Organic Foods Contain Higher Levels of Certain Nutrients, Lower Levels of Pesticides, and May Provide Health Benefits for the Consumer

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Abstract
The multi-billion dollar organic food industry is fueled by consumer perception that organic food is healthier (greater nutritional value and fewer toxic chemicals). Studies of the nutrient content in organic foods vary in results due to differences in the ground cover and maturity of the organic farming operation. Nutrient content also varies from farmer to farmer and year to year. However, reviews of multiple studies show that organic varieties do provide significantly greater levels of vitamin C, iron, magnesium, and phosphorus than non-organic varieties of the same foods. While being higher in these nutrients, they are also significantly lower in nitrates and pesticide residues. In addition, with the exception of wheat, oats, and wine, organic foods typically provide greater levels of a number of important antioxidant phytochemicals (anthocyanins, flavonoids, and carotenoids). Although *in vitro* studies of organic fruits and vegetables consistently demonstrate that organic foods have greater antioxidant activity, are more potent suppressors of the mutagenic action of toxic compounds, and inhibit the proliferation of certain cancer cell lines, *in vivo* studies of antioxidant activity in humans have failed to demonstrate additional benefit. Clear health benefits from consuming organic dairy products have been demonstrated in regard to allergic dermatitis.
(Altern Med Rev 2010;15(1):4-12)

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Introduction

Organic food consumption is one of the fastest growing segments of U.S. domestic foodstuffs. Sales of organic food and beverages grew from $1 billion in 1990 to $21.1 billion in 2008 and are on track to reach $23 billion in 2009.[1] Consumers generally perceive these foods to be healthier and safer for themselves and the environment.[2,3] A plethora of studies in the last two decades have assessed whether organic foods have higher levels of vitamins, minerals, and phytochemicals than conventionally raised foods and whether they have fewer pesticide residues. Far fewer studies have been conducted to assess either the potential or actual health benefits of eating organic foods.

Factors Affecting Nutritional Content of Produce

Determining the potential nutritional superiority of organic food is not a simple task. Numerous factors, apart from organic versus inorganic growing, influence the amount of vitamins and phytochemicals (phenols, flavonoids, carotenoids, etc.) in a crop. These factors include the weather (affecting crops year-to-year), specific environmental conditions from one farm to the next (microclimates), soil condition, etc. Another major factor not taken into account in the published studies was the length of time the specific plots of land had been worked using organic methods. Since it takes years to build soil quality in a plot using organic methods and for the persistent pollutants in the ground to be reduced, this can significantly affect the outcome of comparative studies. The importance of these different factors is apparent from a review of the recent studies examining the nutrient content in tomatoes.

Differences between Growers and Soil Quality

Of six recent studies of nutrient content of organic tomatoes, only one showed no significant differences between organic and conventional farms.[4] This study, conducted in Taiwan, did find that while there was no difference in lycopene levels between the types of farms, farm management skills and site-specific effects (e.g., geographical area and orientation to the sun) did make a difference in how much lycopene was present. A California study of four different growers in one year found organically raised tomatoes have

Key words: organic, pesticides, health food, nutritional value, herbicides

significantly higher levels of soluble solids and titratable acidity but lower red color, ascorbic acid, and total phenolics.[5] They also noted that differences among growers reached statistical significance. The authors did not note farm management skills as a possibility for the differences, suggesting it was due to differing soil conditions as well as the type of tomato used.

Differences Due to the Weather Conditions from Year-to-Year

A three-year study at the University of California (UC), Davis, found significant differences in phytochemical levels of tomatoes among varieties and from year-to-year.[6] Organically raised Burbank tomatoes were found to have significantly higher levels of ascorbic acid (26% higher) and the flavonoids quercetin (30% higher) and kaempferol (17%). But the other tomato cultivar (Ropreco), while showing 20-percent more kaempferol in the organic variety, had a less robust overall showing. This three-year study also revealed significant differences in nutrient content of the tomatoes from year-to-year within each plot. So, while the growing practices stayed the same, the weather conditions from year-to-year changed the outcome.

