A Comparative Study of Organically vs. Conventionally Grown Foods: A Review of the Literature

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According to the CRS Report for Congress on Organic Agriculture in the U.S., interest in organic farming migrated to America from Europe in the early 1900s. It was not until the 1950s, however, that organic farming practices were adopted, due to an increased public awareness of the adverse effects of "factory farming methods" on health and the environment. Interest in the organic movement has grown immensely, as the sale of organic products was estimated to be $10.4 billion in 2003. Sales have been growing at an average rate of twenty percent since 1990, when the federal government took its first steps in regulating the organic market (Rawson, 2005).

What Is Organic?

Congress passed the Organic Foods Production Act in 1990, which sanctioned the establishment of a National Organic Program (NOP) within the U.S. Department of Agriculture, to create standards for producers and processors of organic foods. Furthermore, it permitted these operations to label their products with a "USDA Organic" seal after official certification by an authorized USDA agent. According to standards established by the NOP, organic farming is "a production system that is managed in accordance with the Organic Foods Production Act and regulations…to respond to sitespecific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity" (Rawson, 2005, p.1). Thus, organic food production utilizes biological methods and avoids the use of synthetic crop and livestock production inputs.

Because food safety has become an emergent issue, due to outbreaks of Bovine Spongiform Encephalopathy (aka "mad cow disease"), the use of genetically modified organisms, and irradiation in food production, consumer concerns have stimulated interests in "safer" alternatives, predominately in the arena of organic foods (Magkos et al., 2006). There is a widespread belief that organic food is healthier and safer than conventionally grown food, and consumers are willing to pay higher prices to obtain it. Scientific evidence in support of this view, however, is limited in scope. Therefore, the objective of this paper is to provide a critical overview of the literature concerning the nutrient content and food safety (with regard to pesticides, environmental pollutants, and natural toxins) of organic goods.

Nutrient Content

Because organic farming systems avoid the use of manmade fertilizers, pesticides, growth regulators, and livestock feed additives, consumers believe that they contain higher levels of nutrients (Williams, 2002). Opponents in the "organic debate," however, reject such claims since direct comparative studies between organic and conventional produce are difficult to create and evaluate (Magkos et al., 2006). Strong evidence to support the elevated nutritional content of organic foods does exist, though, and predominately involves studies concerning vitamin C. Research by Woese et al. (1997), writers for

Journal of the Science of Food and Agriculture, revealed that organic produce, mainly leafy vegetables, contained consistently higher levels of vitamin C as compared to the same products produced by conventional means. Another study conducted by Lampkin (1990), editor of Organic Farming, also demonstrated that organic products contained higher concentrations of vitamin C, in addition to iron, potassium, calcium, phosphate, and lower levels of sodium (as cited in Williams, 2002). A third study, conducted by Worthington as part of a doctoral dissertation at Johns Hopkins University, examined all available comparisons of crops grown organically with those produced conventionally and used computerized and statistical methods to identify differences and trends in the data. Her findings were consistent with those of Woese and Lampkin, in that organic foods contained a higher content of vitamin C, in addition to iron, magnesium, and phosphorous, and less toxic nitrates.

Although the aforementioned evidence suggests that organic products do have higher nutritional values, one must consider the possible sources of error. For instance, the study conducted by Woese et al. considered over 150 comparisons of organically versus conventionally produced foods published between 1924 and 1994. The accuracy of the designation “organic” could not be confirmed in each instance. In addition, the growing conditions for “conventionally grown” products may have changed due to progressions in farming technology over time. Furthermore, higher levels of vitamin C in organic foods, suggested by both studies, could be attributed to the lower water content of these products, thus providing for a higher concentration of the vitamin (Williams, 2002).

Regarding mineral, nitrate, and other vitamin content of organic versus conventionally grown produce, findings have proved inconclusive. In the study by Woese et al., no differences existed in the mineral, trace element or B vitamin content in organic vs. conventional cereals, vegetables, or potatoes, and there were also no differences found between the two concerning levels of vitamin A or ß-carotene. Some evidence was produced, however, to suggest that conventionally grown products (vegetables, namely leafy greens) contained higher concentrations of nitrates, which have been claimed, by some, to contribute to cancer in humans (Williams, 2002). Worthington's study also proved inconclusive concerning mineral and trace element content, which was found to be the same in organic as in conventional foods, or higher. However, Worthington did find that organic foods contained higher amounts of nutritionally significant minerals and lower amounts of heavy metals. The quantity of protein was found to be lower, but it has been suggested that the quality (as measured by essential amino acid content) is superior to that found in nonorganic foods (Worthington, 2001).

