (+77%), potassium (+18%), calcium (+10%) and phosphorus (+13%), while a decrease in sodium (−12%) and nitrate (−93%) were observed. In this last work, notwithstanding the production yield was lower than that observed with other fertilisation procedures, the increase in dry matter, vitamin C (+28%) and minerals led authors to suggest that organic foods presented a better nutritional value than conventional ones.

On the other hand, considering the same data reported in literature, Dangour *et al.* (2009), reviewing about organic food characteristics and discussing on the suggestion of a possible superiority of organic foods, reported that, in relation to mineral content (Mg, Ca, K, Zn and Cu), no significant differences could be ascribed to production procedures, even if this kind of foods seemed to contain a higher content of phosphorus and a lower of nitrate with respect to conventional ones. At the moment, it appears that more detailed studies on possible differences about mineral content in organic and conventional foods should be carried out.

Some researches, dealing with the characterisation of vegetables from organic production, showed that in some plants (mustard greens – *Brassica juncea*, lettuce – *Lactuca sativa*, tomato – *L. esculentum* – and collard greens – *Brassica oleracea*), no significant differences in the content of β-carotene and ascorbic acid, in comparison with samples produced conventionally, were observed (Borguini, 2006; Ismail & Fun, 2003). Other studies, carried out by Caris-Veyrat *et al.* (2004) on organic and conventional tomatoes, comparing the content of antioxidant compositions reported that, when the results were normalised with respect to the wet weight, a higher vitamin C, carotenoid and polyphenol content were observed in organic fruit. Conversely, when experimental data were expressed as dry matter, there were no significant differences. Obviously, as organic vegetables appear to contain less water than conventional ones (Mello *et al.*, 2003; Fontanétti *et al.*, 2006), compound content will be differently diluted, leading to differences during analysis. Other works, for example the 6- year study of Fjelkner-Modig *et al.* (2000), did not show significant differences in vitamin C content, expressed as dry matter, in parts of vegetables grown under organic or conventional mode. Obviously, especially when the substance under analysis is characterised by low stability, such as ascorbic acid or polyphenols, care should be paid to experimental conditions during sample preparation and analysis: the drying conditions could negatively affect easily oxidis-

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able substances in the sample. It has to noticed that an irrigation deficit can constitute a powerful tool to improve food nutritional value, because of a reduced amount of water available to the fruit; thus, the dry matter content and concentration of nutrients in the fruit will increase (Juroszek *et al.*, 2009).

The content of other vitamins, or vitamin precursors, in real samples was observed to depend on the cultivation procedure. Eggert & Kahrmann (1984) reported significant differences in β-carotene content between organically and conventionally fertilised carrots (*Daucus carota*), although β-carotene was evaluated only once. Leclerc *et al.* (1991) found that organic fertilisation yielded higher β-carotene and vitamin B1 contents in carrots. Moreover, other works showed no difference in lycopene content when comparing the effect of the cultivation system (Juroszek *et al.*, 2009).

Phenolic compounds, even if not directly related to food nutritional quality, have been receiving increasing attention, because of their peculiar biological activity. An attractive hypothesis suggests that vegetable foods, containing these kind of secondary metabolites, possess beneficial effects to human health, among those are anti-inflammatory and antioxidant activities (Hollman & Katan, 1999; Harbone & Williams, 2000). It is now well documented that the more an antioxidant is able to eliminate free radicals, the higher the effect on prolonging organism lifetime can be expected, because of the direct correlation of their antioxidant and protective action with a decrease in the risk of diseases (Storz, 2006). Early studies indicated that flavonoids (a class of polyphenolic compounds) may reduce blood pressure, thus reducing the risks of heart diseases and haemorrhages (Commenges *et al.*, 2000; El Gharras, 2009). These substances were also associated with the reduction in the risk of certain types of cancer and insanity (Hertog *et al.*, 1993; Commenges *et al.*, 2000).

It is reported in literature that some vegetables of organic origin present a higher content of flavonoids, when compared to the same products coming from conventional cultivation, as in the work of Chassy *et al.* (2006), where authors compared organic with conventional tomatoes. Ren *et al.* (2001) determined the content of polyphenols in five vegetables (collard greens – *B. oleracea*, Chinese cabbage – *Brassica rapa*, spinach – *Spinacia oleracea*, garlic – *Allium sativum* and green bell pepper – *Capsicum annuum*) commonly consumed in Japan, produced by organic and conventional cultivation. The contents of a flavonoid (quercetin) and caffeic acid in organically grown plants were 1.3–10.4 times higher than that found in conventional plants, suggesting the influence of different cultivation practices on human health.

Mitchell *et al.* (2007) compared organic tomatoes with conventional ones regarding flavonoid content and concluded that organic tomatoes possess almost double the amount of these substances. They stated that, in average, organic tomatoes contain +79% quercetin and +97% kaempferol than conventional ones, and they attributed this difference to the concentration of nitrogen in soil. According to the same authors, the differences in flavonoid contents are probably because of the absence of fertilizers in organic agriculture. Flavonoids, in fact, are produced by plants as a defense mechanism that can be induced by nutrient deficiencies, such as lack of nitrogen in the soil.

The effects of organic and conventional cultures on anthocyanins, total phenolics and antioxidant activity in blueberry fruit were studied (Wang *et al.*, 2008), and the results showed that fruit produced following organic procedure showed a higher content of phytochemicals (myricetin-2-arabinoside, quercetin-3-glucoside, delphinidin-3-galactoside, delphinidin-3-glucoside, delphinidin-3-arabinoside, petunidin-3-galactoside, petunidin-3-glucoside and malvidin-3-arabinoside) with respect to conventionally grown plants.

In the study of Grinder-Pedersen *et al.* (2003), the growing conditions of fruits and vegetables (conventional vs. organic) affected the content of flavonoids, and it resulted in differences in the urinary excretion of major dietary flavonoids, like quercetin. The study showed a higher content of quercetin after consuming organically produced diets than in the conventionally produced diets, which was also reflected in the urinary levels of quercetin. Authors also observed that the total plasma antioxidant capacity was significantly lower after exposure to organic diets. However, differences in quercetin content because of varietal differences cannot be excluded, because flavonoid contents may show wide variations in different varieties of fruits and vegetables (Crozier *et al.*, 1997; Juroszek *et al.*, 2009).

