

ORGANIC AND CONVENTIONAL FOODS: DIFFERENCES IN NUTRIENTS

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ABSTRACT

Organic agriculture represents a sustainable crop system focused on producing food without environmental degradation. Consumer confidence in organic food is based both in lowering environmental impacts and health diseases. The aim of the present review is to compare nutritional properties of agricultural products cultivated following organic and conventional procedures. The heterogeneity of published results does not permit to conclude definitely the higher presence of nutrients in organic foods; even there are clear evidences for some antioxidants. Comparative studies are challenging for the several factors influencing plant quality such as climate, soil type, cultivars and time of storage that should be considered. Holistic approaches whit nutritional, technological parameters and sensorial quality of food seem to be the best way for future comparative studies.

Keywords: food quality, nutrients, organic food, sustainable agriculture

1. INTRODUCTION

Organic agriculture consists of many practices that emphasize farming based on ecosystem management, integrated cropping and livestock systems, diversity of products, reliance on natural pest and disease control without the use of chemical inputs. The principal objectives of organic agriculture are to produce healthy and sustainable food only using biological and ecological processes (AZADI et al., 2011).

The increase in production and consumption of organic foods is one of the major market trends of last years. In fact U.S. sales of organic products were an estimated \$28.4 billion in 2012 - over 4% of total food sales - and will reach an estimated \$35 billion at the end of 2014 (USDA, 2014). In Europe, while sales in some countries were rather stagnating in 2012, others displayed a growth of more than 10% (Finland, Norway and the Netherlands) (FIBL, 2014).

Fresh fruits and vegetables have been the top selling category since the organic food industry started retailing products over 3 decades ago. Produce accounted for 43% of U.S. organic food sales in 2012, followed by dairy, packaged/prepared foods, beverages, bread/grains, snack foods, meat/fish/poultry and condiments.

The growth of organic agriculture, its production and trade needed of an increase in national and international legislation, in order to set the specific requirements and create the institutional framework for certification.

Organic farming and production has been regulated in the context of EU farm policy reform since 1991, when the European Council of Agricultural Ministers adopted Regulation (EEC) No 2092/91 on organic farming and labelling of organic farm produce and foods. Evolutions in the regulations are set by Council Regulation (EC) No 834/2007 defining the official EU aims, objectives and principles of organic farming and production, and by two implementing regulations (No 889/2008 and No 1235/2008) detailing the organic production, labelling and import rules. The principal topics regard sustainable management system for the respect of nature's cycle based on risk assessment and precautionary measures (exclusion of chemical fertilizers and mechanical treatments, respect of biodiversity, use of natural sources and respect of animal welfare standards).

In recent years, several studies confirm people belief in healthier properties of food from organic agriculture as consequence of the environmental-friendly management (HARPER and MAKATOUNI, 2002; YIRIDOE et al., 2005). But until now, there is a lack of strong scientific evidences that organic food is significantly different from the conventional regarding nutritional properties and health impact. This is due to several important aspects that need to be considered in the experimental design of comparative studies and, consequently, in their interpretation. In fact, many factors impact the nutrient density of crops, whether they are grown organically or conventionally. Some factors impact both production systems equally, while a few factors tend to have a larger impact on one production system over the other. In order to carry out a valid comparison between organic and conventional agriculture food products at first, plants have to be of the same cultivar, and have to be cultivated in near farms, with similar soils, under similar climatic conditions (GASTOL and DOMAGALA-SWIATKIEWICZ, 2013). Furthermore, products must be sampled at the same time and pre-treated similarly, analyzed by accredited laboratories employing validated methods and results statistically treated. Generally, studies are divided into three classes: market-oriented studies, surveys and cultivation tests. In the first type of works, products are taken from organic and conventional shops; no information about origin, ripeness, variety, climate and condition of production is considered during comparisons. In surveys, instead, products derived from selected organic and conventional farms (SIDERER *et al.*, 2005). Environmental factors and condition of production can be used in studies comparison selecting neighbouring farms,

but the precision of these parameters cannot be verified. The last category of works is represented by cultivation tests that permit to assess the difference in quality between organic and conventional products; unfortunately results can be applied only in the specific farm situation considered (RIGBY and CÀCERES, 2001).

