CATÓLICA
ESCOLA SUPERIOR DE BIOTECNOLOGIA
PORTO

# CHEMICAL CONTAMINATION OF ORGANIC PRODUCTS VERSUS CONVENTIONAL PRODUCTS

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January 2019

## Abstract

The objective of this thesis was to delve into a sector of food safety which is lacking research, chemical contamination of organic foods. In regards to studies that have been conducted on organic products, a majority of the research has focused on the biological contamination of organic foods verses conventional products. A systematic review was conducted using the databases Academic Search Premier and PubMed to gather peer reviewed publications. Also, regulations were referenced to determine if chemical contaminants are being adequately controlled in both organic and conventional products. The results indicated that there are various factors that can lead to the chemical contamination of crops despite their mode of production. Such factors include: exposure of pollutants through the air, contaminated water, soil, food fraud, and packaging materials. A significant difference, however, between organic and conventional products is that pesticides are restricted in organic agriculture. Therefore, these products contain less pesticide vestiges. The results also demonstrated that globally, there are strict regulations to effectively control pesticide exposure. EFSA found that in the European Union 96.2% of crops complied with legal standards and in the United States, the USDA found that 99.5% fulfilled legal standards. Thus, this diminishes a key argument that organic products are superior on the premise that they contain inferior amounts of pesticides because the contamination of pesticides in conventional foods is not a significant danger to begin with.

Keywords: chemical contamination, organic farming, food safety

## Resumo

Esta tese tem por objetivo investigar um setor da segurança alimentar menos investigado, a contaminação química dos alimentos orgânicos para determinar se são superiores no que duz respeito a segurança. Foi realizada uma revisão sistemática usando as bases de dados Academic Search Premier e PubMed. Os resultados demonstram que existem vários fatores que levam à contaminação química dos alimentos, muitos quais o método de produção não pode controlar. Tais como os poluentes no ar, fontes de água contaminadas e metais naturalmente no solo. Também, químicos contidos nas embalagens podem migrar para os produtos alimentícios. Apesar de existir estudos que implicam que os alimentos orgânicos têm benefícios de saúde superiores comparados com os convencionais, os consumidores que optam pela compra de produtos orgânicos têm a tendência de se preocupar mais com a saúde e consequentemente se empenham em atividades de promoção da saúde. Uma diferença significativa, no entanto, entre produtos orgânicos e convencionais é que os pesticidas são restritos na agricultura orgânica. Por isso, esses produtos contêm menos vestígios de pesticidas. Os resultados também demonstram que, globalmente, existem regulamentos rigorosos para controlar efetivamente a exposição aos pesticidas. A EFSA constatou que na União Européia 96,2% das lavouras cumpriam as normas legais e a USDA nos Estados Unidos concluiu que 99,5% cumpriram os padrões legais. De acordo com os resultos desta revisão, produtos orgânicos não são superiores em relação à contaminação química.



Palavras-chave: contaminação química, agricultura biológica, segurança alimentar

Contents

## Abbreviations

| | |
|---|---|
| CFC | Consideration of Future Consequences |
| DBP | Di-n-butylphthalate |
| DEHP | Di(2-ethylhexyl)phthalate |
| DEHT | Di-(2-ethylhexyl) terephthalate |
| EFSA | European Food Safety Authority |
| EPA | Environmental Protection Agency |
| FDA | Food and Drug Administration |
| GMO | Genetically modified organism |
| LOQ | Limit of quantification |
| MRL | Maximum Residue Limit |
| NOP | National Organic Program |
| OFPA | Organic Foods Production Act |
| PDP | Pesticide Data Program |
| USDA | United States Department of Agriculture |