According to Velimirov *et al.* (2010), the most important influence of nutrition on humans is based on diet composition, but the quality of the consumed products can have a modulating positive effect, and this notion has been attributed to the reduction in synthetic pesticide residues, as well as the potential increase in health-promoting compounds. Authors claimed that the outcome of the studies dealing with the comparison of test diets characterised by the same nutritional value, only differing in the way of production, necessitates an extension of the quality concept and entailed the application of new quality assessment methods. Noteworthy, the ingestion of flavonoid, frequently found in vegetables and fruits, is supposed to reduce cancer risk in humans (Kale *et al.*, 2008). Knekt *et al.* (1997) found an inverse correlation between flavonoid intake by diet and tumour development. Accordingly, only the intake of food free from pesticides and containing a high phenolic content would be recommendable. So, it seems that organic foods could be related to the treatment and the prevention of diseases, because of the presence a

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higher content of phenolic compounds. The reason for the highest content of phenolic compounds and the lack of pesticides residues found in the organic grown plants can be attributed to the peculiar characteristic of the cultivation procedure, that is, the absence of pesticides, leading the plants to produce secondary metabolites as a defense mechanism, such as phytoalexins. Although the same mechanisms may result in the elevations of other plant secondary metabolites, this may be of toxicological rather than nutritional significance (Winter & Davis, 2006). Therefore, according to other authors, the different phenolic content (included flavonoids) is probably because of the absence of fertilizers in organic agriculture (Nicolas *et al.*, 1994).

Other studies did not detect significant differences in the content of phenolic compounds in relation to the cultivation procedure, as the work of Luthria *et al.* (2010), regarding two cultivars of eggplants (*Solanum melongena*) and of Häkkinen & Törrönen (2000), with strawberries (genus *Fragaria*). Whereas a study on marionberries (*Rubus* L. subgenus *Rubus*) showed a significantly higher content of total phenolic compounds in fruit varieties that were organically produced when compared to conventionally produced ones (Asami *et al.*, 2003). Similar results were reported on beet (*Beta vulgaris*) by Rossetto *et al.* (2009) and on miscellaneous plant species by Lima *et al.* (2008). Carbonaro *et al.* (2002), comparing peaches and pears cultivated following organic and conventional procedures, observed a higher content of phenolic compounds and a higher polyphenol oxidase (PPO) activity in organic fruits, with the concomitant increase in vitamin C content in peaches and α-tocopherol in pears, providing evidence that an improvement in the antioxidant defense system of the plant occurred as a consequence of the organic cultivation practice.

In the study by Roussos & Gasparatos (2009) on apples cultivated following organic and conventional procedures, the results are similar for total phenols: higher concentration of diphenols and flavonoids was observed in fruits from conventional cultivation. Singh *et al.* (2009) also describe similar results in eggplants. However, a review relating to the content of secondary metabolites in organic products stated that it is premature to conclude that a production system (organic) is superior to the other (conventional) with respect to nutritional composition (Winter & Davis, 2006).

At the moment, it appears that, generally, antioxidant compounds tend to increase in plants cultivated following organic procedures. The content of phenolic compounds in plants has also been found to increase as a response to infections by phytopathogens (Lattanzio *et al.*, 1994; Asami *et al.*, 2003), in agreement with the proposed role of these compounds in plant defense mechanisms. Infected plant tissues and resistant tissues have been found to be characterised by a common shift in the metabolic pattern that includes activation of phenol-oxidising enzymes and peroxidases (Carbonaro & Mattera, 2001).

The application of pesticides and fertilizers can be related to the modulation of the biosynthetic pathways leading to polyphenol formation in plant tissues (Daniel *et al.*, 1999), indirectly affecting the activity of enzymes related to tissue browning (Martinez & Whitaker, 1995). The phenomenon appears during fruit ripening. Organically produced plants can have a longer ripening period compared to conventional ones (Santos *et al.*, 2001), and as flavonoids are formed in the ripening period, one could expect a higher content of polyphenol compounds in organically grown plants (Grinder-Pedersen *et al.*, 2003). The degree of browning also depends on the presence of pesticides (Daniel *et al.*, 1999), oxygen, reducing substances, metallic ions, pH, temperature and on the activity of different oxidising enzymes, especially PPO (Sánchez-Ferrer *et al.*, 1995) and peroxidases (POD), which catalyse the oxidation of phenolic compounds containing two *o*-dihydroxy groups to the corresponding *o*-quinones (Joslin & Pointing, 1951).

Nevertheless, according to the data reviewed above, organically grown plants tend to present a higher content of polyphenolics. Anyway, it should be noticed that some of these compounds are desirable, while others can have antinutritional properties. Plant phenolic compounds, such as anthocyanins, anthoxanthins, catechins and tannins, can inhibit the activity of some digestive enzymes, as α-amylase, trypsin, chymotrypsin and lipase (Salunkhe *et al.*, 1982). The presence of tannins can be considered nutritionally undesirable, because they decrease the bioavailability of macromolecules, such as protein, carbohydrates, amino acids, vitamins and metal ions, forming stable complexes with these substances (Chung *et al.*, 1998). On the other hand, many phenolic compounds were revealed important to human health because of their antioxidant activity.

Effect of thermal processing on micronutrient retention of organic and conventional vegetable foods

Thermal processing (boiling in water) can alter the content of phenolic compounds in foods. Some works reported that cooking vegetables may increase the concentration of carotenoids, while decreasing the content of phenolic compounds in organic products, when compared with samples produced conventionally (Zhang & Hamauzu, 2004; Rossetto *et al.*, 2009). Domestic thermal processing, such as cooking, seems to have a dramatic effect on phenolic content in food, and as a consequence, on antioxidant activity of the food (Racchi *et al.*, 2002; Lima *et al.*, 2009). Gener-

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ally, during the cooking process, beyond the rapid oxidation of phenolic compounds observed at high temperature, the interruption of the biosynthesis of phenolics occurs, because of enzyme inactivation and/or denaturation inside cellular structures (Vallejo *et al.*, 2003).

The cooking process can directly promote the degradation of phenolic compounds or can induce the production of chemical modifications, which can affect food quality. Alternatively, some other compounds can be quite stable when exposed to high temperatures, preserving their antioxidant capacity and, as a consequence, food quality (Vallejo *et al.*, 2003), such as carotenoids (Zhang & Hamauzu, 2004; Rossetto *et al.*, 2009). Regarding the effect of cooking processes on vegetables, a research carried out by Lima *et al.* (2009) showed that the content of phenolics in Chinese cabbage (*B. rapa*) and corn (*Z. mays*) was higher in plants cultivated organically, while the process considerably reduced the content of these substances in both kind of samples and, as a consequence, decreased food antioxidant activity. Faller & Fialho (2009) reported that thermally processed organic vegetables (carrot – *D. carota*, onion – *Allium cepa*, potato – *Solanum tuberosum*, broccoli – *B. oleracea* var. *Italica*, and white cabbage – *B. oleracea* var. *Capitata*), following several different processing procedures, were more sensitive to heating than those of conventional origin. Furthermore, they found that even if conventional vegetables presented a lower content of phenolic compounds, they are less affected by the cooking treatment.