Organic foods differ from the conventional ones predominantly because the absence of pesticides, fertilizers and heavy metals residues as application of regulated production rules; the majority of literature studies dealing with organic food quantify these compounds to verify the limits. The absence of pesticides use and nitrogen fertilization influences the production of bioactive compounds and plant metabolites; an example is given by those involved in the defensive mechanisms of plants. As consequence, a natural functional food is expected to have higher contents of health promoting substances if cultivated under organic agricultural system.

The present review focuses attention on such bioactive compounds, noted to improve human health, to evaluate if their content in foods can be use to discriminate between the two type of agriculture systems. For this scope, in this review we have considered the most relevant scientific papers published in the period 2000-2015, searched in three databases (Scopus, PubMed, Web of Science), written in English and comparing chemical composition of organic and conventional foods. The exposure terms searched were: "organic" and "conventional" combined with "food", "agricultural crops", "livestock", "agriculture" and terms for nutritionally relevant substances.

Results are organized on the base of polyunsaturated fatty acids, essential amino acids, vitamins, minerals and polyphenols contents.

2. ORGANIC VS CONVENTIONAL COMPARATIVE STUDIES

The debate about the differences in nutritional properties between organic and conventional food interested largely researchers, as shown by the consistent number of papers and reviews published in few years.

All the reviews existing about this topic reported different results. Some of these, concluded that organic foods have higher content of such constituent instead others underlined the absence of differences in nutritional values between the two alternatives (WOESE *et al.*, 1997; BOURN and PRESCOTT, 2002; HUNTER *et al.*, 2011; GASTOL and DOMAGALA-SWIATKIEWICZ 2013; JENSEN *et al.*, 2013). The opposite outcomes were principally ascribed to the lack of coherence in study design and implementation. In fact, frequently, inaccurate comparisons led to assert the superior quality of organic respect to conventional foods.

At first, nutrient content is strictly affected by varieties; furthermore, other factors such as geographic locations of crops, characteristics of soil and clime, maturity from harvest to storage and testing must not be neglected in the way of comparison between organic and conventional agricultural methods. In the last years, systematic reviews were realized to compare the content of chemical compounds in different foods, checking at the same time for differences in study methodologies and implementation. In this way, the available scientific literature on the subject of interest is screened and the outcomes of all articles meeting predefined quality criteria, analysed by a systematic approach. (BENBROOK *et al.*, 2008; DANGOUR *et al.*, 2009; BRANDT *et al.*, 2011; SMITH-SPANGLER *et al.*, 2012; BARAŃSKI *et al.*, 2014).

In 2008, the meta-analysis by Benbrook *et al.*, analyzed differences in nutrient content between organic and conventional food samples within 236 matched pairs. Nutrients considered were Vitamin C, beta-carotene, Vitamin E, potassium and phosphorous, nitrates, total proteins, total phenolics, total antioxidant capacity, and the polyphenols

quercetin and kaempferol. This review found that total phenolics, vitamin E, vitamin C, quercetin, and total antioxidant capacity of organics exceeded that of conventionally grown produce in the case of total antioxidant capacity, by 80%. Conventional products had higher levels of potassium, phosphorous, and total protein, all basic constituents of conventional fertilizers.

DANGOUR *et al.* (2009) systematic review, based only on studies of satisfactory quality including field trials, farm surveys and basket studies, underlined the absence of differences in nutrient parameters between organically and conventionally produced foodstuffs. The small differences in nutrient content detected were ascribed as biologically plausible and generally related to differences in cultivation methods.

HUNTER *et al.* (2011) evaluated the micronutrient composition of organic and conventional plant foods with a systematic analysis. Organic plant foods (vegetables, legumes and fruit) were found to have a 5.7% higher content of vitamins and minerals than their conventionally grown counterparts. Irrespective of cultivar, soil type, harvest conditions, and chemical analysis, organic plant foods contained significantly higher amounts of minerals, including phosphorus, compared to conventional foods. These results were explained by the hypothesis of accelerated growth, as a result of conventional agricultural methods, that down-regulates the synthesis of carbon-containing metabolites, such as ascorbic acid. Furthermore, it has been proposed that organically produced plants synthesize higher levels of ascorbic acid than conventionally-grown plants, in response to biological and ecological stresses, and the absence of protection conferred by synthetic pesticides.