Length of Time Using Organic Methods

Another UC-Davis study on flavonoid content of tomatoes (no ascorbic acid levels tested) was conducted using dried tomatoes that had been archived over a 10-year period.[7] The tomatoes were grown in experimental plots as part of the Long-Term Research on Agricultural Systems (LTRANS) project. Over the decade of crop production, it was found that organic tomatoes averaged 79-percent more quercetin and 97-percent more kaempferol than the conventionally grown tomatoes. Interestingly, while the flavonoid levels in tomatoes from conventional plots stayed relatively constant over 10 years, those from organic plots kept increasing each year. The increase in flavonoid levels corresponded with increasing levels of organic matter in the soil and the reduction of manure application after the plots became rich in organic matter. It is also interesting to note that, in the previously mentioned study,[6] the plots that provided Burbank and Ropreco tomatoes with higher flavonoid levels had been in organic-only care for 25 years prior to the beginning of the study, indicating the longer the soil has been worked using organic methods, the greater the nutritional difference from conventionally grown plots. Therefore, it appears that measuring produce from non-mature organic farms is not a valid method of comparison of the nutrient content of organic foods versus conventional foodstuffs.

Two other recent studies examined the difference between organically and conventionally grown tomatoes. The Italian study revealed that organic tomatoes have more salicylates than conventional tomatoes, but less ascorbic acid and lycopene.[8] The study specified that the tomatoes were grown in different parts of the same farm with sufficient distance between the organic and non-organic plots to "prevent the drift of chemical treatments." How this was determined to be a safe distance was not revealed, and since chemicals have been shown to literally travel the globe, this is a questionable statement. The study also specified that the organic plots had been "organic" for only three years, which means they were not fully mature organic farms. This could account for the difference between these results and those of other tomato studies. The French study found results that were more consistent with the California studies, showing organic varieties had higher levels of ascorbic acid, carotenoids, and polyphenols than conventionally-raised tomatoes.[9]

Understanding these factors puts studies of organic versus conventional growing practices into better perspective. Without an appreciation of these issues, the outcome of the study may not accurately reflect the true nutritional differences between agricultural methods.

Vitamin and Mineral Content

Several reviews on nutritional differences between organic and non-organic foods have been published in the last decade.[10-14] Earlier studies looked primarily at the mineral and vitamin content, while recent studies looked at phytochemicals (phenols, etc.) in the foods. The research on vitamin and mineral content will be discussed here. Factors affecting variability discussed above must be kept in mind, something the earlier studies did not take into account. Factoring in these variables would presumably strengthen the findings reviewed below.

Lairon's review[10] reported that, regarding minerals, organic foods have 21-percent more iron and 29-percent more magnesium than non-organic foods. When vitamins were studied, ascorbic acid was the most common vitamin found in higher quantities in many organic fruits and vegetables tested. Worthington[11] reached much the same conclusions, stating that four nutrients were found in significantly higher levels in organic produce

– ascorbic acid averaged 27-percent higher, iron 21-percent higher, magnesium 29-percent higher, and phosphorus 13.6-percent higher. Both Worthington and Lairon reported the studies they reviewed showed conventional foods were typically higher in nitrates – 15-percent higher in conventional foods according to Worthington. The systematic review by Dangour[12] that was published in the *American Journal of Clinical Nutrition* also reported significantly higher nitrate content in conventionally grown foods, although the authors changed the term from nitrate to "nitrogen compounds." They failed to find significant differences between organic and conventional foods for ascorbic acid, iron, or magnesium, but did report higher phosphorus levels in organic produce. Unfortunately, this widely publicized review did not include references for the 55 studies used for its conclusions, so validation of the findings is not possible. For this reason, this article will focus on conclusions for vitamin and mineral differences from the other reviews.

Regarding nutrients the other reviews agree on, organic foods have more vitamin C, iron, phosphorus, and magnesium than conventional foods. While this is an important finding, it is cast in a brighter spotlight when it is recognized that during the last 50 years vitamin C, phosphorus, iron, calcium, and riboflavin content has been declining in conventional foodstuffs grown in this country.[15] Since quantities of some nutrients seem to be increasing in organic foods, organic foods appear to provide better nutrition.

Phytonutrient Content

In the last 20 years the importance of the phytonutrient content of foods has been established. These compounds, including carotenoids, flavonoids, and other polyphenols, have been the focus of much study, and many are now provided as dietary supplements. Flavonoid molecules are potent antioxidants.[16-18] The carotenoid lycopene has been shown to help reduce cancer risk.[19] The anthocyanin compounds in berries have been shown to improve neuronal and cognitive brain functions and ocular health and protect genomic DNA integrity.[20] Because of the health benefits of phytonutrients, they have been the focus of much recent research on the nutritional value of organic foods (Table 1).