While most of the evidence found in the previous studies suggests higher nutrient content in organic products, the results found are likely due to differences in soil ecology and pesticides (which can affect mineral content in foods). Before any further analysis can be warranted, additional research of better quality is necessary to confirm these results, since the findings are inconsistent among crops (Williams, 2002).

Pesticides: Effects of Ingestion on the Body

The growing demand for organic products is centered around the idea that pesticide consumption is hazardous to human health. According to health specialist Doug Brugge of Tufts University, "pesticides known as organophosphates can cause problems in early childhood neurological development." Brugge suggests, however, that "organic food is a viable intervention to control pesticide exposure" (as cited by Harder, 2005, p. 1). While the government has restricted the use of many harmful pesticides, the organophosphates malathion and chlorpyrifos are still legally used on many conventionally grown crops.

A study conducted by Chensheng Lu of Emory University demonstrated how people consuming only organic food could avoid these potentially toxic pesticides. Twenty-three suburban families fed their children, age 3 to 11 years, only conventionally grown produce. The children then ate organic substitutes for the same foods for a period of eight days. After this time, they resumed consumption of conventional products. Lu's team collected two urine samples twice daily throughout the duration of the experiment and then tested these samples for by-products of malathion, chlorpyrifos, and other organophosphates. The by-products were present in all the urine samples in which the children ate conventionally grown foods, but were undetectable when the children ate only organic products (Harder, 2005). Similar studies conducted in Germany and Arkansas returned comparable results, suggesting, perhaps, that maintaining an organic diet provides protection against pesticide exposure in infants and young children whose diets frequently consist of fresh fruits and vegetables, fruit juices, and wheat-containing items (Lu et al., 2006; Heudorf et al., 2003; Hill et al., 1989). The findings in this study support conclusions made by the National Research Council report Pesticides in the Diets of Infants and Children (1993) that dietary intake represents the major source of pesticide exposure in children (as cited in Lu et al., 2006).

Because farmers extensively use pesticides in conventional agriculture (herbicides, insecticides, fungicides, and rodenticides) there is a high probability of contamination as a result of plant treatment and food storage procedures (Bouvier et al., 2005). Their presence in food has been documented and detected by urine analysis of various samples of children around the world (as noted above). These chemicals are rapidly metabolized after ingestion in the human body. Approximately 90% of the compounds are excreted within 6-24 hours after uptake (Fisher et al., 1985). Currently, no evidence exists of the long-term accumulation of these chemicals in the body; thus it is difficult to determine the adverse effects, if any, that pesticides have on human health (Heudorf et al., 2005). However, various studies have demonstrated that pesticides are associated with reproductive and developmental toxicity and immunotoxicity, in addition to the causation of neurological disorders and cancers (Bouvier et al., 2005).

Bell, writer for Epidemiology, investigated studies that examined the association between pesticide exposure and reproduction. The experiments suggest that these chemicals have a negative impact on embryonic development and can often lead to fetal death if the mother is overexposed during pregnancy (Bell et al., 2001). Many scientists are now also examining, in closer detail, the effect of chronic exposure to low doses of pesticides on the human immune system. It has been suggested that such contact with pesticides (ingestion from foods and inhalation and absorption from the residential environment) can reduce immune activity, resulting in increased susceptibility to infectious diseases, or enhance the normal immune response, leading to allergy (Colosio et al., 1999). Other risks associated with pesticide contact include vulnerability to neurological disorders, such as Parkinson’s disease and Alzheimer’s. However, the studies related to these findings have established only that occupational exposure to chemicals, and not ingestion, is associated with these diseases (Baldi et al, 2003). Further investigation has linked childhood pesticide exposure (predominately residential exposure from home and garden pesticide use) to certain cancers, such as leukemia, lymphoma, and brain tumors (Leiss, 1995; Infante-Rivard, 1999). Many studies, such as the one conducted by Menegaux (2006), writer for Occupational and Environmental Medicine, have demonstrated that, like the neurological disorders mentioned above, the risk associated with these cancers is related to residential exposure to chemicals (and not ingestion from contaminated foods). While eating foods tainted with pesticides (predominately those conventionally as opposed to organically grown) has certainly proven to be a source of these harmful substances, the body generally excretes them within a short period of time. This is not to say that eating contaminated foods is safe, but rather, since the adverse effects of inhaling and absorbing these chemicals from the residential environment are known, precautions should be taken around the home to minimize human contact with these chemicals.

