Citation:
Oates, L and Cohen, M 2009, 'Human consumption of agricultural toxicants from organic and conventional food', Journal of Organic Systems, vol. 4, no. 1, pp. 48-57.

HUMAN CONSUMPTION OF AGRICULTURAL TOXICANTS FROM ORGANIC AND CONVENTIONAL FOOD

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Abstract

Over the past 60 years both the number of agricultural toxicants in use and rates of toxin-related diseases have increased dramatically, and countless studies attest to a link between the two. While data from residue surveys confirms higher levels of toxicants in conventionally farmed produce, few studies directly assess whether consuming organic produce results in a reduction in pesticide exposure in humans or confers any health benefits. Future research needs to confirm whether and to what extent agricultural toxicant levels vary between consumers of organic and conventional produce before attempting to draw any conclusions about the potential health implications of such differences.

Keywords: organic farming, agricultural toxicants, pesticides, safety

Introduction

Chemical use has increased dramatically in developed countries since the 1940s and more recently in other regions. In excess of 80,000 chemicals are now commercially available for use by agriculture and industry and many potentially toxic compounds have been embraced to increase productivity and financial gain (Erickson 2009). These ‘toxicants’ are widely distributed in nature and many lack an established NOAEL (no observed adverse effect level) or consensus about long term health effects. The presence of toxicants in humans is ubiquitous, increasing with age and exposure, and this has been widely confirmed by studies analysing breast milk (Somogyi & Beck 1993) and other human tissue (Dewailly et al. 1999).

Both the number of toxicants in the environment and rates of toxin-related diseases have increased dramatically in the past 60 years, and countless published studies attest to a link between toxicants and health risks. For instance, comprehensive reviews highlight numerous studies which have identified a positive relationship between exposure to pesticides and the development of certain cancers, as well as adverse reproductive, metabolic and mental health effects (Sanborn et al. 2004,Maroni & Fait 1993). The ‘*Agricultural Health Study’*, a large prospective cohort study conducted in the United States in the 1990’s also identified, among other things, cancer risks associated with direct exposure to pesticides and other agricultural agents (Alavanja et al. 2003 , Lee et al. 2007 , Alavanja et al. 2004).

Such findings have lead some consumers to turn to organic produce in the hope that limiting the consumption of conventionally farmed food will result in a reduction in exposure to agricultural toxicants (especially pesticides) and therefore reduce any associated health risks. European surveys indicate that 70% of EU citizens are ’worried’ about pesticide residues in food (Tasiopoulou et al. 2007). Similarly a 2004 Australian survey conducted on a randomly selected population from Victoria (n=223) reported that 74% of respondents agreed with the statement ‘Organic food is healthier than conventionally grown food because it has no pesticide residues’ (Lea & Worsley 2005). While this notion makes intuitive and theoretical sense, according to the New Zealand Food Safety Authority, at present ‘there is no conclusive evidence to suggest that organic food in general is more or less safe or nutritious than conventionally produced foods’ (NZFSA 2009).

The Food Standards Agency (UK) recently commissioned two separate systematic reviews evaluating these issues. The first review compared the composition (nutrients and other nutritionally-relevant substances) of organically and conventionally produced foods (Dangour et al. 2009). The second review evaluating the putative health effects of organic food is yet to be released (FSA 2008). As the study protocols specifically exclude addressing contaminant content (such as herbicide, pesticide and fungicide residues) these reviews are unlikely to further our understanding of the potential health impact of residues in organic or conventional foods. A team of European scientists affiliated with the Quality Low-Input Food project are currently working on assessing the effect of organic and ‘low input’ production methods on food quality and safety and human health (QLIF 2008) and this may prove more useful to consumers.

Consumer interest appears to be focused on whether a reduction in toxicant exposure by way of organic food consumption, might mitigate the perceived health risks associated with agricultural toxicants (especially

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pesticides). To confidently establish this, researchers will firstly need to demonstrate that the differences in residues noted in surveys of fresh produce result in differences in toxicant levels in humans.

This paper will review current evidence regarding health risks associated with agricultural toxicants, differences in residue levels in the produce itself and to what extent the consumption of foods produced by organic and conventional farming methods affect these toxicant levels in humans. It will further discuss some of the difficulties associated with comparing organic and conventional produce, and in assessing the human health risks from agricultural toxicants.

