

Differences in Antioxidants and Polyphenolic Compounds among Organically Grown and Conventionally Grown Fruits and Vegetables

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ABSTRACT

Consumers believe that organically grown fruits and vegetables are nutritionally better than conventionally grown fruits and vegetables. I reviewed one aspect of this nutrition: antioxidants and polyphenolic compounds. These compounds limit cell damage by disabling free radicals in the body. In my review of the literature, the data suggest that organically grown fruits, and, to a lesser extent, vegetables, have higher levels of antioxidants and polyphenolic compounds than conventionally grown fruits and vegetables. This difference may be because organically grown fruits and vegetables are subject to increased biotic and abiotic stresses (e.g., insect attack) that conventionally grown fruits and vegetables are not subject to, and plants increase their synthesis of antioxidants and polyphenolic compounds in response to these stresses. Further research is needed into how these results may translate into a biological benefit to humans in the area of disease prevention and maintenance.

INTRODUCTION

Worldwide demand for organic foods continues to expand rapidly. In developed countries, consumers are prepared to pay premium prices for organic fruits, vegetables, grains and packaged foods, based on their perception that organic foodstuffs are safer, cleaner, better-tasting, more nutritious, more environmentally friendly, and overall, better for one's health (*Lester 2006*). As a result, numerous recent studies have sought to determine whether significant differences in nutrient content and quality exist between organically grown versus conventionally managed foods (*Lester 2006*). Myriad variances within production systems have made it difficult to quantify differences that may or may not exist between organic and conventional foods. In short, there are just too many factors to control. Some of these factors include: plant genetics, variety/cultivar, geography, soil type and structure, temperature, humidity, light, rainfall, season, fertilizer type/rate of application, cultivation system, post-harvest practices, and lastly, storage and handling. One question that arises is: how do we glean accurate information from the existing research about whether organic or conventional foods are nutritionally superior to one another?

My question requires an in-depth look at the existing data gathered over the last 15 to 20 years from farm-based field trials, agricultural research initiatives, market studies, and consumer surveys. Results from reviews and comparison studies in each of these four broad categories must be taken on a case-by-case basis, as much of the evidence of enhanced nutrients in organic versus conventional systems is ineligible for extrapolation to the broader agricultural picture. For this reason, I chose a set of research papers from peer-reviewed journals which focus on two specific health-enhancing nutrients: antioxidants and polyphenolic compounds.

Polyphenols are compounds found mostly in foods of plant origin that act as major antioxidants in a balanced diet (*Scalbert and others 2005*).

Comprehensive research on these dietary constituents is lacking, partly due to their chemically complex nature and virtually unknown bioactivity in the human body. Several hundred polyphenols have been identified in food, of which the two main types are flavonoids and phenolic acids (*Scalbert and others 2005*). Animal and clinical trials and epidemiological studies show that polyphenolic compounds exhibit antioxidant potential. This finding may be relevant to human health, especially as it relates to disease prevention.

Degenerative diseases such as cancer, cardiovascular disease, osteoporosis, aging and other mutagenic processes are caused by oxidative damage to cell components and human DNA. Antioxidants present in food can help limit this damage by disabling free radicals and other harmful reactive species (thus minimizing oxidation) and by stimulating the body's own defense systems to fight disease by using these groups of protective chemicals (*Scalbert and others 2005*).

MATERIALS AND METHODS

My analysis used all available studies that compared quantities of antioxidants and polyphenolic compounds in fruit and vegetable crops produced with either organic fertilizers or conventional fertilizers. Only peer-reviewed journal articles were selected from databases such as Academic Search Complete, Science Direct, PubMed, and AGRICOLA. Only journals focused on food science/chemistry, nutrition, plant sciences/horticulture, and agriculture were selected for consideration as these correspond to my education (a major in Consumer Foods).