BRANDT *et al.* (2011) meta-analysis, focused on secondary metabolites and vitamins content in fruits and vegetables, collecting data from different studies had the scope to detect effects of systematic factors, separately from factors that occur randomly.

The results obtained show that organic plant material had higher levels of all analyzed secondary metabolites and of vitamins C than conventional vegetables and fruits, together with higher content of phenolic acids and total phenolics.

Instead, for the content of flavones and flavonols (non-defence-related compounds), differences between two cultivations systems were heterogeneous, while for the content of carotenes no significant differences were found.

The systematic analysis by SMITH-SPANGLER *et al.* (2012) based on 223 literature study on nutrient and contaminant levels underlined that heterogeneity in results were too high to estimate significantly higher nutritional properties of organic food. About pesticides residues, lower levels were found in organic than conventional product, but differences in risk for exceeding maximum allowed limits were small. Of the entire nutrient evaluated, only phosphorus content was homogeneous and significantly higher in organic food, but this difference was not statistically significant.

GASTOL and DOMAGALA-SWIATKIEWICZ (2013) made an evaluation on Polish organic and conventional fruit and vegetables juices. The results of this comparative study that covered 33 neighbouring pairs of organic/conventional fields with six evaluated species, confirmed the absence of differences in nutritional properties between the organic and conventional food analyzed. Only in few species, parameters such as polyphenolic content, antioxidant activity and dry matter significantly discriminate the two types of cultivation products.

The systematic review by JENSEN *et al.* (2013) dealt with the comparison between organic and conventional agriculture in terms of nutrients content, bioavailability of nutrients and potential effect on human health. About nutritional differences between the two type of agricultural products, results highlighted the difficulty of make direct comparison because of the variability of influencing factors and study designs. The approach of using a systematic review permitted to conclude that organic food contained higher levels of

vitamin E, vitamin C, phosphorus and lower content of pesticides than organic produce; no clear effects were established on health-related biomarkers.

The most recent systematic review by BARAŃSKI *et al.* (2014), based on an extensive data set of 343 peer-reviewed publications, indicated that organic crops and foods have a higher antioxidant activity and contain higher concentrations of a wide range of nutritionally desirable antioxidants/polyphenolics, but lower concentrations of Cd metal. This study, for plant secondary metabolites is in accordance with results carried out by BRANDT *et al.* (2011), but it contradicts the results of the most systematic reviews/meta-analyses published previously, which indicated that there are no significant composition differences between organic and conventional crops. The main reason for the inability of previous studies to detect composition differences was adduced, by the authors, probably to the highly limited number of studies or data sets available or included in the analyses, which could decrease the statistical power of the meta-analyses. In addition, authors used a weighted meta-analysis based on SMD (standardised mean difference), not used in most of the previous studies that is recommended when combining data from studies that measure the same parameter (e.g. the major phenolic compounds found in different crops), but use different scales.

Results of relevant scientific works considered in this review, from cultivation tests and surveys, are described below. Differences are underlined considering the content of functional compounds (polyunsaturated fatty acids, essential amino acids, vitamins and minerals, polyphenols) in organic and conventional foods.

2.1. Polyunsaturated fatty acids

The majority of studies dealing with PUFAs in conventional and organic products are focused on olive oil, for high contents in this matrix (Table1). GARCÍA-GONZÁLEZ *et al.* (2014) compared certified organic and conventional olive oil samples from different Spanish cultivars (*Arbequina*, *Cornicabra*, *Hojiblanca* and *Picual*). By application of multivariate algorithms (Principal Component Analysis and Multidimensional Scaling), authors concluded that fatty acids and sterols profile and content were only able to discriminate olive oil samples according to fruit cultivar. Differences in total PUFAs content were not statistically significant between organic (0.28 ± 0.06 mgKg⁻¹) and conventional (0.28 ± 0.07 mgKg⁻¹) oils. Also SAMMAN *et al.* (2008), comparing organic and conventional edible oils (coconut oil, olive oil, canola oil, mustard oil seed and sesame oil) found insignificant differences in the content of PUFAs. The influence of the cultivation method on the quality indices of virgin olive oils was also investigated by ANASTASOPOULOS *et al.* (2013). Olive oils (*Koroneiki cv.*) produced in different geographical origins and seasons, years 2000 and 2004, showed differences in PUFAs content. Those from organic production system and season 2004 had a PUFAs level (expressed as Mean \pm SD% on total content) of 79.25 ± 0.18 that resulted significantly higher of 79.05 ± 0.18 , content of conventional products.