The Organic Industry and its Consumers

The organic food industry is currently undergoing a global expansion. According to the most recently published data (as at the end of 2007), there are currently 1.2 million organic producers, and 32.2 million hectares of land worldwide certified according to organic standards. Australia continues to account for the largest certified organic surface area globally, covering an area of 12.02 million hectares, a slight decrease on the previous year, with around 1,550 certified farms. New Zealand accounts for 65,000 hectares. In 2007 the global market for organic products was valued at over US$46 billion, up from US$38.6 billion in 2006, and more than double that of 2000 (Willer et al. 2009).

As yet, there is no consistent international definition of the term ‘organic’ although many regions have comprehensive standards regulating the production and processing of ‘certified organic’ food products. Most common definitions emphasise production practices and principles, and standards often refer to the avoidance of substances foreign to nature (such as synthetic fertilisers and pesticides); as well as promoting local, renewable resources; maintaining diversity; and consideration of animal welfare (United Nations 2008).

In addition to concerns about the health implications of pesticide (and other chemical) exposure, consumer decisions to purchase organic produce are influenced by various factors including beliefs that organic foods have a superior nutritional profile and taste; and that they are better for the environment, farm workers and animal welfare (Lockie et al. 2002, Lea & Worsley 2005). Lockie et al (2004, p 135) state that ‘on the basis of the precautionary principle alone, choosing organic foods appears to be an entirely rational decision’ (Lockie et al. 2004, p 135).

Agricultural Toxicants and Health Risks

More than 9000 agricultural and veterinary (AgVet) chemicals are currently approved for use by the Australian Pesticides and Veterinary Medicines Authority (AVPMA) (Haddad 2009) and more than 2000 by Agricultural Compounds and Veterinary Medicines (ACVM) in New Zealand (Owens 2009). These agricultural toxicants include: synthetic fertilisers, pesticides (herbicides, insecticides, fungicides), fumigants, mycotoxins, hormonal growth promotants, anthelmintics, antibiotics, and other medications.

While food regulatory bodies worldwide fail to report any health benefits of organic foods, it has been acknowledged that ‘since organic production systems minimise the use of synthetic compounds it is likely organic produce will have lower residues than conventional produce’ (NZFSA 2009). The fact that these chemicals are widely utilised in conventional farming but are largely prohibited by organic certifying bodies suggests that organic food consumption should result in reduced human exposure to these chemicals, yet to date, only three published reports have directly assessed this (Lu et al. 2009, Lu et al. 2008, Curl et al. 2003). Furthermore, it is difficult to definitively determine the health impact of such exposure. Much of the current research is based on animal data, epidemiological studies of occupational exposure and reports of acute poisoning. The following is a summary of some of the major purported health concerns.

Pesticides

A number of large studies have attempted to identify links between pesticide use and chronic health effects. In the 1990’s researchers in the United States’ conducted a large prospective cohort study of pesticide applicators and their spouses known as the *Agricultural Health Study*. The study identified links between various pesticides and prostate, lung, rectal and colon cancers (Alavanja et al. 2003, Alavanja et al. 2004, Lee et al. 2007). More recently the *Systematic Review of Pesticide Human Health Effects* (Sanborn et al. 2004) assessed eighty three studies that met rigorous inclusion criteria. Studies with poor methodology (less than 4 on a 7-point scale) or those conducted on organochlorine pesticides (OCPs), which have been banned in many regions under the Stockholm Convention (DEH 2006), were excluded. A positive relationship was identified between exposure to pesticides and development of many cancers as well as the risk of genotoxic, immunotoxic and neurotoxic and adverse reproductive effects and an increased incidence of psychiatric and dermatological conditions.

Another review suggested that adverse effects from pesticide exposure are more likely to occur in children and highlighted concerns regarding neurobehavioral toxicity and endocrine disruption as well as implications for childhood cancer and adverse reproductive outcomes (Garry 2004). In addition correlations have been made between levels of agricultural toxicants in surface water and higher risk of birth defects (Winchester et al. 2009).

Persistent Environmental Chemicals

Numerous chemicals, classed as persistent organic pollutants (POPs), have the ability to persist in the environment long after they have been utilised in farming. An example are the organochlorine pesticides once commonly used in conventional agriculture, hence the term organic in this context relates to the chemical structure of the substance rather than their approved use in 'organic' farming systems.