# 1. Introduction

A majority of the research piloted on organic foods concentrates on biological contamination (14). The objective of this research is to delve into a sector of food contamination that is less explored. The focus of this study is to compare the difference between chemical contamination of organic products verses conventional products. Chemical food contamination occurs when chemicals have entered the food chain. Chemical contaminants can enter food through cross-contamination, soil, air, agrochemicals, food packaging, etc (1, 15). Examples of chemical contaminants include: metals, cleaning products, pesticides, and dioxins (14). In this thesis, the term "conventional products" refers to those which have not been certified as being organic. Organic products are foods that have been qualified and meet the respective standards to be classified as such (5, 14). Requirements of being labeled as organic can slightly differ among different countries. For instance, in the United States, the USDA imposes standards (5). Countries belonging to the European Union must abide by criteria set by the European Union (17). However, in order to be classified as organic, all products must adhere to specific farming principles. They refrain from using artificial pesticides and fertilizers, genetically modified organisms, and ionizing radiation. Animals that comply with organic standards cannot be administered antibiotics or growth hormones (5). The European Union has drawn out strict standards for a product to be labeled organic, which are defined by Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91 (8). In the Unites States, in order for products to be certified as organic, they must adhere to the standards that have been set by Title 7, Part 205 of the Code of Federal Regulations (5).

Consumers that opt to purchase organic food are often lead to believe that these products are safer and have superior health benefits compared to conventional foods because they refrain from using toxic chemicals (14). However, by definition, they abide by specific agricultural practices that are aimed to protect the environment and promote biodiversity (10). Thus, organic products have no correlation with food safety or nutrition (14).

Over the past decades, purchasing organic foods has become increasingly more popular (14). In 1996, the American organic industry was profiting circa $3.5 billion. By 2010, the

market had more than tripled to approximately $28.6 billion (38). Organic farming is an industry that has been flourishing worldwide. As of 2015, nearly 60 million hectares globally were occupied by organic farming (38). Just like any industry, organic brands use conniving advertisements to make their products appear more superior to increase profits. Therefore, it is likely that deceitful claims regarding safety have been made to purposely attract more attention (14).

## 2. Materials and Methods

A systematic review was conducted using various peer-reviewed articles which were gathered by browsing the databases Academic Search Premier and PubMed. Keywords that were used during the database search included: organic food consumers, organic food and pesticides, organic food benefits, organic food consumption, organic food trends, organic food vs. conventional food, and organic food vs. non-organic. Articles were retrieved regarding factors outside of production methods that can lead to chemical contamination. In addition, EFSA Pesticide Residue Reports from the last available years were referenced to obtain data pertaining to pesticide residue levels in the European Union. Also, statistics from the reports were retrieved concerning the percentage of samples that contained residue levels below the limit of quantification (LOQ) for both organic and conventional products. The results were then graphed to compare both products and determine the safety of both. Lastly, government agency websites were consulted to gain a closer understanding of current regulations in force (i.e. EFSA) and their effectiveness in ensuring that products are safe from chemical contamination. To guarantee that the data collected was not outdated, the search was filtered to exclude publications that had been published more than ten years ago.

## 3. Results and Discussion

### 3.1 Persistent Organic Pollutants

Crops, despite their mode of production are subject to the contaminants in the air. Persistent organic pollutants, or POP's are synthetic organic substances that result from industrial pollution, application of pesticides, and burning of waste (16). These chemicals are hazardous because they have extended half-lives so they remain in the environment for long periods of time. They also biomagnify so as they move up to higher levels on the food chain, they become more concentrated (14). Furthermore, POP's are a large concern because they are omnipresent in the environment. They can migrate to different regions because they can be carried by wind and water (16). Thus, they can be found in areas far from where they were produced, potentially migrating to areas of organic agriculture. Furthermore, they can negatively impact human health. The body has a difficult time metabolizing and expelling them. POP's are lipophilic meaning they have an affinity for fat cells and accumulate in fatty tissues of animals and humans over time (16). Research has shown that they have the potential to impact the reproductive, nervous, immune, and endocrine systems. Research has also found a correlation with behavioral diseases and an increased risk of certain cancers (i.e. breast cancer). Furthermore, they are transferred to fetuses via the placenta (14, 16). Humans are mainly exposed to these substances through the consumption of contaminated food (16). Since these substances are ubiquitous, they can contaminate organic and conventional products equally (14).