An initial search in Academic Search Complete included, in all combinations, the terms "nutritional," "differences," "between," "fruits," "vegetables," combined with "organic," "conventional," and "foods." A more in-depth search of Science Direct, AGRICOLA, and PubMed included all combinations of the terms "phenolic compounds," "polyphenols," "antioxidants," "differences," with "organic," "conventional," "fruits," and "vegetables." Several articles retrieved during my basic search were deemed unusable due to their focus on animal meat, dairy products, edible oils, and grains. This brought my total number to 29 articles from scientific, peer-reviewed journals whose subject matter matched my research keywords between 1975 and August 2009. Of the 29 articles retrieved, 24 came from food science, nutrition and/or chemistry journals, 2 from alternative medicine journals, 1 from a plant science/horticulture journal, 1 from an agronomy journal, and 1 from the USDA's Agricultural Research Service.

RESULTS

Of 29 scientific journal articles, 7 were reviews, 18 were actual agricultural studies, 3 were comparison studies and 1 was an op-ed piece, written as a response to a scientific literature review. The 18 agricultural studies were

selected for further study; 14 articles focused specifically on 15 varieties of fruit (Table 1), 3 articles focused specifically on 6 varieties of vegetables (Table 2), and 1 article focused on 2 varieties of fruit as well as 1 vegetable (Tables 1 and 2). Many of the articles focused on both antioxidants and polyphenols, while others mentioned either antioxidants or polyphenols.

Twelve of the 17 fruits studied (71%) and 2 of the 7 vegetables studied (29%) reported higher levels of antioxidants, polyphenols, or both in the organically grown produce. Four of the 17 fruits studied (24%) and 5 of the 7 vegetables studied (71%) reported no differences in antioxidants or polyphenols between organically grown and conventionally grown produce. Only 1 of 17 fruits studied (6%) found higher levels of antioxidants and polyphenols in the conventionally grown produce. No support was found for higher levels of total antioxidants and polyphenols in conventionally grown vegetables.

DISCUSSION

The data show that organically grown fruits, and, to a lesser extent, vegetables, contain higher levels of secondary metabolites known as

antioxidants and polyphenolics than conventionally grown fruits and vegetables. Current available research shows that these chemicals may prevent heart disease, certain types of cancer, and other mutagenic, oxidative disease processes of the human body. This information should enhance consumer confidence that organically grown food is better for one's health, at least with regard to antioxidants and polyphenolics than conventionally grown food.

Interestingly, many articles reviewed for this paper link secondary metabolite synthesis to cultural production methods, namely, biotic and abiotic stresses (*Young and others 2005*). With regard to biotic stresses, *Anttonen and others (2006)* noted a relationship between increased disease pressure due to a lack of pesticide use and elevated levels of polyphenolics in organically grown foods. With regards to abiotic stresses, fertilization may be a key component of secondary plant metabolism. According to *Stracke and others (2009)*, organic fertilizers contain higher amounts of available phosphorous (a nutrient linked to increased photosynthetic activity) and less-available forms of nitrogen. Finally, conventional herbicides may decrease a plant's ability to perform carbon fixation (in effect, decreasing

secondary metabolite synthesis; *Lombardi-Boccia and others 2004*). Further research is needed into how these stresses may translate into a biological benefit to humans in the area of disease prevention and maintenance.

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| Table 1: Fifteen journal articles comparing antioxidants (anti) and polyphenols (poly) in organic and conventional fruits, and whether the results support organic farming, conventional farming, or there was no difference. | | | | | | |
|--|-------------|-------------|------------------------|-----------------------------|----------------------|--|
| Fruit | Anti | Poly | Support Organic | Support Conventional | No Difference | Reference and Notes |
| Apple (A) | X | X | X | | | Stracke et al., 2009; three-year controlled study. Polyphenol levels and antioxidant capacity were statistically 14-19% higher in organics. |
| Apple (B) | X | X | | | X | Briviba et al., 2007; focused on antioxidant potential in humans; comparing organic vs. conventionally grown apples and their affect on DNA damage in blood lymphocytes. |
| Apple (C) | | X | | | X | Valavanidis et al., 2009; two-year study comparing 5 apple cultivars; polyphenol content was similar for both organic and conventionally grown apples' flesh and skin. |
| Apple (D) | | X | X | | | Hecke et al., 2006; 11 varieties of organic apples and 7 different varieties of conventional apples were tested. |
| Black Currants | X | X | | | X | Anttonen and Karjalainen, 2006; currants were culled from 5 conventional farms and 3 organic farms within a similar climatic region. |
| Blueberries | X | X | X | | | Wang et al., 2008; significantly higher levels of total polyphenols, total anthocyanins, and overall antioxidant activity in organic blueberries. |
| Grapes | X | X | X | | | Dani et al., 2007; organic grape juices significantly higher in polyphenols, resveratrol, and anthocyanins; specifically purple juices over white juice varieties. |
| Marionberry | | X | X | | | Asami et al., 2003; organically grown 20.8% higher in total polyphenols. Sustainably grown 21.8% higher in total polyphenols than conventional. |
| Peaches | | X | X | | | Carbonaro and Mattera, 2001; total polyphenol content was statistically higher in all 3 organic peach samples. Same cultivar was used for all. |