ROUPHAEL *et al.* (2015) investigated the presence of PUFAs in the seeds of Perilla, an annual plant of the mint family *Lamiaceae*.

Irrespective of the farming systems, the linolenic acid was the predominant fatty acid in seeds, representing 62% of the total fatty acids in the lipid fraction. No differences were recorded among treatments for the content of palmitic C16:0 (avg. 6.0%), stearic C18:0 (avg. 1.0%), and oleic C18:1 (avg. 14.0%), and linoleic acid (avg. 15.0%).

Table 1: Comparison of polyunsaturated fatty acids contents in organic and conventional foods.

References	Study design	Compounds analyzed	Compounds contents		Units	Statistical comparison
			organic	conventional		
García-González <i>et al.</i> , 2014	16 samples of extra virgin olive oil of 4 Spanish cultivars taken from cooperative societies.	palmitic acid, palmitoleic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid.	0.28±0.06	0.28±0.07	Means ± SD of PUFAs in mg kg ⁻¹	No differences in PUFA content
Samman <i>et al.</i> , 2008	59 certified organic and 53 conventional oils purchased from markets in Sydney. Edible oils considered: Coconut oil (1), Olive oil (2), Canola oil (3), Mustard seed oil (4), sesame oil (5).	palmitic acid, palmitoleic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid.	(1) 2.63±0.86 (2) 10.59±3.26 (3) 25.73±9.08 (4) 46.07±0.45 (5) 48.2±1.09	3.86±0.46 12.09±9.6 29.51±0.53 28.21±13.79 44.18±3.8	Means ±SD % of PUFA on total fatty acids content	No differences in PUFA content
Anastasopoulos <i>et al.</i> , 2013	Virgin olive oil (Koroneiki variety) produced in Messinia, Peloponnesus, Greece from different harvesting periods: season 2000(1) and 2004(2).	palmitic acid, palmitoleic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid.	(1) 77.43±1.95 (2) 79.25±0.18	77.90±1.40 79.05±0.18	Means±SD% of PUFAs on total content	Higher PUFA content in organic olive oil
Rouphael <i>et al.</i> , 2015	Perilla plants grown under conventional and organic farming in a typical Mediterranean area such as Southern Italy, season 2005.	palmitic acid oleic acid linoleic acid linolenic acid stearic acid	6.3 13.5 14.7 61.9 1.9	6.3 13.9 14.6 61.6 1.9	Means% of PUFAs on total content	No differences in PUFA content

2.2. Essential amino acids

Few literature studies investigated for differences in amino acids content in organic and conventional foods (Table 2). Furthermore, essential and non-essential amino acids were generally analyzed together in the same food. RÖHLING and ENGEL (2010) analyzed the influence of the input system on several metabolites of three maize cultivars (*Amadeo*, *Lukas* and *Flavi*). In the text numeric data results were not shown. Authors only reported results of statistical tools used: Principal component analysis (PCA) and analysis of variance (ANOVA). Amino acids levels, as well other compounds investigated (polar compounds, organic acids, sugar and sugar alcohols) showed the absence of a direct relationship between metabolites content and agricultural practice. Authors suggested that only genotype and environment contributed to differentiations in metabolite profiles of maize.

An absence of differences among organic and conventional food was also found by MADER *et al.* (2007) analyzing protein and amino acids content in wheat (*Triticum aestivum* L.). MAGGIO *et al.* (2008), investigating in tubers (*Agria* and *Merit cv*), found that the organically grown ones contained only significant higher levels of threonine (24.5 mg 100g⁻¹ of Fresh Weight) respect to conventional tubers (24.0 mg 100g⁻¹ of Fresh Weight).