## 3.2 Water Sources

Over the last decades, pollution has decreased the accessible clean water supply and consequently reduced the available water for irrigation. As a result, many developing countries have resorted to the use of wastewater to irrigate their crops (15). Wastewater can transfer metals directly to plants and also will compile in the soil and contaminate future crops. Metals also pose a threat to the food chain because they accumulate in the soil and are absorbed by plants, which then enter the food supply (1, 15).

Runoff water is an additional factor that can contribute to chemical contamination. Irrigation sources can be polluted through various methods including rain, flooding, and anthropogenic activities (15). In the United States, organic and conventional crops must be

separated by an area known as the Buffer Zone. However, there are no standards that specify the size of the dimensions. Rather, the decision is left to the producers as literature states that buffer zones must be “sufficient to prevent contamination” (5). Thus, it is probable that Buffer Zones are ineffective. For instance, water used to irrigate conventional crops can manipulate its way to the organic section and transport chemicals that are forbidden in organic agriculture, such as pesticides (1, 15).

Arsenic is a prevalent metal that can be found naturally on the surface of the Earth. It can be present in surface water and groundwater (1). Arsenic contamination in water is a global issue. Research conducted in various countries, including: Croatia, Bangladesh, Vietnam, Argentina, India, China, USA, Mexico, Chile, Hungary, Serbia, Slovakia, Romania, and Canada has demonstrated that potable water contains concentrations of Arsenic that exceeds the recommendations, thus, posing another risk for organic crops (17).

## 3.3 Metals

Metal contamination in food is of great concern because diet accounts for a majority of human metal exposure (1). High levels of metals in the human body can result in toxic effects, including different types of cancer. There are also metals that mimic essential nutrients. This is cause for alarm because these metals can bind to receptors and prevent other nutrients from attaching. For instance, cadmium and nickel compete for the same binding locations as zinc and can then displace it (1).

Excluding occupational exposure, food is the major cause of metal exposure (1). Metals exist in the environment including in the air, bodies of water, irrigation water, and soil (1, 15). Common metals that are found in the soil include: lead (Pb), aluminum (Al), zinc (Zn), cadmium (Cd), arsenic (As), nickel (Ni), and chromium (Cr). Metals can accumulate in the soil and then are taken up by plants which enter the food chain (15).

The agrofood industry can lead to metal contamination through the application of pesticides and fertilizers (1). Although these substances are restricted in organic agriculture,

metals can still enter the food chain via environmental contamination. Cadmium, Lead, Arsenic and Mercury are metals that frequently contaminate food and are eminently potent (15).

## Cadmium

Cadmium serves no significant importance in the human body. It has various chronic consequences such as nephrotoxicity, an association with hypertension, impacts the skeletal system (i.e. osteoporosis), an increased risk for developing diabetes, and carcinogenic properties (1). Cadmium is a naturally occurring metal in the soil. Thus, food is already being exposed to this chemical, despite the method of production. Furthermore, anthropogenic activities are increasing the cadmium levels in our food. A major source of cadmium contamination is through the application of phosphate fertilizers (15).

## Lead

Another metal that has noxious consequences on human health is lead. The group that is most vulnerable is children because of their immature Blood Brain Barrier, which functions to prevent foreign substances to enter the brain, facilitates its passage (1). Research has demonstrated that it is associated with decreased cognitive development and lowered intelligence in children (1, 17). Absorption of lead also effects adults. It has been associated with an increase of blood pressure and cardiovascular disease (17) Crops are already exposed to lead because it exists in Earth's crust and traces are found naturally in the soil. Mining and smelting activities result in an increase of this metal in the environment. Also, many pipes used in plumbing contain lead, which when used in irrigation systems can be transferred to crops (1). Hence, both conventional and organic crops are subject to lead contamination.