Thermal treatment can affect other nutritional compounds, beside the ones already mentioned, such as vitamin C. According to Zhang and Hamauzu (2004), the cooking process lead to variation in physical and chemical characteristics of vegetal foods, in particular on vitamin C content, because of its high solubility and thermal instability. Thermal processing represents one of the most important methods developed by human beings to improve food storage period and availability. At the same time, the process can lead to a reduction in food nutrient content, which was originally present. In the case of vitamins, this kind of treatment can be controlled to reduce losses, without jeopardising sensorial aspects and food safety (Pinheiro-Sant'Ana *et al.*, 1999). However, more studies should be carried out, mainly in relation to powdered crops and thermal treatment effects on a wider vegetable species.

Nitrate content

Food and Agriculture Organization of United Nations (FAO) suggests that the maximum daily admissible level of nitrate and nitrite should be 5 and 0.2 mg kg^{-1} body weight, respectively.

The problem of the absorption of nitrate by humans can be serious, if we think that nitrate can be reduced to nitrite in our gastrointestinal tract and that this latter compound is suspected of involvement in the formation of carcinogenic nitrosamines, probably in the human stomach under acidic conditions prevailing there (Tannenbaum & Correa, 1985). Nitrate content should be controlled in foods, in particular, in those from conventional origin and mainly if their destiny is children's feeding (Huarte-Mendicoa *et al.*, 1997).

Chemical fertilizers can affect the content of several compounds produced by plant metabolism. For example, nitrogen-containing fertilizers, usually employed in conventional and hydroponic cultivation, can lead to the accumulation of nitrate in some plants tissues (Lyons *et al.*, 1994). Some studies indicated that vegetables (potato, carrot, cauliflower, lettuce and others), produced under conventional systems, presented a higher nitrate content than vegetables produced under biodynamic or organic systems (Bourn & Prescott, 2002). Hundreds of rigorous tests have failed to reveal better-tasting properties or improved nutritional value, but have consistently shown that organic products have a lower nitrate and protein content (Woese *et al.*, 1997).

Worthington (2001) reviewed the properties of various crops, comparing nitrate content between organically and conventionally grown plants. Authors reported that among 176 samples, 127 (72%) presented a higher content of nitrate, when coming from conventional foods, while organic ones presented a higher nitrate content in forty-three cases (24%). The remaining samples gave no differences.

During food cooking process, a decrease in nitrate content can be observed, because this ion tends to diffuse into the cooking water (Olmedo & Bosch, 1988; Meah *et al.*, 1994). Lima *et al.* (2009) evaluated the content of polyphenols and nitrate in Chinese cabbage and corn cultivated under organic and conventional procedures. The analysis of raw and cooked samples showed a higher content of nitrate and phenols in plants cultivated organically, but the cooking process reduced considerably the content of nitrate and phenolic compounds and, as consequence, decreased sample antioxidant activity.

Polyamines

Polyamines, such as putrescine, spermidine and spermine, are present in all the organisms and are related to cellular proliferation and differentiation (Pegg & Mccann, 1982). Some authors reported that polyamine privation in alimentary diet can be beneficial in reducing tumour growth (Sarhan *et al.*, 1989; Löser *et al.*, 1999). In healthy cells, polyamine content is controlled by biosynthetic and catabolic enzymes, and, for each organism, the need of dietary polyamines is dependent on individual's physiological condition. The ingestion of

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polyamine-rich foods may be helpful for health maintenance, especially in the old age (Nishimura *et al.*, 2006). However, it should be mentioned that patients with cancer should avoid polyamine-rich foods (Nakaike *et al.*, 1988). Thus, studies about polyamine content in foods derived from organic and conventional crops are extremely important, because information on their distribution in different foods and on their daily intake are limited, mainly on organic foods (Bardócz, 1995; Hernández-Jover *et al.*, 1997; Eliassen *et al.*, 2002; Kalač & Krausová, 2005; Kalač *et al.*, 2005; Nishibori *et al.*, 2007). Lima *et al.* (2009), comparing several vegetables cultivated under organic and conventional procedures, reported a higher polyamine content in organic vegetables and attributed this result to the positive relationship between polyamines and plant longevity (Altman, 1982). Alternatively, the increased amount of these substances in plants could be related to the response against stress. In fact, plant cultivated following organic procedures may be subjected to stress conditions, because of the absence of pesticides, and they can be easily attacked by pests or diseases (Legaz *et al.*, 1998). Another work comparing organic and conventional vegetables was accomplished by Rossetto *et al.* (2009), who observed the occurrence of a higher polyamine content in pulp and peel and a lower in stalks and leaves of beets from conventional cultivation, compared with those from organic origin. The choice between organic or conventional food could be important because the source of substances that can be delivered to the body, as described, may be different depending on manuring system and thus may help or hinder medical treatments.

The role of polyamines as facilitators of cell growth was reported (Russell & Snyder, 1968), and several studies have shown their ability to protect cells from apoptosis (Seiler *et al.*, 1990; Seiler & Raul, 2007). Depending on the tumour type, polyamines seem to be involved in tumour growth (Gerner & Meyskens, 2004), and their intake by intestinal cells has been suggested to be an important regulatory mechanism of intracellular polyamine concentration. It was shown that they are preferentially taken up by tumours and tissues with high polyamine demand (Clark & Fair, 1975; Bardócz *et al.*, 1993). Furthermore, as reported earlier, polyphenol content could affect human physio-pathological conditions, such as some cancers, and probably the balanced intake of polyamines and polyphenols could be useful in patients suffering from tumours.

Pesticides

Organic foods, unsurprisingly, appear to possess a lower content of pesticide residues, or more precisely, they do not contain detectable amounts of these substances. However, the lack of data about the presence of pesticide residues in organically produced foods does not permit to reach a definitive conclusion (Borguini & Torres, 2006). Noteworthy, the favourable behaviour of the population could be attributed to the common idea that these foods can be considered free from pesticides (Roitner-Schobesberger *et al.*, 2008).