Pesticides: Effects on Reproductive Viability

Reproductive performance is generally considered a strong environmental health indicator because it is less affected by genetic determinants than other outcomes (Williams, 2002). Studies conducted between 1926 and 1992 report data concerning reproductive performance of rodents and rabbits fed organic (no pesticides) versus conventionally grown (with pesticides) products. Only one study, conducted in 1934 by Scheunert et al., observed worse performance in organically fed rats, while earlier studies revealed clear confirmation for reduced egg production and abnormal histology (animal tissue structure) in conventionally fed animals (as cited by Williams, 2002). The small number of studies, however, in addition to the lack of consistency in design, and the dated nature of much of this work, suggests that lucid conclusions cannot be drawn at the present time.

Few experiments have been conducted regarding human reproductive potential, but evidence does exist that provides a correlation between organic diets and higher sperm counts in men. Juhler et al. conducted an experiment, "Human Semen Quality in Relation to Dietary Pesticide Exposure and Organic Diet," to test whether or not farmers having a high intake of organic products have a high semen quality due to their expected lower level of dietary pesticide intake. Semen samples from 256 farmers (171 traditional and 85 organic) were taken before and after spraying season. The current individual dietary intake of 40 pesticides was estimated using food frequencies and generalized serving size data in conjunction with data from the National Danish Food Monitoring Program on pesticide concentration in food commodities. The estimated dietary intake of the pesticides was significantly lower among men who consumed primarily organic foods (but was below dangerous limits for all the farmers). After the two samples of semen were compared, it was found that the farmers without organic food intake had a lower proportion of normal sperms.

Sanchez-Pena et al. conducted a similar study to test the effects of organophosphate pesticide exposure on sperm DNA structure, since alterations in these structures have been associated with decreased fertility rates in males. The study examined sperm from 227 agricultural farm workers in Villa Juarez, Mexico, who had been exposed to pesticides on a daily basis. Two samples taken from each man were assessed on the basis of concentration, motility, morphology (structure of sperm heads), and viability (overall health). The results revealed that human semen is often denatured (malformed or made nonfunctional) and altered in the presence of agricultural chemicals. Therefore, it is accurate to conclude that semen is sensitive to organophosphate exposure (Sanchez-Pena et al., 2004).

Another study conducted by Pant et al. (2004) also investigated the association between pesticides and semen quality. Scientists examined the correlation between the pesticides DDT and HCH in semen accessory sex glands and found that these chemicals influence the quality of semen by affecting seminal and prostatic functions in infertile men. Comparisons were then made regarding the levels of chlorinated pesticides in fertile versus infertile men – higher levels were detected in infertile men. Speculation suggests that these elevated levels are due to the extensive use of pesticides on food products and, consequently, the consumption of food contaminated with these chemicals (Pant et al., 2004).

Environmental Pollutants

In a study published by Risk Analysis, conducted by Williams and Hammitt, regarding consumer concerns about food safety issues, survey results suggest that respondents believe that organically grown produce will pose fewer health risks to consumers and farm workers than conventionally grown produce (Williams & Hammitt, 2001). However, what the public is unaware of is the fact that a large portion of chemical contaminants in food result from general environmental pollutants from the diffusion of chemicals through the environment and industrial activity (mining, chemical manufacturing, and refining) and waste disposal (Magkos et al., 2006).

According to a report published by the Food and Agriculture Organization, soil contaminants, namely heavy metals, cannot be avoided through organic farming practices because they are constantly present in farmland (FAO, 2000). Furthermore, many pollutants occur in the air, so their absence or presence in produce largely depends on farm location – whether farms are near areas of heavy industrial activity (Tirado & Schmidt, 2001). Linden, writer for Archives of Environmental Toxicology, also claims that fertilizer use can introduce pollutants, such as cadmium, a known carcinogen. Phosphate fertilizers, sewage sludge, and farmyard manure are the main sources of this dangerous metal (as cited by Magkos et al., 2006). The use of phosphate fertilizers has declined in organic farming, and conventional practices often utilize inorganic phosphate fertilizers, which have been treated to remove most cadmium before application on crops, in an attempt to reduce levels of this carcinogen in products. However, sewage sludge and animal manure are still major sources of cadmium and are frequently employed in both organic and conventional farming practices (Kirchmann & Thorvaldssson, 2000).