## Arsenic

Arsenic is a carcinogen that has been linked to an elevated risk of several cancers, particularly lung, liver, kidney, skin, and bladder (1). In addition, arsenite has been demonstrated to be a cocarcinogen. Research has shown that rats exposed to arsenic have a higher incidence of

cancer provoked by the sun's ultraviolet rays (1, 26). Furthermore, arsenic has negative impacts on pregnant women and has been correlated with miscarriages. One way that it can enter the food chain is through the application of pesticides (26). However, it is also naturally found in the Earth's crust and frequently contaminates water sources, which when used for irrigation purposes, exposes both conventional and organic crops to arsenic (27).

### Mercury

Mercury is another metal of concern, specifically to the renal system as it has damaging effects (1). Other organs that mercury targets are the liver, nervous, and immune system. In addition, pregnant women and children must take additional caution to limit mercury intake. It has the capacity to cross the placenta as well as the Blood Brain Barrier (1, 21). Organic crops can easily be exposed to mercury because plants have the capacity to uptake mercury from the soil and air (1).

## 3.4 Food Fraud

Food fraud is the expression given to the premeditated alteration of food with the intention of receiving a financial gain. Acts of food fraud include: substituting ingredients, adding ingredients, altering a product, and false claims regarding a product in order to have a financial gain (4). When companies deceitfully label a product as organic, they are committing food fraud. Businesses may due this for economic gain because organic products are costlier (14). When this occurs, consumers can be exposed to pesticides or GMOs that would not be permitted in organic products.

## 3.5 Chemical Contamination Through Packaging

Food products can become contaminated through their packaging. Ortho-phthalates are generally referred to as phthalates and are a group of synthetic chemicals that are being utilized in food contact materials. A large concern is that migration of these chemicals can occur. This happens when molecules of the plasticizer pass into the food because phthalates are loosely bonded to PVC (13).

Di(2-ethylhexyl)phthalate (DEHP) and di-n-butylphthalate (DBP) are phthalates that are frequently used as plasticizers in food packaging due to being cost-effective (13). One study investigated the migration of DEHP and DBP. Plastic containers were purchased and solutions with varying acidity were tested to mimic different types of food. The samples were heated using a microwave from one to five minutes, the typical amount of time that consumers at home reported heating their foods. The samples that were heated longer suffered increased migration levels (13). Thus, phthalate contamination in food is concerning because consumers typically reheat food in plastic containers, which when exposed to heat leach phthalates. Additionally, the manufacturer of the containers alleged that the products were safe for the microwave, indicating that such claims do not necessarily mean that the products are exempt from migration of phthalates (13). Therefore, when organic products are stored and reheated in plastic containers, they are being subject to the migration of chemicals.

Phthalate contamination is of concern because there is research demonstrating that they are endocrine disruptors (13, 23). This is cause for alarm because these substances mimic hormones and create interference. For instance, they can block hormones which are vital in maintaining homeostasis of the body as well as for human development (13, 23). Endocrine disruptors have been associated with reproductive, developmental, immune, and neurological ramifications (23).

Growing concern of the health repercussions caused by phthalates have led to the increased usage of non-phthalate plasticizers (18, 40). Di-(2-ethylhexyl) terephthalate, also referred to as DEHT or DOTP, is an example created by Eastman Chemical Company and is advertised to not interfere with reproduction, unlike many phthalate plasticizers (40).

Eastman also argues that DEHT is a terephthalate which differs from ortho-phthalates because of its structure. The name suggests that DEHT is a phthalate; however, it is not. Phthalates come from phthalic acid and terephthalates come from an isomer, terephthalic acid.

Although the structures of isomers are similar, they can perform very differently. Terephthalates have a para position which allow them to be broken down into different and less potent metabolites than ortho-phthalates (40).