Many POPs have been shown to exert carcinogenic and endocrine disrupting effects (Jandacek & Tso 2001). Despite recent efforts to reduce their use, they continue to contaminate water, soil and air around the globe and their affinity for lipids, chemical stability and long biological half-lives has resulted in bioaccumulation and biomagnification throughout the world's food chain (Jandacek & Tso 2007). Although organic standards prohibit their use and are somewhat protective against future occurrences of a similar nature, human consumers are unavoidably exposed to these substances whether they eat organic or conventional produce (Magkos et al. 2006). Residue surveys have identified these substances in both conventional and organic produce, most likely due to historical use (McGowan 2003, Tasiopoulou et al. 2007).

Synthetic Fertilisers

While fertilisers used on organic farms contain nitrogen bound to organic material from which it is slowly released (Benbrook et al. 2008), chemical fertilisers are absorbed rapidly into the plant and increase nitrate/nitrite levels and may result in formation of nitrosamines which have been associated with leukaemia and gastrointestinal cancers (Rembialkowska 2007).

Mycotoxins

Mycotoxins (fungal toxins) are secondary metabolites produced by microfungi which can cause acute toxicity or chronic health effects such as cancer, kidney or liver toxicity and immune suppression (Bennett & Klich 2003). An example is zearalenone, a metabolite of *Fusarium spp.* which possesses potent oestrogenic activity and may occur naturally or be added as a synthetic growth promotant known as zeranol (banned by the European Union since 1989).

It is estimated that one quarter of the world's crops are contaminated to some extent with mycotoxins which can be transferred to humans through the ingestion of contaminated crops or animals (Bennett & Klich 2003). On average mycotoxin levels in conventional food are twice as high and detected 50 percent more frequently than in corresponding organic food (Benbrook 2005). This is attributed to the use of nitrogen based fertilisers and somewhat ironically to the use of synthetic fungicides which may lead to resistance or trigger shifts in the population mix of fungi that favour mycotoxin-producing strains.

Pathogens

The use of outdoor husbandry and manure application, and limited use of AgVet agents in organic farming systems has lead to speculation that organic produce may be more vulnerable to bacterial and fungal contamination. However, there is no firm evidence that organic crops are more or less susceptible to microbial contamination or that animal health status is compromised (Magkos et al. 2006). In fact there appears to be a trend towards faster decline in E. coli O157:H7 levels in organic compared to conventional soils (Franz et al. 2005).

In organically farmed animals, it has been reported that while parasite problems tend to be worse, other health traits tend to be the same or better than in conventional farming (Lund & Algers 2003). New Zealand researchers have reported on the challenges of controlling parasites without anthelmintics (medicines used to control internal parasites in animals) and were cautiously optimistic that an integrated approach by parasitologists, plant breeders, agronomists, and farming systems researchers may lead to the development of alternative methods for parasite control (Niezen et al. 1996).

Veterinary medicines

Arguably the most controversial of the veterinary medicines used in conventional agricultural practice are antibiotics. Antibiotics have been used extensively as growth promotants and for the control of infection in large-scale animal confinement operations (Dolliver et al. 2007). In addition, livestock feed produced as a byproduct of ethanol production may contain antibiotic residues providing another route of exposure for animals. The presence of antibiotic residues in manure used on farmland may also contribute to uptake by plants and spread to aquatic environments (Dolliver & Gupta 2008, Blackwell et al. 2009). As a result all human food sources may potentially contain antibiotic residues.

Concerns have been raised regarding the presence of antibiotic residues in foods produced for human consumption and the resulting development and spread of antibiotic resistant bacteria. Recent studies have confirmed that organic farming practices result in reduced frequency of resistant strains (Schwaiger et al. 2008) however the implications for humans is unclear. In addition researchers have warned about the potential impact of chronic cumulative exposure to antibiotics, risk of allergic reactions and disruption of digestive function (Dolliver et al. 2007).

Secondary Metabolites

It has been proposed that organic farming practices encourage endogenous plant defence mechanisms to protect them against predators, resulting in increased toxin production (Magkos et al. 2006). While it is true that organic produce appears to be higher in plant derived secondary metabolites (phytochemicals) (Rembialkowska 2007) whether these substances exert positive or negative health effects is unclear, although the potential for positive health effects is suggested by evidence that many phytochemical compounds possess antioxidant, antimicrobial and other properties (Hounsome et al. 2008).