| Table 1: Continued | | | | | | |
|---------------------------|-------------|-------------|------------------------|-----------------------------|----------------------|--|
| Fruit | Anti | Poly | Support Organic | Support Conventional | No difference | Notes |
| Pears | | X | X | | | Carbonaro and Mattera, 2001; total polyphenol content found was statistically higher in 2-of-3 organic peach samples. Same cultivar used for all. |
| Red Oranges | X | X | X | | | Tarozzi et al., 2006; total polyphenols, anthocyanins, Vitamin C and total antioxidant activity. Also looked at the protective effect of organic red oranges and their compounds, at the cellular level. |
| Strawberry (A) | X | X | X | | | Olsson et al., 2006; five cultivars of strawberries were analyzed and their effect on two types of human cancer cells was studied. |
| Strawberry (B) | X | X | X | | | Asami et al., 2003; sustainably grown 20.3% higher in antioxidant ascorbic acid. Sustainably grown 19.1% higher in total polyphenols. |
| Tomato (A) | X | X | X | | | Caris-Veyrat et al., 2004; significant differences seen in antioxidant levels and certain polyphenols; mostly in fresh matter. Study also looked at micronutrient levels in blood plasma and found no significance between production systems. |
| Tomato (B) | | X | X | | | Toor et al., 2006; three inorganic and 2 organic fertilizer methods were compared to determine if nitrogen availability affects the production of polyphenols in plants. |
| Tomato (C) | X | X | | | X | Barrett et al., 2007; four growers with matched fields used different growing methods, soils and cultivars. Poorly designed; better controls needed. |
| Yellow Plums | X | X | | X | | Lombardi-Boccia et al., 2004; varied findings with some supporting conventionally grown (total polyphenols) and others supporting organically grown yellow plums (certain phenolic acids and flavonols ranked higher). |
| Total | 11 | 17 | 12 | 1 | 4 | |

| Table 2: Four journal articles comparing antioxidants (anti) and polyphenols (poly) in organic and conventional vegetables, and whether the results support organic farming, conventional farming, or there was no difference. | | | | | | |
|---|-------------|-------------|------------------------|-----------------------------|----------------------|---|
| Vegetable | Anti | Poly | Support Organic | Support Conventional | No Difference | Reference and Notes |
| Carrots | X | | | | X | Stracke et al., 2009; no difference found in carotenoid content or antioxidant capacity between production systems. |
| Chinese Cabbage | | X | | | X | Lima et al., 2009; focus on the unedible parts of the plant. Organically grown cabbage higher in polyphenols but not significantly different. |
| Collards | | X | | | X | Young et al., 2005; higher level of some individual phytochemicals in organically grown collards but not significantly different. |
| Corn (A) | | X | | | X | Lima et al., 2009; focus on the unedible parts of the plant. Organically grown corn higher in polyphenols but not significantly different. |
| Corn (B) | X | X | X | | | Asami et al., 2003; organically grown 52.4% higher in antioxidant ascorbic acid. Sustainably grown 66.7% higher in antioxidant ascorbic acid and 58.5% higher in total polyphenols. |
| Lettuce | | X | | | X | Young et al., 2005; higher level of some individual phytochemicals in organically grown lettuce but not significantly different. |
| Pac Choi | | X | X | | | Young et al., 2005; significantly higher levels of total polyphenolics found in organically grown pac choi versus conventionally grown. |
| Total | 2 | 6 | 2 | | 5 | |