Some studies can be found in literature reporting on pesticide analysis in foods of organic origin. Rossetto *et al.* (2009) found the presence, by TLC analysis, of organo-chlorides, organo-phosphates and carbamates in leaves and peels of conventionally cultivated beets. Furthermore, they noticed that pesticides disappeared following cooking, probably because boiling in water lead to the leaching of these substances. A problem to human health would arise in the case of ingestion of the cooking water, if the origin of the product is not declared. However, the consumption of cooking water could be a source of important chemical substances for human health, such as carotenoids, which can be partly solubilised during cooking (Rodriguez-Amaya, 1997). However, because of the lack of specific analytical data on the composition of cooking water, care should be paid to avoid its consumption to minimise the risk to ingest pesticide residues, in particular as they have a cumulative effect in organisms. On the other hand, one of the most important problems following the ingestion of raw vegetable foods, possibly polluted by pesticides, could relate to children's health, because they often consume, or they should do, fruits, vegetables and juices, in particular in early childhood. Curl *et al.* (2003) observed a higher presence of pesticides in urine of children consuming foods of conventional origin, when compared with children usually eating organic foods. Efforts should be addressed to improve our knowledge on the presence of pesticides in foods for children. An important work dealing with pesticide content in infantile feeding was carried out by Lu *et al.* (2006) on children of the elementary school fed with conventional foods. They reported the presence of pesticides, such as malathion and chlorpyrifos, in children body fluids, and the content of these substances decreased after the ingestion of an organic-derived diet. Authors proposed that a diet comprising organic foods provides a dramatic and immediate protective effect against the exposures to organo-phosphate pesticides, commonly used in agricultural production. Authors also concluded that children were almost completely exposed to this organo-phosphate exclusively through the diet.

The health concern of consumers and working personnel of organic food systems contribute to the reduction in occupational pesticide poisoning. However, no data exist on health risks for producers using permitted organic pesticides per year related to occupational pesticide use, which also can cause widespread illness, including Parkinson's disease. However, no data exist on health risks for producers using permitted

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organic pesticides such as copper chloride or plant extracts (Moretto, 2004). For organic consumers, benefits include a lower incidence of allergies and an improved human health because of the above-mentioned nutritional advantages (Scialabba, 2007). For these reasons, the change in the feeding habits towards the consumption of products containing a lower amount of chemical residues would be very important to improve population health conditions.

For it is known that substance neurotoxicity contributes to several mental and neurological disturbances, it becomes important to register and to analyse epidemiological data regarding the appearance of environmental neurotoxins. Including this context, neurotoxic disorders cause alarm on health professionals and efforts of national and international health organisation, aimed to the prevention of risk occurrence because of neurotoxic substances, are growing.

The cooking process seems to reduce the content of pesticides in several foods and in organically cultivated vegetables. In agreement with Winter & Davis (2006), the found that pesticide residues can be found with lower frequencies and in lower amounts in organic foods suggests that organic foods may be less risky than conventional ones. As most crops are eaten after cooking, the pesticides used on crops can be degraded and decomposed during food cooking or processing before the ingestion (Tsumura-Hasegawa *et al*., 1992; Nagayama, 1996). In agreement with Nagayama (1996), some residual pesticides were transferred from the raw materials into the cooking water, according to their water solubility, and some other pesticides may remain in processed food. For this reason, the cooking of vegetables, even if organic, could be an effective treatment to decrease their content in foods.

To reduce pesticide ingestion, according to Trewavas (2001), organic pesticides could be used, even if generally more frequent treatments are required in organic farms, as an example with copper sulphate than those recommended for good conventional practice. Natural pyrethroids must be used at a much higher dose than that of prohibited, but much more effective, synthetic pyrethroids, such as bioresmethrin. At the moment, we suggest that the collection of analytical data on pesticide content in organic vegetables should be improved, considering that many farms performing organic cultivation are really close to conventional producers, increasing the probability of cross-contamination.

There is the need to review some traditional concepts on the real differences between organic and conventional products, that is, in the first instance, if this difference is really significant; because nowadays, with the increase in the world population, there is a need to guarantee that the food production is sufficient for all human beings of our planet. Many works can be found in literature concerning the differences between organic and conventional food, but it is necessary to be careful about reported statements, because, as discussed by Trewavas (2004), researches are carried out in different countries and different environments, soils and conditions, introducing enormous variability among samples. On the other hand, the use of substances that produce low environmental contamination, substituting current pesticides, is essential to improve the health of future generations.

Conclusions

In conclusion, there is the clear need to improve studies about on the differences between organic and conventional vegetables. This task should be carefully accomplished, considering that several factors can alter the nutritional quality of a food, such as crop time, climate, soil characteristics, environmental conditions, cooking processes as commented by Trewavas (2004). The potential for organic agriculture to improve the amounts of many important nutrients on the dinner plate is not yet fully established. The present review, of course not exhaustive, verifies that some points need to be more deeply clarified, in particular in relation to the possible superiority of organically derived plant-based foods. Careful work should be carried out in the determination of some substances, principally antioxidants in organically grown plants, taking into account differences because of species, climatic conditions, irrigation, among others. At the same time, it should be considered that certified organic foods could not present direct effect, considering only their nutritional values. At the moment, most of the published works reporting on organic plant-based foods show a lower content of pesticides, hormones, lower nitrate content and a higher content of some vitamins. These data suggest that this kind of food will be useful to improve human health, even if up to now it is only a suggestion and many more experimental works should be performed to definitely prove the effect of organic foods on human beings. On the other hand, the most important aspect regards the need to provide the consumer with enough information to carry out the correct buying choice. Even if organic products have not yet been proven to contain the highest nutrient content, it certainly should contain the lowest content of pesticides and substances harmful to health, such as nitrates. We should realise that, at the present time, the complete elimination of pesticides is very difficult, because much more work is needed to maintain a high yield in food production, while reducing the dependence on pesticides. Considering the enormous number of hungry people, this is a very important point. In this context, the incentive to develop more profitable organic family agriculture could be an important factor to motivate small farmers to produce foods with good nutritional quality and reduced content of dangerous

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compounds, reducing dependence on pesticides through organic production and biological control of pests and parasites.

Furthermore, in organic production field, the number of plant-eating insects does not reach dangerous levels and preserve the presence of natural enemies and pollinators, which tend to decrease using pesticides continuously (Kremen *et al.*, 2002). Insect disappearance will lead to a deleterious decrease in plant-based food production, considering that in many world areas food production is not sufficient to satisfy human beings needs. Another aspect regards the relatively high consumer price of organic-based food, which could be decreased by providing incentives to this kind of agronomical practice. The substitution of synthetic fertilizers with more natural products will lead to a decrease in the production costs and a concomitant increase in employment, contributing to the return correct health exploitation and to the production of health-promoting foods.

References

Altman, A. (1982). Retardation of radish leaf senescence by polyamines. *Physiologia Plantarum*, **54**, 189–193.

Asami, D.K., Hong, Y.J., Barrett, D.M. & Mitchell, A.E. (2003). Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices. *Journal of Agricultural and Food Chemistry*, **51**, 1237–1241.