Comparisons of Organic and Conventional Produce

Difficulties in comparing organic and conventional produce

There are a number of barriers for researchers attempting to distinguish between organic and conventional produce for comparison purposes. Both organic and conventional farming practices vary widely and there are many factors that influence the final toxicant levels in produce as outlined below. While similar, the lack of complete uniformity in certification requirements by the hundreds of different certifying bodies worldwide makes cross-comparison of published studies problematic. In addition, some conventional farmers, while not certified as organic, may employ organic farming techniques or minimise chemical use for financial, environmental or other reasons. Therefore differentiating the two farming methods for comparison can be difficult.

Despite restrictions, rare cases of contamination of organic produce with ‘non-allowed’ residues have been reported (McGowan 2003). This may occur due to historical use or current use on neighbouring farms resulting in contamination of soil, groundwater or irrigation water; spray drift; percolation through soil on sloping fields; unauthorised use; or due to inadvertent contamination during transport, processing and storage (Magkos et al. 2006). Regulatory authorities such as the Australian Quarantine and Inspection Service recognise that it is virtually impossible to guarantee ‘product claims’ acknowledging that ‘non-allowed’ residues may occur and therefore permit certified organic produce to contain up to 10% of the Maximum Residue Levels (MRLs) and still be sold on the export market as ‘organic’ (AQIS 2008). Many certifying bodies however, have lower tolerance levels and may withdraw certification if certain residues are detected.

Whether chemical residues are detectable on produce at the point of sale and consumption will depend upon: the amount and how often it was applied; the persistence of the chemical; how long prior to harvest it was used; whether the part consumed received direct application of the chemical (e.g. leafy greens); the addition of post-harvest treatments (e.g. fungicides); the fat content of the food; and food preparation techniques (washing, peeling and cooking) (Rumbold 2008). Furthermore the ‘lower limits of detection’ (LOD) used by laboratories assessing residues may vary and in some cases may be higher than the MRLs set by international regulatory bodies (Reichstein 2009). Therefore the use of chemicals in conventional farming does not always result in ‘detectable’ residues.

Residue Surveys

Residue surveys of agricultural and veterinary chemicals and environmental contaminants in food commodities are conducted in many countries to assess compliance with regulations and provide quality assurance to export markets. Organic produce is not always differentiated for analytical purposes, but where it is, studies consistently show that organically farmed produce contains lower levels of contaminants than conventional produce (McGowan 2003, Tasiopoulou et al. 2007, Baker et al. 2002).

In New Zealand chemical residue surveys have not identified any specific concerns relating to organic food products (NZFSA, 2009). In Australia results collected from the National Residue Survey (NRS) and Victorian Produce Monitoring Program (VPMP) suggest that maximum residue levels (MRLs) for individual toxicants are rarely exceeded (<1%) even in conventional produce. Moreover Australian research has confirmed that organically-certified produce has even fewer pesticide residues than conventional food crops (McGowan 2003).

In a 2003 technical report to the Department of Primary Industries (DPI) 100% of 300 organic samples tested fell below the MRLs, 99.4% of which recorded no detectable residues for any of the 45 pesticides assessed. These included organophosphates, organochlorines, synthetic pyrethroids and others such as Atrazine and Carbaryl. Only two samples recorded any detectable pesticide residues. Dieldrin (~50% of the MRL) was reported in a sample of organic rockmelon most likely due to historical use in an old orchard on the property, and iprodione (<2% of the MRL) was detected in a sample of apples likely due to contamination of a wooden crate that had previously stored conventional produce (McGowan 2003).

International studies have similarly reported higher levels of contaminants in conventional compared to organic plant produce. An Italian residue survey reported 10-fold greater contamination in conventional (27%) compared to organic products (2.6%) with multiple residues reported in 8.8% of conventional and only 0.8% of organic samples (Tasiopoulou et al. 2007). US data shows organically grown foods consistently record about one-third as many residues as conventionally grown foods, with multiple pesticide residues reported in 26.7% of conventional and 2.6% of organic samples (Baker et al. 2002).Recent comparative data is more difficult to obtain in Australia where the NRS is conducted with the funding and direction of industry bodies and organic produce is not differentiated in reports (Reichstein 2009).

While it can be assumed that organic food of animal origin contains fewer chemical and veterinary drug residues than conventional products, adequate research to support this assumption is currently lacking (Magkos et al. 2006). The NRS in Australia tests some residues in animal products however organic produce is not differentiated in the results.