Natural Toxins

In their study on food safety issues and the perceived benefits of organically grown produce, Williams and Hammitt (2001) elicited the consumer response that approximately 45% of respondents associate organically grown produce with lower natural toxin risks. While much emphasis has been placed on the difference between natural and synthetic chemicals, people should not assume that natural toxins are safer or less harmful.

In the article “Natural pesticides and bioactive components in foods,” published in Reviews of Environmental Contamination and Toxicology, writer R. C. Beier states that plants produce natural toxins as a defense mechanism when they are “stressed” to protect them against predators (as cited by Magkos et al., 2006). Experiments have been conducted to test the carcinogenic nature of some natural toxins, and the results have demonstrated that many natural chemicals are just as potent mutagens as their synthetic counterparts. For example, the chewing of betel nuts with tobacco has been associated with oral cancer, drinking various herb teas containing certain compounds has been linked to nasopharyngeal and esophageal cancer, and the consumption of other herbal medicines and teas has been correlated with the development of cirrhosis of the liver (Ames et al., 1990b). Furthermore, it has been calculated that "99.99% (by weight) of the pesticides in the American diet are chemicals that plants produce to defend themselves" (Ames et al., 1990a, p. 1). All plants possess these chemicals, but they produce large amounts, which can be toxic to humans, only when attacked by pests or predators. Ames et al. (1990a) estimates that the American population consumes approximately "1.5 grams of these natural pesticides every day, which is about 10,000 times more than they eat of synthetic chemicals" (p. 7777). However, intake of natural toxins depends on personal diets; thus vegetarians would consume larger amounts of these chemicals since their diet is composed almost entirely of vegetables. In addition, individuals consuming large amounts of brown rice, whole wheat, and corn would ingest more of these natural toxins, since they are present in higher amounts in these foods (Ames et al., 1990a).

Limited experiments have been conducted to test the carcinogenicity of natural toxins. The tests that have been conducted, however, have demonstrated that plant toxins found in commonly consumed foods, such as apples, apricots, bananas, broccoli, cantaloupe, coffee, eggplant, grapes, mangos, mushrooms, potatoes, raspberries, etc., have tested positive as rodent carcinogens. Scientists are not claiming, though, that the consumption of these foods will lead to cancer in humans (Ames et al., 1990a). Rather, according to USDA guidelines, Americans should consume fruits and vegetables in an effort to reduce the risk of cancer, since these foods are rich in anticarcinogenic vitamins and antioxidants (USDA, 2006). "What is important in the analysis," Ames states, "is that exposures to natural rodent carcinogens may cast doubt on the relevance of far lower levels of exposures to synthetic rodent carcinogens" (p. 7779).

According to the information cited earlier from Beier, natural toxin production is increased when plants are stressed by insect or pest attack. As a result, farmers have investigated different methods to suppress the manufacture of these chemicals and have concluded that since synthetic insecticides and pesticides deter plant predation, they are effective in reducing plant stress. Thus, they are successful in diminishing the creation of natural toxins (Mattsson, 2000). Furthermore, adequate crop protection ensures greater crop yield and, in turn, the production of higher-quality and more affordable fruits and vegetables (Mattsson, 2004). Consumers, however, are more suspicious about produce treated with pesticides due to concerns regarding the safety of these chemicals. Many people are under the false impression that because plant toxins are natural in origin, they are therefore safer to consume. Results from the studies cited above demonstrate the fallacy of this notion, as high doses of natural chemicals were correlated to illness in animals. In addition, standards have been established for the acceptable daily intake of synthetic pesticides, while no guidelines exist for the consumption of natural toxins since less is known about these chemicals (Mattsson, 2004).

Implications of the Organic Food Debate

The growing American interest in food safety issues and healthier eating alternatives has been accompanied by a surge in the organic food retail market. Stores such as Whole Foods, Wild Oats, and Trader Joe's have expanded significantly, each stocking approximately one hundred to one hundred and fifty stores across the country (Scheer, 2003). The emergent health-consciousness craze has led people to seek organic alternatives to many daily favorites – everything from pasta, cereal, and dairy products to beer (Motavalli, 2002). "USDA Certified" labels distributed by the federal government further strengthen the public's faith in organic products. This, in turn, has led to confusion and misinterpretation regarding nutrient, pesticide, and natural toxin content of organically versus conventionally grown products. While organic foods are produced using biological methods and in the absence of synthetic crop inputs, this does not guarantee more nutritious, healthier, and safer products. While studies have been conducted, most of the results were deemed inconclusive because too few experiments with too much variation have been performed. Thus, consumers should be wary when purchasing food products, since "organic" does not necessarily equal superior food quality.

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