Azadi, H. & Ho, P. (2010). Genetically modified and organic crops in developing countries: a review of options for food security. *Biotechnology Advances*, **28**, 160–168.

Bardócz, S. (1995). Polyamines in food and their consequences for food quality and human health. *Trends in Food Science and Technology*, **6**, 341–346.

Bardócz, S., Grant, G., Brown, D.S., Ralph, A. & Pusztai, A. (1993). Polyamines in food – implications for growth and health. *Journal of Nutrition Biochemistry*, **4**, 66–71.

Barrett, D.M., Weakley, C., Diaz, J.V. & Watnik, M. (2007). Qualitative and nutritional differences in processing tomatoes grown under commercial organic and conventional production systems. *Journal of Food Science*, **72**, C441–C451.

Batte, M.T., Hooker, N.H., Haab, T.C. & Beaverson, J. (2007). Putting their money where their mouths are: consumer willingness to pay for multi-ingredient, processed organic food products. *Food Policy*, **32**, 145–159.

Beuchat, L.R. & Ryu, J.H. (1997). Produce handling and processing practices. *Emerging Infectious Diseases*, **3**, 459–465.

Borguini, R.G. (2006). Antioxidant potential and physical–chemical characteristics of organic tomato (*Lycopersicon esculentum*) in comparison with conventional tomato. Thesis, Universidade de São Paulo, 161p.

Borguini, R.G. & Torres, E.A.F.S. (2006). Organic food: nutritional quality and food safety. *Segurança Alimentar e Nutricional*, **13**, 64–75.

Bourn, D. & Prescott, J. (2002). A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. *Critical Reviews in Food Science and Nutrition*, **42**, 1–34.

Brandt, K. & Mølgaard, J.P. (2001). Organic agriculture: does it enhance or reduce the nutritional value of plant foods? *Journal of the Science of Food and Agriculture*, **81**, 924–931.

Carbonaro, M. & Mattera, M. (2001). Polyphenoloxidase activity and polyphenol levels in organically and conventionally grown peach (*Prunus persica* L., cv. *Regina bianca*) and pear (*Pyrus communis* L., cv. Williams). *Food Chemistry*, **72**, 419–424.

Carbonaro, M., Mattera, M., Nicoli, S., Bergamo, P. & Cappeloni, M. (2002). Modulation of antioxidant compounds in organic vs conventional fruit (Peach, *Prunus persica* L., and Pear, *Pyrus communis* L.). *Journal of Agricultural and Food Chemistry*, **50**, 5458–5462.

Caris-Veyrat, C., Amiot, M.-J., Tyssandier, V. *et al.* (2004). Influence of organic versus conventional agricultural practice on the antioxidant microconstituent content of tomatoes and derived purees; consequences on antioxidant plasma status in humans. *Journal of Agricultural and Food Chemistry*, **52**, 6503–6509.

Carvalho, A.M., Junqueira, A.M.R., Vieira, J.V. & Botelho, R. (2005). Análise sensorial de genótipos de cenoura cultivados em sistema orgânico e convencional. *Horticultura Brasileira*, **23**, 805–809.

Chassy, A.W., Bui, L., Renaud, E.N.C., Horn, M.V. & Mitchell, A. (2006). Three-year comparison of the content of antioxidant, microconstituents and several quality characteristics in organic and conventionally managed tomatoes and bell peppers. *Journal of Agriculture and Food Chemistry*, **54**, 8244–8252.

Chung, K-T., Wong, T.Y., Wei, C-I., Huang, Y-W. & Lin, Y. (1998). Tannins and human health: a review. *Food Science and Nutrition*, **38**, 421–464.

Clark, R.B. & Fair, W.R. (1975). The selective *in vivo* incorporation and metabolism of radioactive putrescine in the adult male rat. *Journal of Nuclear Medicine*, **16**, 337–342.

Commenges, D., Scotet, V., Renaud, S., Jacqmin-Gadda, H., Barberger-Gateau, P. & Dartigues, J.-F. (2000). Intake of flavonoids and risk of dementia. *European Journal of Epidemiology*, **16**, 357–363.

Crozier, A., Lean, M.E.J., McDonald, M.S. & Black, C. (1997). Quantitative analysis of the flavonoid content of commercial tomatoes, onions, lettuce, and celery. *Journal of Agricultural and Food Chemistry*, **45**, 590–595.

Curl, C.L., Fenske, R.A. & Elgehun, K. (2003). Organophosphorus pesticide exposure of urban and suburban preschool children with organic and conventional diets. *Environmental Health Perpectives*, **111**, 377–382.

Dangour, A.D., Dodhia, S.K., Hayter, A., Allen, E., Lock, K. & Uay, R. (2009). Nutritional quality of organic foods: a systematic review. *American Journal of Clinical Nutrition*, **90**, 680–685.

Daniel, O., Meier, M.S., Schlatter, J. & Frischknecht, P. (1999). Selected phenolic compounds in cultivated plants: ecologic functions, health implications, and modulation by pesticides. *Environmental and Health Perspectives*, **107**, 109–114.

Davis, D.R., Epp, M.D. & Riordan, H.D. (2004). Changes in USDA food composition data for 43 garden crops, 1950 to 1999. *Journal of the American College of Nutrition*, **23**, 669–682.

Eggert, F.P. & Kahrmann, C.L. (1984). Response of three vegetable crops to organic and inorganic nutrient sources. In: *Organic Farming: Current Technology and Its Role in a Sustainable Agriculture* (edited by D.M. Kral). Pp. 97–109, ASA Spec. Publ. 46. Madison, WI: American Society of Agronomy.

El Gharras, H. (2009). Polyphenols: food sources, properties and applications – a review. *International Journal of Food Science and Technology*, **44**, 2512–2518.

Eliassen, K.A., Reistad, R., Risoen, U. & Ronning, H.F. (2002). Dietary polyamines. *Food Chemistry*, **78**, 273–280.

Evers, A.M. (1989). The role of fertilization practices in the yield and quality of carrot (*Daucus carota* L.). *Journal of Agricultural Science in Finland*, **61**, 329–360.

Faller, A.L.K. & Fialho, E. (2009). The antioxidant capacity and polyphenol content of organic and conventional retail vegetables after domestic cooking. *Food Research International*, **42**, 210–215.

FAO/WHO. Codex Alimentarius Commission. (1999). Guidelines for the production, processing, labeling and marketing of organically

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produced foods. http://www.fao.org/organicag/doc/glorganicfinal.pdf (accessed January 2010).

Fjelkner-Modig, S., Bengtsson, H., Stegmark, R. & Nystrõm, S. (2000). The influence of organic and integrated production on nutritional, sensory and agricultural aspects of vegetable raw materials for food production. *Acta Agriculturae Scandinavica. Section B, Soil and Plant Science*, **50**, 102–113.