Table 2: Comparison of essential aminoacids contents in organic and conventional foods.

Reference	Study design	Compounds analyzed	Compounds contents		Units	Statistical Comparison
			organic	conventional		
Rohling and Engel, 2010	Three maize cultivars grown in the season 2004 at two locations. The same procedure was repeated in the season 2005.	histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine	numeric data not reported.	numeric data not reported.	-	No differences in essential amino acids content
Mader et al., 2007	Wheat (<i>Triticum aestivum</i> L.) grown in a 21 year agrosystem comparison in central Europe	histidine isoleucine leucine lysine methionine phenylalanine threonine tryptophan valine	47.2 23.1 34.6 67.1 26.3 13.5 45.9 31.0 11.4 42.8	46.6 22.8 35.4 67.0 25.4 13.3 46.4 30.5 10.8 42.8	means g kg ⁻¹ total protein	No differences in essential amino acids content
Maggio et al., 2008	Tubers harvested on July, 2003. Six potatoes, collected from each plot, treated and analyzed	histidine isoleucine leucine lysine methionine phenylalanine threonine tryptophan valine	104.9 14.8 11.8 36.6 16.7 16.0 24.5 10.6 34.1	98.5 17.1 15.1 38.4 16.7 19.2 24.0 11.2 37.3	mg 100g ⁻¹ fresh Weight	Only threonine is in significant higher levels in organic tubers
Pieper and Barret, 2009	Processing tomatoes of the same cultivar (<i>Lycopersicon esculentum</i> var. AB2) grown and harvested in season 2006 (1) and 2007(2) from three commercial growers in California.	Phenylalanine Histidine Methionine Lysine Threonine	(2) 1.41±0.27 0.56±0.09 0.10±0.02 0.68±0.10 0.76±0.15	(1) 1.81±0.28 0.78±0.14 0.15±0.03 0.89±0.17 1.15±0.28	g kg ⁻¹ fresh weight	No differences in essential amino acids content

Conventional potatoes were grown with varying levels of nitrogen fertilization and as result, a significant decrease in some amino acids content (including alanine, glutamate and histidine) was correlated to a highest nitrogen levels used. Other amino acids levels varied principally with cultivar variety. PIEPER and BARRET (2009) analyzed the effect of production system on quality and nutrient content of tomatoes (*Lycopersicon esculentum* var. AB2) from two consequential years of cultivation, 2006 and 2007. Results indicated that differences in nutrient content were not statistically significant between production systems. Furthermore, non-essential amino acids such as glutamate, glutamine and tyrosine, were significantly higher in conventional tomatoes. Authors justified results obtained depending by the amount of available nitrogen, generally greater in conventional crops.

2.3. Vitamins and minerals

Many studies investigated micronutrient levels in organic and conventional products, due to their vital importance in human diet (Table 3).

Table 3: Comparison in minerals and vitamins content in organic and conventional foods.