Pesticide Content

World pesticide use exceeded 5.0 billion lbs in both 2000 and 2001 (total cost, $64.5 billion) with the United States accounting for 1.2 billion lbs per year at an annual cost of $11 billion.[39] While the totals are staggering, so too is the infinitesimal amount of those five billion pounds a year that actually make it to the target pest – less than 0.1 percent.[40] No one has accounted for where the other 99.9 percent ends up, and it is known these compounds can travel thousands of miles around the globe.[41,42] Both the amount of pesticide residue on foodstuff and the amount released into the atmosphere are factors that should be considered when individuals purchase organically raised food.

Although organic farming methods prohibit the use of synthetic pesticides, the produce can be exposed to chemicals already in the soil from previous use and from compounds that percolate through the soil. Except for crops grown under cover, organic farms are also subject to exposure from pesticide drift from neighboring farms and global transport of chemicals. This exposure occurs from compounds that settle to the ground during both the growing season and the off season, and exposure can continue during transport and distribution. The level of various heavy metals in organically raised produce was higher in crops grown in open fields compared to the same crops grown in a greenhouse.[43] The researchers noted this was due to atmospheric contamination; root vegetables also absorbed toxins from the soil.

While no pesticides or herbicides can be used to grow crops that are certified organic, these crops are not free of insecticide residues, although significantly less so than the same foods grown by non-organic methods (including integrated pest management systems).

Levels of pesticide residue on foods in the United States are monitored through the Pesticide Data Program of the U.S. Department of Agriculture (USDA). A review that utilized the USDA data, along with data from Consumers Union and the Marketplace Surveillance Program of the California Department of Pesticide Regulation, reported that organically raised foods had one-third the amount of chemical residues found in conventionally raised foods.[44] When compared to produce grown with integrated pest management techniques, the organic produce had one-half the amount of residue. In addition, organic foods were much less likely than

Table 1. Nutrient Content of Foods: Organic versus Non-Organic[21-38]

Food	Nutrient(s) Tested	Results
Potatoes in Czechoslovakia	Ascorbic acid; chlorogenic acid (the polyphenol that is responsible for much of the antioxidant activity of coffee, and that has been shown to protect paraoxonase 1 activity[21])	Organically grown potatoes had lower levels of nitrate and higher levels of ascorbic acid and chlorogenic acd.[22]
Highbush blueberries in New Jersey	Sugars, malic acid, total phenolics, total anthocyanins, and antioxidant activity	All nutrients tested were higher in organic than conventionally grown blueberries.[23]
Strawberries, marionberries, and corn from an organic farm in Oregon	Ascorbic acid and total polyphenols	All three foods had significantly higher amounts of ascorbic acid and total polyphenols than their conventionally grown counterparts.[24]
Black currants from five conventional and three organic farms in Finland	Total polyphenols	Slight but not statistically different amounts of total polyphenols from organic farms (4.73 versus 4.24 g/kg); no information on how long the farms had been organic.[25]
Syrah grapes from France	Anthocyanin content	Conventionally grown grapes had higher levels of anthocyanins; no information of history of the organic vineyards.[26]
Grape juice from Brazil	Total polyphenols; resveratrol	Significantly higher levels of total polyphenols and resveratrol in organic juice.[27]
Golden Delicious apples (three-year study)	Total antioxidant activity (polyphenols provide 90 percent of the total antioxidant activity)[28]	Two of three years the antioxidant activity of organic apples was 15-percent higher than conventional apples; no difference in the third year.[29]
Plums	Ascorbic acid, alpha- and gamma-tocopherol, beta-carotene; total polyphenols	Organic orchards with soil left as natural meadow, ascorbate, tocopherols, and beta-carotene were highest; in organic orchards with Trifolium groundcover, total polyphenols were highest, although highest levels of total polyphenols were in the conventional plums.[30]
Peaches and pears (three-year study; five-year-old orchards)	Total antioxidant activity, total polyphenols, ascorbic acid	Higher antioxidant, total polyphenols, and ascorbic acid in organic fruit.[31]
Red oranges from Italy	Total polyphenols, total anthocyanins, ascorbic acid, total antioxidant activity	Organic oranges had higher levels of total polyphenols, total anthocyanins, ascorbic acid, total antioxidant activity.[32]
Varieties of wheat from India	Protein, starches, gluten	Higher protein, more easily digestible starch, and lower gluten in the organic wheat; no information on history of the organic farms.[33]
Oats from Sweden	Total polyphenols	No significant difference between organic and non-organic; differences from year-to-year and among cultivars; no information on history of the organic farms.[34]
Milk	Omega-3 fatty acids (alpha-linolenic acid [ALA] and eicosapentaenoic acid)	Organically raised dairy cattle yielded higher levels of omega-3s;[35,36] no difference in vitamins A or E.[37]
Grana Padano cheese from Italy	Conjugated linoleic acid (CLA), ALA	Higher levels of CLA and ALA in cheese samples from organic milk.[38]