Fontanétti, A., Carvalho, G.J., Gomes, L.A.A., Almeida, K., Moraes, S.R.G. & Teixeira, C.M. (2006). The use of green manure in crisphead lettuce and cabbage production. *Horticultura Brasileira*, **24**, 146–150.

Gerner, E.W. & Meyskens, F.L. Jr (2004). Polyamines and cancer: old molecules, new understanding. *Nature Reviews Cancer*, **4**, 781–792.

Grinder-Pedersen, L., Rasmussen, S.E., Bugel, S. *et al.* (2003). Effect of diets based on foods from conventional versus organic production on intake and excretion of flavonoids and markers of antioxidative defense in humans. *Journal of Agricultural and Food Chemistry*, **51**, 5671–5676.

Haglund, A., Johansson, L., Berglund, L. & Dahlsted, L. (1999). Sensory evaluation of carrots from ecological and conventional growing systems. *Food Quality and Preference*, **10**, 23–29.

Häkkinen, S.H. & Törrönen, A.R. (2000). Content of flavonols and selected phenolic acids in strawberries and *Vaccinium* species: influence of cultivar, cultivation site and technique. *Food Research International*, **33**, 517–524.

Harbone, J.B. & Williams, C.A. (2000). Advances in flavonoid research since 1992. *Phytochemistry*, **55**, 481–504.

Heaton, S. (2001). *Organic Farming, Food Quality and Human Health – A Review of the Evidence*. Bristol, UK: Soil Association.

Hernández-Jover, T., Izquierdo-Pulido, M., Veciana-Nogués, M.T., Mariné-Font, A. & Vidal-Carou, M.C. (1997). Biogenic amine and polyamine contents in meat and meat products. *Journal of Agricultural and Food Chemistry*, **45**, 2098–2102.

Hertog, M.G.L., Feskens, E.J.M., Hollman, P.C.H., Katan, M.B. & Kromhout, D. (1993). Dietary antioxidant flavonoids and risk of coronary heart disease: the Zutphen Elderly Study. *Lancet*, **342**, 1007–1011.

Hogstad, S., Risvik, E. & Steinsholt, K. (1997). Sensory quality and chemical composition in carrots: a Multivariate Study. *Acta Agriculturae Scandinavica. Section B, Soil and Plant Science*, **47**, 253–264.

Hollman, P.C.H. & Katan, M.B. (1999). Dietary flavonoids: intake, health effects and bioavailability. *Food and Chemical Toxicology*, **37**, 937–942.

Huarte-Mendicoa, J.C., Astiasarán, I. & Bello, J. (1997). Nitrate and nitrite levels in fresh and frozen broccoli. Effect of freezing and cooking. *Food Chemistry*, **58**, 39–42.

International Federation of Organic Agricultural Movements. (1998). Basic standards for organic production and processing. In: IFOAM General Assembly, Argentina.

Ismail, A. & Fun, C.S. (2003). Determination of vitamin C, β-carotene and riboflavin contents in five green vegetables organically and conventionally grown. *Malaysian Journal of Nutrition*, **9**, 31–39.

Joslin, M.A. & Pointing, J.D. (1951). Enzyme-catalyzed oxidativebrowning of fruit products. *Advances in Food Research*, **3**, 1.

Juroszek, P., Lumpkin, H.M., Yang, R.-Y., Ledesma, D.R. & Ma, C.-H. (2009). Fruit quality and bioactive compounds with antioxidant activity of tomatoes grown on-farm: comparison of organic and conventional management systems. *Journal of Agricultural and Food Chemistry*, **57**, 1188–1194.

Kalač, P. & Krausová, P. (2005). A review of polyamines: formation, implications for growth and health and occurrence in foods. *Food Chemistry*, **90**, 219–230.

Kalač, P., Křížek, M., Pelikánová, T., Langová, M. & Veškrna, O. (2005). Contents of polyamines in selected foods. *Food Chemistry*, **90**, 561–564.

Kale, A., Gawande, S. & Kotwal, S. (2008). Cancer phytotherapeutics: role for flavonoids at the cellular level. *Phytotherapy Research*, **22**, 567–577.

Knekt, P., Jarvinen, R., Sepanen, R. *et al.* (1997). Dietary flavonoids and the risk of lung cancer and other malignant neoplasm. *American Journal of Epidemiology*, **146**, 223–230.

Kremen, C., Williams, N.M. & Thorp, R.W. (2002). Crop pollination from native bees at risk from agricultural intensification. *Proceedings of the National Academy of Sciences of the United States of America*, **99**, 16812–16816.

Lattanzio, V., De Cicco, D., Di Venere, D., Lima, G. & Salerno, M. (1994). Antifungal activity of phenolics against fungi commonly encountered during storage. *Italian Journal of Food Science*, **6**, 23–30.

Leclerc, J., Miller, M.E., Joliet, E. & Rocquelin, G. (1991). Vitamin and mineral contents of carrot and celeriac grown under mineral or organic fertilization. *Biology, Agriculture and Horticulture*, **7**, 339–348.

Legaz, M.E., De Armas, R., Pinon, D. & Vicente, C. (1998). Relationships between phenolics-conjugated polyamines and sensitivity of sugarcane to smut (*Ustilago scitaminea*). *Journal of Experimental Botany*, **49**, 1723–1728.

Lima, G.P.P., Rocha, S., Takaki, M., Ramos, P.R.R. & Ono, E.O. (2008). Comparison of polyamine, phenol and flavonoid contents in plants grown under conventional and organic methods. *International Journal of Food Science and Technology*, **43**, 1838–1843.

Lima, G.P.P., Lopes, T.V.C., Rossetto, M.R.M. & Vianello, F. (2009). Nutritional composition, phenolic compounds, nitrate content in eatable vegetables obtained by conventional and certified organic grown culture subject to thermal treatment. *International Journal of Food Science and Technology*, **44**, 1118–1124.

Loncarevic, S., Johannessen, G.S. & Rorvik, L.M. (2005). Bacteriological quality of organically leaf lettuce in Norway. *Letters in Applied Microbiology*, **41**, 186–189.

Löser, C., Eisel, A., Harms, D. & Folsch, U.R. (1999). Dietary polyamines are essential luminal growth factors for small intestinal and colonic mucosal. *Gut*, **44**, 12–16.

Lu, C., Toepel, K., Irish, R., Fenske, R.A., Barr, D.B. & Bravo, R. (2006). Organic diets significantly lower children's dietary exposure to organophosphorus pesticides. *Environmental Health Perspectives*, **114**, 260–263.