References	Study design	Compounds analyzed	Compounds content		Units	Statistical Comparison
			organic	conventional		
Gastol <i>et al.</i> , 2013	66 fruit and vegetable fields (36 farms) producing organic and conventional crops	Cu, B, Fe, Mn, Zn, Ni, Pb, Cd, Ca, P, Mg, S, Na,	Numeric data not shown	Numeric data not shown	-	Higher amounts in organic product
Colla <i>et al.</i> , 2002	10 years of organic and conventional management practices on soil chemical properties, processing tomato yields and fruit mineral composition	N,P,K,Ca,Mg, Na	Numeric data not shown	Numeric data not shown	-	Organic fruit contain higher amounts of Ca and P
Laursen <i>et al.</i> , 2011	Samples of winter wheat, spring barley, faba bean, and potato(1), obtained from field trials undertaken in 2007 and 2008 at three different Danish geographical locations.	K Mg P S Ca Fe Mn B Zn Cu Mb Sr Na	(1) 2.28±0.24 0.11±0.01 0.24±0.03 0.16±0.01 180±67.4 21.0±7.66 6.16±1.01 4.46±0.46 11.6±0.77 5.30±0.99 0.35±0.07 0.75±0.20 69.3±16.0	2.08±0.16 0.11±0.01 0.21±0.04 0.15±0.01 206±78.4 20.0±7.57 6.19±0.90 4.57±0.51 10.1±0.51 4.31±0.78 0.21±0.02 0.91±0.26 48.7±15.4	mg kg ⁻¹	No differences in mineral levels
Gorenjak <i>et al.</i> , 2012	52 samples of lettuce, conventional and organic, from 15 different areas of northeast Slovenia.	Nitrate/nitrite concentration	1258±1018.3	1359±960.6	mg kg ⁻¹ fresh weight basis	Nitrate levels higher in conventional foods
Ismail and Fun, 2003	5 types of green vegetables grown organically and conventionally selected based on popular consumption among Malaysian market.	vitamin C	124.80	114.70	mg 100 g ⁻¹	No differences in vitamins content
Weibel <i>et al.</i> , 2000	Apples (Golden delicious cv) harvested of 5 pair of organic/conventional fruit farms with similar micro climate, soil condition and planting system.	P Vitamin C	Numeric data not shown Numeric data not shown	Numeric data not shown Numeric data not shown	-	No differences in vitamin C content

The most investigated essential elements were phosphorus (P), potassium (K), magnesium (Mg), iron (Fe), copper (Cu), sulphur (S), calcium (Ca), zinc (Zn) and sodium (Na). Differently by vitamins, minerals are present in the soil and are bio-available for plant acquisition. In conventional agricultural management many minerals (P, K and N), are commonly used in the form of soluble chemical fertilizers, so it could be expected a highest quantity of such minerals in conventional products than in the organic alternatives. But different results were obtained considering levels of minerals in organic and conventional fruit and vegetables (BRANDT *et al.*, 2011). Many scientific studies showed how different agricultural systems have a strong influence on mineral content in products; in particular organic food were higher in such compounds content (Table 3). COLLA *et al.* (2002), investigating tomatoes elemental composition, reported only

statistical results from which, organically grown fruits had highest amounts of P and Ca instead of conventionally grown tomatoes richest in N and Na. GASTOL and DOMAGALA-SWIATKIEWICZ (2012), found none relationships between agricultural processes and minerals content in some fruits because of heterogeneity in results. Only in blackcurrant juice, results shown with the use of histograms, authors found significant higher amounts of minerals in the organic fruit. Further, a multi-element fingerprinting of potatoes and cereals, stated the absence of systematic differences between levels of minerals in products and different factors (crop management, location and year of cultivation) (LAURSEN *et al.*, 2011). In Table 3 levels of minerals are indicated only for potatoes.

Also nitrate content was evaluated in organic food for the risks on human health. GORENJAK *et al.* (2012), estimated nitrate content in lettuce (*Lactuca sativa*) of different geographical origins. The mean of nitrate content, expressed as mg kg⁻¹ of fresh weight basis, was significantly lower in organically cultivated lettuce (1258±1018.3) than in conventional products (1359±960.6).

On the contrary of minerals, plant itself is responsible for the production of vitamins depending mainly by variety, ripeness of fruits and crop size. For such these factors, heterogeneous results came from research studies about the content of vitamins in organic and conventional plant foods. Some studies underlined a significant relation between vitamin C content in fruit and vegetables and organic procedure; others didn't found a consistent trend (WEIBEL *et al.*, 2000; REMBIALKOWSKA, 2007). Few studies focused on the presence of other vitamins and their precursor.

ISMAIL and FUN (2003) determined vitamin C, β-carotene and riboflavin contents in five green vegetables from organic and conventional systems. Only organic swamp cabbage was highest in all vitamins content; for this vegetable only statistical results are shown. Organic Chinese mustard resulted in significant higher levels of β-carotene and in lower content of riboflavin. No significant differences were found in β-carotene content for Chinese kale, lettuce and spinach grown using the two different agricultural techniques while riboflavin content in conventionally grown Chinese kale and spinach was not detected compared to the organically grown vegetables.