Lessmann et al. investigated the exposure of non-phthalate DEHT in Portuguese children. The children in the study who ingested processed foods, which are packaged unlike fresh produce, had elevated levels of DEHT metabolites (18). Thus, the results demonstrated that DEHT has migratory properties. In conclusion, food contact materials, even those that use alternative chemicals are being leached into our foods. Organic agriculture does not designate which food packaging materials must be used, thus contaminating conventional and organic crops equally (5).

## 3.6 Pesticides

Many consumers have a distorted notion of the definition of organic food. In order for products to be labeled as organic, they must follow specific agricultural practices which are intended to protect the environment and encourage biodiversity (5, 14). In 2005, the USDA's National Organic Program (NOP) defined organic as "a production system that…respond[s] to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biological diversity" (5). Thus, the definition of organic is by no means related to safety or nutrition of food (10). Also, it is commonly mistaken that organic products are superior because they do not contain harmful chemicals, particularly pesticides. However, organic farming does not prohibit the use of all pesticides. There are pesticides that have been approved for use in organic agriculture. For instance, the European Union and United States permit the application of pyrethrins and copper as pesticides. Pyrethrins are compounds that are derived from a chrysanthemum flower and are potent to insects (7). They are used in organic agriculture as an alternative to organophosphate pesticides (19). Although derived from a natural source, they can still have side effects in humans, including: worsening of asthma symptoms, headache, nausea, tingling of extremities, and additional nervous system complications (7). Despite the fact that copper is an essential

nutrient for humans, in high concentrations it has toxic ramifications. Copper containing pesticides are used as fungicides. Side effects of these substances include: vomiting, nausea, and damage of the kidneys and liver (6).

Furthermore, in the United States, The National List of Allowed and Prohibited Substances dictates which substances are permitted and which are forbidden in organic production. Pesticides that are acceptable can be found in this document (14, 37).

A benefit of organic farming, however, is that pesticide usage is constrained (5, 14). Consequently, there are decreased residue levels of pesticides compared to conventional food production. Furthermore, such restraints also limit occupational exposure (1, 8). Research has illustrated that consuming organic products decreases pesticide exposure. Lu et. al conducted a study that investigated the impact that conventional foods had on pesticide exposure. Twenty-three elementary school students underwent three phases: days one to three, they were exposed to a conventional diet, days four to eight, an organic diet, and days nine to fifteen, they resumed a conventional diet. During phases one and three, the children were significantly excreting higher amounts of urinary metabolites of organophosphorus pesticides (19). Hence, the data shows that diet is a significant element in pesticide exposure. However, limitations of the study include a small research group. A larger study would have minimized error. Other factors could have skewed the results, such as exposure to application of pesticides at home. Thus, having more subjects would offset such aspects.

Organophosphate pesticides, OP's, are frequently applied to crops in the United States as insecticides to ward off insects that are harmful to crops (19). An American study used 4,466 participants to compare the exposure of organophosphate pesticides. Organophosphate pesticides are metabolized into dialkyl phosphate byproducts. Consequently, these metabolites can be measured to indicate exposure to organophosphate pesticides. Questionnaires were completed to determine the subjects' exposure to organic foods and data was then gathered on alkyl phosphate metabolites. The results indicated that those who reported organic foods had lower levels of dialkyl phosphate and thus were less exposed to organophosphate pesticides. Organophosphate pesticides are of concern because they have demonstrated neurological effects in studies performed not only in animals but also humans. In addition, diet is the main source of exposure (19). A limitation of the study, however, was relying on the questionnaire to determine the

subject groups. This leaves room for error because the participants could have inaccurately answered the questions. For instance, individuals could have falsely reported consuming organic foods. Also, the quantity of organic food was not monitored.

Research published by EFSA has also demonstrated that conventional products are more likely to contain pesticides. Data from the last available five years has shown that each year, organic products are more likely to contain pesticide residue concentrations below a measurable amount (Figures 3.1 and 3.2) (32-36). For instance, in 2016, 50.7% of conventional products had pesticide residue levels below LOQ compared to 83.1% of organic foods (36). The research also validates that organic products, despite a lower amount, can also contain vestiges of pesticides (32-36).