Luthria, D., Singh, A.P., Wilson, T., Vorsa, N., Banuelos, G.S. & Vinyard, B.T. (2010). Influence of conventional and organic agricultural practices on the phenolic content in eggplant pulp: plant-to-plant variation. *Food Chemistry*, **121**, 406–411.

Lyons, D.J., Rayment, G.E., Nobbs, P.E. & Mccallum, L.E. (1994). Nitrate and nitrite in fresh vegetables from Queensland. *Journal of the Science of Food and Agriculture*, **64**, 279–281.

Magkos, F., Arvaniti, F. & Zampelas, A. (2003). Putting the safety of organic food into perspective. *Nutrition Research Reviews*, **16**, 211–221.

Malmauret, L., Parent-Massin, D., Hardy, J.L. & Verger, P. (2002). Contaminants in organic and conventional foodstuffs in France. *Food Additives and Contaminants*, **19**, 524–532.

Martinez, V.M. & Whitaker, J.R. (1995). The biochemistry and control of enzymatic browning. *Trends in Food Science and Technology*, **6**, 195–200.

Meah, M.N., Harrison, N. & Davies, A. (1994). Nitrate and nitrite in foods and the diet. *Food Additives & Contaminants*, **11**, 519–532.

Mello, J.C., Dietrich, R., Meinert, E.M., Teixeira, E. & Amante, E.R. (2003). Efeito do cultivo orgânico e convencional sobre a vida-de-prateleira de alface americana (*Lactuca sativa* L.) minimamente processada. *Ciência e Tecnologia de Alimentos*, **23**, 418–426.

Mitchell, A.E., Hong, Y.-J., Koh, E. *et al.* (2007). Ten-year comparison of the influence of organic and conventional crop management practices on the content of flavonoids in tomatoes. *Journal of Agricultural and Food Chemistry*, **55**, 6154–6159.

Moretto, A. (2004). Occupational aspect of pesticide toxicity in humans. In: *Pesticide Toxicolgy and International Regulation* (edited by T.C. Mars & B. Ballantyne). Pp. 431–472. Chichester, UK: John Wiley and Sons.

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Nagayama, T. (1996). Behavior of residual organophosphorus pesticides in foodstuffs during leaching or cooking. *Journal of Agricultural and Food Chemistry*, **44**, 2388–2393.

Nakaike, S., Kashiwagi, K., Terao, K., Iio, K. & Igarashi, K. (1988). Combined use of α-difluoromethylorinithine and an inhibitor of S-adenosylmethionine decarboxylase in mice bearing P388 leukemia or Lewis lung carcinoma. *Japanese Journal of Cancer Research*, **79**, 501–508.

Natvig, E.E., Ingham, S.C., Ingham, B.J., Cooperband, L.R. & Roper, T.R. (2002). *Salmonella enteric* Serovar *Typhimurium* and *Escherichia coli* contamination of root and leaf of vegetables grown in soils with incorporated bovine manure. *Applied and Environmental Microbiology*, **68**, 2737–2744.

Nicolas, J.J., Richard-Forget, F.C., Goupy, P.M., Amiot, M.J. & Aubert, S. (1994). Enzymatic browning reactions in apple and apple products. *Critical Reviews in Food Science and Nutrition*, **34**, 109–157.

Nishibori, N., Fujihara, S. & Akatuki, T. (2007). Amounts of polyamines in foods in Japan and intake by Japanese. *Food Chemistry*, **100**, 491–497.

Nishimura, K., Shiina, R., Kashiwagi, K. & Igarashi, K. (2006). Decrease in polyamines with aging and their ingestion from food and drink. *Journal of Biochemistry*, **139**, 81–90.

Oliveira, M., Usall, J., Viñas, I., Anguera, M., Gatius, F. & Abadias, M. (2010). Microbiological quality of fresh lettuce from organic and conventional production. *Food Microbiology*, **27**, 679–684.

Olmedo, R.G. & Bosch, N.B. (1988). Ingestión de nitratos procedentes de productos hortícolas, y sua incidencia toxicologica. *Alimentaria*, **25**, 76–78.

Pegg, A.E. & Mccann, P.P. (1982). Polyamine metabolism and function. *American Journal of Physiology*, **243**, 212–221.

Pell, A.N. (1997). Manure and microbes: public and animal health problem? *Journal of Dairy Science*, **80**, 2673–2681.

Pinheiro-Sant'Ana, H.M., Penteado, M.V.C., Brandão, S.C.C. & Stringheta, P.C. (1999). Stability of B-vitamin in meat prepared by foodservice. 1. Thiamin. *Foodservice Research International*, **11**, 33–52.

Racchi, M., Daglia, M., Lanni, C., Papetti, A., Govoni, S. & Gazzani, G. (2002). Antiradical activity of water soluble components in common diet vegetables. *Journal of Agriculture and Food Chemistry*, **50**, 1272–1277.

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

Robinson-O'Brien, R., Larson, N., Neumark-Sztainer, D., Hannan, P. & Story, M. (2009). Characteristics and dietary patterns of adolescents who value eating locally grown, organic, nongenetically engineered, and nonprocessed food. *Journal of Nutrition Education and Behavior*, **41**, 11–18.

Rodriguez-Amaya, D.B. (1997). Carotenoids and food preparation: the retention of provitamin A carotenoids in prepared, processed, and stored foods. USAID, OMNI Project. Available at http://www.mostproject.org/PDF/carrots2.pdf. Accessed April 2010.

Roitner-Schobesberger, B., Darnhofer, I., Somsook, S. & Vogl, C.R. (2008). Consumer perceptions of organic foods in Bangkok, Thailand. *Food Policy*, **33**, 112–121.

Rossetto, M.R.M., Vianello, F., Rocha, S.A. & Lima, G.P.P. (2009). Antioxidant substances and pesticide in parts of beet organic and conventional manure. *African Journal of Plant Science*, **3**, 245–253.

Roussos, P.A. & Gasparatos, D. (2009). Apple tree growth and overall fruit quality under organic and conventional orchard management. *Scientia Horticulturae*, **123**, 247.

Russell, D. & Snyder, S.H. (1968). Amine synthesis in rapidly growing tissues: ornithine decarboxylase activity in regenerating rat liver, chick embryo, and various tumors. *Proceedings of National Academy of Sciences*, **60**, 1420–1427.

Sagoo, S.K., Little, C.L. & Mitchell, R.T. (2001). The microbiological examination of ready-to-eat organic vegetables from retail establishments in the United Kingdom. *Letters in Applied Microbiology*, **33**, 434–439.

Salunkhe, D.K., Jadhav, S.J., Kadam, S.S. & Chavan, J.K. (1982). Chemical, biochemical, and biological significance of polyphenols in cereals and legumes. *CRC Critical Reviews in Food Science and Nutrition*, **17**, 277–305.