non-organic produce (by a factor of 10) to have two or more residues. Only 2.6 percent of organic foods had detectable multiple residues compared to 26 percent of conventionally grown foods. Data from the Pesticide Data Program reveals conventional produce with the highest percentages of positive (insecticide residue) findings were: celery (96%), pears (95%), apples (94%), peaches (93%), strawberries (91%), oranges (85%), spinach (84%), potatoes (81%), grapes (78%), and cucumbers (74%).[45] The study found that an average of 82 percent of conventional fruits were positive for insecticide residues compared to 23 percent of organic fruits. Regarding vegetables, 65 percent of conventionally grown produce tested positive, compared to 23 percent for organic vegetables.

Fruits and vegetables with the highest and lowest percentages of residues in the USDA study are similar to the listing of the most and least toxic foods available on the internet through the Environmental Working Group (Table 2).[46] Table 3 lists the least toxic produce.

Table 2. The Environmental Working Group's 12 Most Toxic Fruits and Vegetables (in order of toxicity)

Peach	Nectarine	Lettuce
Apple	Strawberries	Grapes (imported)
Bell pepper	Cherries	Carrot
Celery	Kale	Pear

Table 3. The Environmental Working Group's Least Toxic Produce

Onion	Asparagus	Papaya
Avocado	Sweet peas	Watermelon
Sweet corn	Kiwi	Broccoli
Pineapple	Cabbage	Tomato
Mango	Eggplant	Sweet potato

Not only have repeated studies shown that organic foods have lower levels of insecticides, clear evidence also indicates reduced pesticide exposure levels in consumers of organic foods. The reduced level of organophosphate pesticide (OP) on organic foods was demonstrated by a study of Seattle preschoolers.[47] In that study, 39 children were divided into two groups – those whose diets were at least 75-percent organic and those whose diets consisted predominately of conventionally grown foods. Children eating organic foods had a six-fold lower level of organophosphate pesticide residues in their urine than those who ate more conventionally. The same research group tested preschoolers before and after changing their diets from conventionally grown to organic foods. When the shift was made to organic diets the urinary levels of malathion and chlorpyrifos became undetectable until their conventional diets were restored. Five different OP metabolites were measured with mean levels of 0.01, 0.2, 0.3, 4.6 and 5.1 g/L while on conventional diets.[48]

Potential Health Benefits of Organic Foods

Since organically raised food typically has higher levels of health-promoting phytonutrients and certain vitamins and minerals and lower levels of insecticide residues, one could assume that they would provide health benefits. Unfortunately, studies looking at the potential health benefits of organic foods are scarce, and all but one are focused on implied health benefits. The majority of these studies look at antioxidant activity in humans, although some *in vitro* studies examined the anticancer potential of some organic food products.

Antioxidant Studies

Two studies examined whether drinking organic wine provides greater protection against LDL oxidation than conventional wine. Neither study (both by the same group of researchers in the same year) found a difference between organic and non-organic wine; however, red wine of either agricultural method provided greater inhibition of LDL oxidation compared to white wine.[49,50]

A double-blind crossover trial of six Golden Delicious apple consumers was conducted to determine the difference in antioxidant activity between organic and non-organic groups.[51] Golden Delicious apples have some of the lowest polyphenol content of any apple.[28] In this study there was no difference noted in total polyphenol levels between organic and conventional apples, and thus no difference in antioxidant activity. Information on the maturity of the organic orchards was not available for review. As a follow-up study, fruits from mature organic orchards with higher polyphenol content, as noted above,[29] could be used with subsequent measurements to determine whether higher phenol levels would alter the antioxidant status in humans.