To understand evidences of higher content of some vitamins in organic fruit and vegetables, influence on nitrogen fertilization was studied in deep. Nitrogen fertilization, belonged to conventional agriculture, was found to decrease vitamin C content in different fruits and vegetables (potatoes, tomatoes and citrus fruit) as well as increase beta-carotene content (MOZAFAR, 1993; LEE and KADER, 2000).

2.4. Polyphenols

Higher contents of polyphenolic compounds in organic fruits and vegetables were demonstrated in different reports (Table 4).

Organic apples (cv. Golden Delicious) originated from ten neighbouring organic and conventional fruit farms in Switzerland were examined by WEIBEL *et al.* (2000). The content of phenolic compounds (in particular flavanols) was 19% higher in organic apple.

The effect of cultivation methods on the antioxidant capacity of blueberry (cv. *Vaccinium corymbosum* L.) was evaluated in random samples of commercial late harvest fields in New Jersey by WANG *et al.* (2008). Results showed that blueberry fruit grown from organic culture contained significantly higher total phenolics (67.8%), total anthocyanins (59.2%), and antioxidant activity (49.8%) than fruit from the conventional culture.

Higher levels of some polyphenolic compounds were also found in organic peach (cv. Regina Bianca) and pear (cv. Williams) respect to the corresponding conventional samples (CARBONARO *et al.*, 2002).

Table 4: Comparison of polyphenols contents in organic and conventional foods.

Reference	Study design	Compounds analyzed	Compounds content		Units	Statistical Comparison
			organic	conventional		
Weibel <i>et al.</i> , 2000	Apples harvested of 5 pair of organic-conventional fruit farms with similar micro climate, soil condition and planting system.	flavanols, cinnamonic acids, phloretin-glycosides, quercetin-glycosides	only statistical result reported	only statistical result reported	-	Higher levels of phenolics in organic food
Wang <i>et al.</i> , 2008	Organic and conventional samples of blueberry collected from 5 certified organic farms in New Jersey.	anthocyanins: delphinidin 3gal. delphinidin 3-glu. cyanidin 3-gal. delphinidin 3-ara. petunidin 3-gal. petunidin 3-glu. petunidin 3-ara. malvidin 3-gal. malvidin 3-gluc. malvidin 3-ara.	171.59 69.77 29.22 93.53 184.86 127.13 95.70 303.03 303.35 227.12	41.74 24.64 14.24 37.00 75.26 79.00 66.70 289.38 184.92 199.62	$\mu\text{g g}^{-1}$	Higher levels of anthocyanins in organic food
Carbonaro <i>et al.</i> , 2002	Peaches (1) and pears (2), either grown on tilled soil (of the same age, 5 years), obtained from the Istituto Sperimentale per la Frutticoltura (Ciampino, Rome).	Caffeic acid chlorogenic acid catechol α -tocopherol γ -tocopherol tocopherolquinone caffeic acid chlorogenic acid catechol α -tocopherol γ -tocopherol tocopherolquinone	(1) 2174.50±198.20 2655.30±171.20 - 0.57±0.01 0.37±0.01 1.34±0.03 (2) 865.1±43.8 3020.7±235.4 401.4±110.3 0.71±0.05* 0.68±0.15 2.0±0.10	2451.9±126.4 2053.2±145.0 - 0.65±0.02 0.46±0.01 1.80±0.27 674.2±50.5 959.1±100.9 557.1±143.2 0.58±0.03 0.68±0.09 1.43±0.30	PPO activity (unit min-1/100 g f.w.) $\mu\text{g } 100 \text{ g}^{-1}$ fresh weight PPO activity (unit min-1/100 g f.w.) $\mu\text{g } 100 \text{ g}^{-1}$ fresh weight	Higher levels of polyphenolics in organic peach and pear
Lombardi-Boccia <i>et al.</i> , 2004	Yellow plums, conventionally or organically grown in the same farm (Fruit Farming Institute, Rome, Italy).	caffeic acid trans- <i>p</i> -cumaric acid ferulic acid chlorogenic acid neo-chlorogenic acid myricetin quercetin kaempferol	22.6±1.05 8.9±0.32 9.3±0.42 37.5±2.94 46.0±6.9 1.1±0.1 30.2±0.8 0.6±0.2	20.6±1.23 8.5±0.34 8.0±0.63 25.2±1.25 52.0±2.76 0.9±0.2 19.6±1.2 1.7±0.3	mg kg^{-1} fresh weight	Higher polyphenols content in conventional plums
Gastol <i>et al.</i> , 2013	66 fruit and vegetable fields (36 farms) producing organic and conventional crops.	Total polyphenols	Data not shown	Data not shown	-	No differences in polyphenols content
Valverde <i>et al.</i> , 2015	2 varieties of broccoli grown over 2 years (1),(2) in a split-plot factorial system comparison trial.	Total phenolics total flavonoids	(1) 345.70±51.30 16.60±6.90	290.80±3.90 10.20±1.80	$\text{mg } 100 \text{ g}^{-1}$ fresh weight	No differences in polyphenols content
Granato <i>et al.</i> , 2015	Purple grape juices (<i>n</i> = 31) produced in Europe	Total phenolics	826.60±382.99	714.42±244.63	$\text{mg of chlorogenic acid equivalents per liter of juice}$	No differences in polyphenols content