Health Effects of Organic and Conventional Diets

As previously discussed there is some evidence to suggest detrimental health effects from certain agricultural toxicants and data from residue surveys to confirm higher levels of these toxicants in conventional compared to organic produce. It would seem reasonable to assume therefore that consumers of conventional produce are exposed to and accumulate higher levels of these toxicants and are thus at greater risk of associated health problems. Direct evidence to support this assumption however is currently lacking. Little is known about whether and to what extent agricultural toxicants accumulate in the human body and whether ‘normal’ exposure results in any health risks.

Designing high quality, large scale, long-term randomised controlled trials to compare the physiological and clinical effects of ingesting conventional and organic produce is not feasible for ethical and practical reasons. As a result studies comparing the effects of organic and conventional diets on toxicant levels or health-related biomarkers would provide some evidence of a plausible link. At present there are few such studies in either animals or humans. The studies that have been performed along with the difficulties in assessing the potential health effects of toxicant exposure are discussed below.

Animal studies

A number of studies have reported on animal health in organic and conventional farming systems. While an early review reported better growth and reproduction in animals fed organically grown feed (Worthington 1998) it has been suggested that older studies may not be relevant to modern farming practices (Lauridsen et al. 2008).

Feeding studies in rats suggest improvements in some health-related biomarkers for rats fed fertiliser and pesticide free diets (e.g. higher serum IgG concentrations; 14% less adipose tissue; less daytime activity suggestive of more uninterrupted sleep; and shorter half-oxidation time indicative of better hepatic metabolic activity) (Lauridsen et al. 2008) and an increase in immunotoxicity from the consumption of conventional wheat (Finamore et al. 2004). In pigs, immune responses were similar but stress resistance at slaughter was improved in organic animals (Millet et al. 2005).

A 2003 review of comparative studies in the peer reviewed literature regarding animal health in organic systems drew a cautious conclusion ‘that parasite problems tend to be worse but other health traits tend to be the same or better in organic farming compared with conventional’ (Lund & Algers 2003, p 55).

Unfortunately, differences in organic regulations, changes in organic farming practices overtime and the lack of relevance of animal models impairs the application of findings to human consumers of organic food.

Human Data

While the self-reported health and well-being status of farm (field and pack-house) workers in the UK has been shown to be poorer than national norms, there do not appear to be any significant differences between those working on conventional and organic farms (Cross et al. 2008). One exception was that organic farm workers were happier than their counterparts, based on the Short Depression Happiness Scale (SDHS). Multiple regression analysis suggested that the difference was primarily due to an increase in the variety of tasks performed by this group. While this study reported on occupational exposure it did not assess dietary exposure via an organic or conventional diet.

To date few published studies (Lu et al. 2009, Lu et al. 2008, Curl et al. 2003) have directly assessed whether consuming organically-certified produce results in a reduction in pesticide exposure in humans. A recent study of children in Seattle USA demonstrated that substituting organic fresh fruits and vegetables for corresponding conventional food items for a 5-day period, resulted in a reduction in the median urinary

ISSN 1177-4258

metabolite concentrations of malathion and chlorpyrifos (organophosphates) to non-detectable or close to non-detectable levels (Lu et al. 2008). The same research group has also reported a 50% reduction in synthetic pyrethroid insecticides under the same trial conditions, however due to widespread residential use the dietary intervention was not sufficient to lower exposure to non-detectable levels (Lu et al. 2009). A previous study conducted in the same area had assessed pesticide (organophosphate) levels in the urine of pre-school children and determined that 'consumption of organic fruits, vegetables and juice can reduce children's exposure levels from above to below the U.S. Environmental Protection Agency's current guidelines, thereby shifting exposures from a range of uncertain risk to negligible risk' (Curl et al. 2003, p 377).

Children are particularly vulnerable to the toxic effects of chemicals for a number of reasons; they exhibit more hand to mouth behaviour, they eat and drink more per kilogram of bodyweight than adults, their skin is more permeable and their livers do not metabolise chemicals as efficiently (Sanborn et al. 2004). However, levels of POPs such as organochlorines are known to increase with age and exposure suggesting bioaccumulation in tissues (Jandacek & Tso 2007, Nickerson 2006) which may suggest increased levels of certain toxicants in adults. As a result it is not currently known whether findings in child studies can be extended to adult populations.

Difficulties in assessing the health risks of toxicants

While biological reasoning would suggest that reducing the intake of agricultural toxicants (via an organic diet) would result in reduced exposure and therefore reduced health risks, other factors need to be considered. All humans are exposed to environmental toxicants whether they be ingested from food sources, inhaled from polluted air or absorbed through the skin. The effects of these toxicants may be immediate or latent or only evident during certain developmental stages.