Another small study (n=16) was conducted with subjects who were eating either a conventional or an organic diet. Levels of flavonoid excretion and antioxidant function were measured.[52] Surprisingly, although the organic consumers had higher levels of urinary quercetin and kaempferol, they showed no difference in antioxidant activity. However, organic oranges with higher antioxidant content provide greater antioxidant protection *in vitro*.[32]

Anticancer Potential

In a study of the potential for vegetables to suppress the mutagenicity of various environmental toxins, including benzo(a)pyrene (BaP, the main carcinogen in cigarette smoke and auto exhaust), organic vegetables were more active than their conventional counterparts.[53] Against the chemical 4-nitroquinoline oxide, organic vegetables suppressed 37-93 percent of the mutagenic activity, while the commercial varieties suppressed mutagenicity by 11-65 percent. When measured against BaP, organic vegetables suppressed 30-57 percent of the mutagenic action, while commercial vegetables only suppressed 5-30 percent of the mutagenic activity. Organic strawberries also block proliferation of HT29 colon cancer cells and MCF-7 breast cancer cells.[54] For both cancer cell lines the extracts of organic berries were more potent in reducing cellular proliferation than conventional strawberries.

Essential Fatty Acids

The increased amounts of omega-3 and -6 fatty acids in organic dairy were noted in Table 1. The fatty acid content of breast milk from 312 Dutch women was studied to determine whether this resulted in a human effect.[55] CLA content was measured in 186 women who ate a conventional diet, in 33 women who ate a moderate amount of organic meats and dairy, and 37 women whose diets contained at least 90-percent organic meats and dairy. Statistically significant increases (from 0.25 weight % to 0.29 weight %) were found for the women who ate a moderately organic diet compared to the conventional diet, and an even greater increase (0.34 weight %) for those who ate the strict organic diet.

Actual Health Benefits of Organic Foods

Only one article was found that measured whether an organic diet makes an actual difference in human health. This study, by some of the same researchers who examined the CLA content of breast milk, studied whether diets containing varying amounts of organic foods affected allergic manifestations in 815 two-year-olds.[56] Food consumption for the second year of life was studied based on conventional (<50% organic), moderately organic (50-90% organic), or strictly organic (>90% organic) diets. When all organic foods were taken into account, there was a non-significant trend toward lower eczema risk (OR: 0.76) for those on a strict organic diet. But, when the types of organic foods were examined individually, consumption of organic dairy products did result in a statistically significant advantage for lower eczema, those children consuming organic milk and milk products having a 36-percent reduction in risk of having this allergic skin disorder.

Problems to be Resolved for Future Studies

Although recent articles report minimal or questionable health benefit (including nutritional superiority) of organic foods,[12,14] a closer look at the published literature yields a different, but somewhat complicated, picture. First, it is difficult to locate all articles pertaining to organic foods using PubMed. This is partly due to the fact that PubMed does not have a Medical Subject Heading (MeSH) term for "organic food." Instead the term "health food" must be used and paired with other terms such as "nutritional value." The references for this review were discovered only after multiple searches, including "related articles" searches on the initial studies. In addition, other pertinent articles were found in the reference lists of the studies reviewed. Without these reference lists, the only article that actually measured health outcomes with organic food[56] would have been missed.

Recommendations that PubMed add a MeSH term for organic foods can be made at http://www.nlm.nih.gov/mesh/meshsugg.html.

Another major problem for a food to be termed "organic" is that governmental regulations in the United States and the European Union set only minimal benchmarks for organic certifiability. The United States requires that land not have conventional chemicals (non-organic) applied for three years before certification can be received.[57] But, as can be seen from the 10-year tomato study at UC Davis,[7] it can take up to 10 years for an organic plot to mature. The studies on nutrient content of organic foods reveal that results are greatly affected by the length of time a plot is handled organically (the amount of organic matter present and the nutrient balance), as well as by ground cover, local geography, weather patterns, and methods peculiar to the farmers themselves. It is hoped that future studies on organic foods will provide information on the maturity of the organic farm itself, so crops from mature farming operations can be differentiated from those of newer fields.

Summary

Organic food consumption continues to increase as consumers seek foods perceived as healthier (greater nutritional value and fewer toxic chemicals). While the amount of vitamins and minerals will obviously vary from crop to crop and from farmer to farmer, organic varieties do provide greater levels of vitamin C, iron, magnesium, and phosphorus. They also tend to provide greater levels of antioxidant phytochemicals (anthocyanins, flavonoids, and carotenoids), although these levels have not yet been shown to make a difference in *in vivo* antioxidant status. Regarding LDL-oxidation prevention, it appears red wine is more potent than white wine and organic varieties provide no extra benefit. Organic fruits and vegetables appear to have the potential to diminish the mutagenic action of toxic compounds and inhibit the proliferation of certain cancer cell lines. For prevention of allergic dermatitis, the consumption of organic dairy and meats can make a significant difference in health outcomes. In addition, organic foods have fewer insecticide residues than conventional foods.

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