In particular organic peach had statistically higher levels of chlorogenic acid (29.3%) and of total polyphenols (36.1%); organic pear had higher levels of total polyphenols (10.4%) and of caffeic acid (28.3%).

LOMBARDI-BOCCIA *et al.* (2004) found conventional plums (cv. *Shiro*) richest in total polyphenols content. Quercetin was higher in conventional plums (54.1%), but myricetin (22.2%) and kaempferol (183.3%) were higher in organic plums; both in organic and conventional fruits caffeic acid, chlorogenic acid and quercetin were the predominant compounds. In opposite to these results, in vegetable juices from celery, carrot and red beet, GASTOL *et al.* (2013), did not find differences in polyphenolic content between organic and conventional products. In broccoli (*Brassica oleracea* var. *italica*), grown over two years of a split-plot factorial system trial, VALVERDE *et al.* (2015) didn't find differences in total phenols and flavonoids levels between the two agricultural systems. No differences in total phenolics contents was also found by GRANATO *et al.* (2015) analyzing organic and conventional purple grape juices.

Polyphenols, as phytonutrient compounds, are involved in the defensive mechanism of plants after attack by pests or diseases (FALLER and FIALHO, 2010). Many hypotheses were formulated to justify higher concentration of such compounds in organic crops and foods.

At first, plant subjected to stress, tend to accumulate higher content of secondary compounds. When pesticides are avoided, these compounds are also accumulating by natural protection system of plants. Furthermore, polyphenols are mainly synthesized during ripening of plant products. Conventional crop management consisting in higher amounts of nitrogen fertilizers than organic farming, generally accelerates plant growth with the consequent decreasing of plant metabolites production.

4. CONCLUSIONS

Food quality aspects, human health and environmental concerns influence organic food consumer preferences. The rapid growth of organic market, in recent years, is due principally to people belief of more nutritive properties of foods from organic agriculture. In this regard, literature studies considered in this review, dealing with the comparison of nutritive properties between organic and conventional fruits and vegetables, showed a high variability in results. Small differences in nutritive contents exist in foodstuffs belonged to the different cultivation methods. But in almost every study claiming large nutritional and sensory quality differences between organically and conventionally grown produce, the experimenters failed to control or to "pair-up" similar environmental and cultivar inputs that affect plant and fruit development, yield and quality. When this lack of methodological rigor was overcome by the application of a systematic review and meta-analysis approach, significant higher levels of antioxidant compounds and lower cadmium levels in organic food products were demonstrated. A way to improve comparative researches on nutritional value of organic food is to unify the methodologies applied and to better consider the various factors influencing nutrients content of agricultural food. There is also the need to include analysis of food during every step of the production chain and to consider further the effect of processing on nutritional parameters content. In accordance to this aspect, some authors suggest for future studies, the holistic approach in which nutritional and technological parameters together with sensor quality are needed to evaluate in total quality of foods (KAHL *et al.*, 2010).

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