Although safety assessments of toxicants are conducted by government bodies it should be noted that adherence to residue standards does not guarantee food safety. While regulations are set for individual toxicants, humans are exposed to multiple chemicals via multiple routes and single chemicals with relatively low toxicity may combine to act additively or synergistically. A dose-response relationship has been demonstrated in studies that have analysed exposure to multiple rather than single pesticides (Bassil et al. 2007), suggesting that it is not the isolated acute exposure to individual toxicants that is of greatest concern but rather the combined and cumulative effect of multiple toxicants.

Dose addition assumes that the cumulative toxicity of a mixture of chemicals can be predicted from the sum of the toxic potential of each individual chemical (Laetz et al. 2009), however this is not always the case. Mixtures of chemicals may also interact via toxicokinetic (absorption, distribution, metabolism and excretion) or toxicodynamic (binding, interaction and induction of toxicity) processes to produce either antagonistic or synergistic effects (Borgert et al. 2004). Exposure to multiple chemicals need not necessarily be concurrent in order to produce additive or synergistic effects (Thiruchelvam et al. 2002). Thus estimating the impact of multiple environmental chemicals using studies that examine only single chemicals at high doses and often only in animals, may lead to significant underestimations of effects.

Thorough safety assessment is further compromised by: a lack of human data; gaps in the information for many individual chemicals; poorly understood pathways for chemical interaction; different responses among various species and individuals; a lack of sophisticated statistical tools for analysing complex data; and the vast number of potential combinations of chemicals (Laetz et al. 2009). Determining the separate and/or combined effects of different exposures, and the long latency periods between exposure and development of disease further complicates the issue. A further difficulty in assessing the validity of toxicant studies is a lack of consistency in the biomarkers and methods used by various researchers to determine toxicant levels (Sanborn et al. 2004).

Some individuals and population groups may be more vulnerable to the pathological effects of toxicants than others. For example, pregnant and lactating women require specific consideration to minimise exposure of the foetus or infant during critical periods of development when chemicals (such as pesticides) can interact with genes (epigenetics) turning them off or on at inappropriate times. The effects can persist long after the exposure has gone and increase susceptibility to disease even decades later (Hileman 2009). As previously mentioned children may also be particularly vulnerable due to a proportionately higher intake of toxicants and diminished capacity to detoxify them (Sanborn et al. 2004). Paranoxase-1 enzyme (PON1) activity, responsible for the detoxification of many pesticides, is impaired in children until at least 7 years of age (Huen et al. 2009). Even in adults, variations in detoxification capacity or entero-hepatic recirculation may allow toxicants to remain or be reabsorbed into the body (Jandacek & Tso 2007). In addition greater fat stores may increase the body's capacity to accumulate lipophilic contaminants (Schildkraut et al. 1999) and calorie restriction may mobilise stored toxicants allowing them to re-enter the circulation and be deposited in other tissues such as the brain (Jandacek et al. 2004). Genetic weaknesses and exposure to multiple chemicals may further contribute to the likelihood of adverse health effects.

Conclusion

Over the past 60 years both the number of agricultural toxicants in the environment and rates of toxin-related diseases have increased dramatically, and countless studies have been published suggesting a link between toxicants and health risks. As a result an increasing number of consumers are choosing to pay a price premium for organic food in the belief that it will reduce their exposure to agricultural toxicants and in turn reduce associated health risks. Health authorities currently maintain that there is 'no conclusive evidence to suggest that organic food in general is more or less safe or nutritious than conventionally produced foods'. While there is some evidence to suggest health risks from certain agricultural toxicants and data from residue surveys to confirm higher levels of these toxicants in conventional compared to organic produce, the significance of this for human dietary exposure is uncertain. To date only three published reports have directly assessed whether consuming organically farmed produce results in a reduction in the levels of pesticides (or other agricultural toxicants) in humans. While biological reasoning would suggest that reducing the intake of agricultural toxicants (via an organic diet) would result in reduced exposure and therefore reduced health risks, other factors need to be considered, and more research is required. Future research needs to confirm whether and to what extent agricultural toxicant levels vary between organic and conventional consumers before attempting to draw any conclusions about the potential health implications of such differences.

Acknowledgments

The authors would like to thank Dr Lesley Braun (Alfred Hospital, Melbourne).

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