Samman, S., Kung, F.P., Carter, L.M. *et al*. (2009). Fatty acid composition of certified organic, conventional and omega-3 eggs. *Food Chemistry*, **116**, 911–914.

Sánchez-Ferrer, A., Rodríguez-López, J.N., García-Cánovas, F. & García-Carmona, F. (1995). Tyrosinase: a comprehensive review of its mechanism. *Biochimica et Biophysica Acta*, **1247**, 1–11.

Santos, R.H.S., da Silva, F., Casali, V.W.D. & Conde, A.R. (2001). Post harvest conservation of lettuce cultivated with organic compost. *Pesquisa Agropecuária Brasileira*, **36**, 521–525.

Sarhan, S., Knödgen, B. & Seiler, N. (1989). The gastrointestinal tract as polyamine source for tumor growth. *Anticancer Research*, **9**, 215–222.

Schuphan, W. (1974a). Nutritive value of crops as influenced by organic and inorganic fertilizer treatment. *Qualitas Plantarum: Plant Foods for Human Nutrition*, **23**, 333–358.

Scialabba, N.El.-H. (2007). Organic agriculture and food security. *International Conference on Organic Agriculture and Food Safety*, FAO, Italy, 25p.

Seiler, N. & Raul, F. (2007). Polyamines and the intestinal tract. *Critical Reviews in Clinical Laboratory Sciences*, **44**, 365–411.

Seiler, N., Sarhan, S., Grauffel, C., Jones, R., Knödgen, B. & Moulinoux, J.-P. (1990). Endogenous and exogenous polyamines in support of tumor growth. *Cancer Research*, **50**, 5077–5083.

Siderer, Y., Maquet, A. & Anklam, E. (2005). Need for research to support consumer confidence in the growing organic food market. *Trends in Food Science and Technology*, **16**, 332–343.

Singh, A.P., Luthria, D., Wilson, T. *et al*. (2009). Polyphenols content and antioxidant capacity of eggplant pulp. *Food Chemistry*, **114**, 955–961.

SOEL (2003). Stifung Okologie and Landbau, available at http://www.soel.de/inhalte/publikationen/s/s_74.pdf.

Smith, B.L. (1993). Organic foods vs. supermarket foods: element levels. *Journal of Applied Nutrition*, **45**, 35–39.

Storz, P. (2006). Reactive oxygen species-mediated mitochondria-to-nucleus signaling: a key to aging and radical-caused diseases. *Science STKE*, **332**, http://stke.sciencemag.org/cgi/content/full/sigtrans;2006/332/re3.

Tannenbaum, S.R. & Correa, P. (1985). Nitrate and gastric cancer. *Nature*, **317**, 675–676.

Tauxe, R., Kruse, H., Hedberg, C., Potter, M., Madden, J. & Wachsmuth, K. (1997). Microbial hazards and emerging issues associated with produce: a preliminary report to the National Advisory committee on microbiological. Criteria for foods. *Journal of Food Protection*, **60**, 1400–1408.

Torjusen, H., Lieblein, G., Wandel, M. & Francis, C.A. (2001). Food system orientation and quality perception among consumers and producers of organic food in Hedmark County, Norway. *Food Quality and Preference*, **12**, 207–216.

Trewavas, A. (2001). Urban myths of organic farming. Organic agriculture began as an ideology, but can it meet today's needs? *Nature*, **410**, 409–410.

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

Tsumura-Hasegawa, Y., Tonogai, Y., Nakamura, Y. & Ito, Y. (1992). Residue levels of dichlorvos, chlorpropham, and pyrethrins in postharvest-treated potatoes during storage or processing into starch. *Journal of Agricultural and Food Chemistry*, **40**, 1240–1244.

Vallejo, F., Tomás-Barberán, Fa. & Garcia-Vigueira, C. (2003). Phenolic compound contents in edible parts of broccolli in inflores-

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cences after domestic cooking. *Journal of the Science of Food and Agriculture*, **83**, 1511–1516.
Velimirov, A., Huber, M., Lauridsen, C., Rembialkowska, E., Seidel, K. & Bügel, S. (2010). Feeding trials in organic food quality and health research. *Journal of Science and Food Agriculture*, **90**, 175–182.
Wang, S.Y., Chen, C.-T., Sciarappa, W., Wang, C.Y. & Camp, M.J. (2008). Fruit quality, antioxidant capacity, and flavonoid content of organically and conventionally grown blueberries. *Journal of Agriculture and Food Chemistry*, **56**, 5788–5794.
Warman, P.R. & Havard, K.A. (1998). Yield, vitamin and mineral contents of organically and conventionally grown carrots and cabbage. *Agriculture, Ecosystems & Environment*, **68**, 207–216.
Weibel, F.P., Bickel, R., Leuthold, S., Alföldi, T. & Niggli, U. (1999). Are organically grown apples tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality. Proceedings of the 12th International IFOAM Scientific Conference, IFOAM, 147–153.
Weibel, F.P., Bickel, R., Leuthold, S. & Alföldi, T. (2000). Are organically grown apple tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality *Acta Horticulturae*, **517**, 417–426.
Willer, H. & Yussefi, M. (2006). The world of organic agriculture. Statistics and Emerging Trends SOL, 2006. http://orgprints.org/5161/1/yussefi-2006-overview.pdf (last accessed 01 March 2010).
Williams, C.M. (2002). Nutritional quality of organic food: shades of grey or shades of green? *Proceedings of the Nutrition Society*, **61**, 19–24.
Winter, C.K. & Davis, S.F. (2006). Organic foods. *Journal of Food Science*, **71**, R117–R124.
Wisniewski, J., Frangne, N., Massonneau, A. & Dumas, C. (2002). Between myth and reality: genetically modified maize, an example of a sizeable scientific controversy. *Biochimie*, **84**, 1095–1103.
Woese, K., Lange, D., Boess, C. & Bögl, K.W. (1997). A comparison of organically and conventionally grown foods. Results of a review of the relevant literature. *Journal of Science and Food Agriculture*, **74**, 281–293.
Worthington, V. (2001). Nutritional quality of organic versus conventional fruits, vegetables, and grains. *Journal of Alternative and Complementary Medicine*, **7**, 161–173.
Zhang, D. & Hamauzu, Y. (2004). Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. *Food Chemistry*, **88**, 503–509.
Zhao, Z., Chambers, E. IV, Matta, Z., Loughin, T.M. & Carey, E.E. (2007). Consumer sensory analysis of organically and conventionally grown vegetables. *Journal of Food Science*, **72**, S87–S91.

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