However, in accordance with EFSA's Pesticide Residue Report, in recent years pesticide residues on organic food has been on the rise (Figures 3.1 and 3.2) (32-36). In 2014, 86.4% of sampled foods contained residue levels below LOQ (34). In 2015, 85.8% had residues inferior to LOQ and in 2016 81.3% (35, 36). Thus, in recent years, less foods are being found to have limits below the LOQ indicating that pesticide exposure is rising among organic products (34-36).

**Table 3.1**

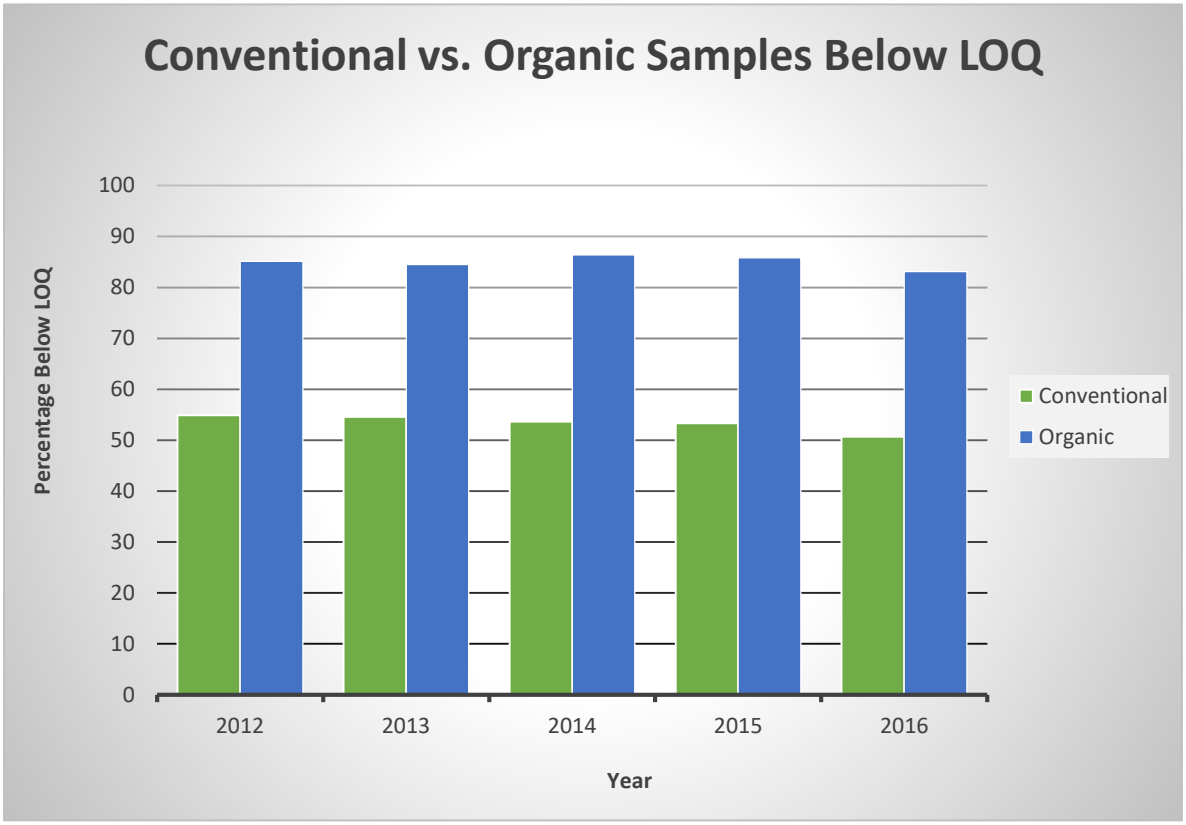
Conventional vs. Organic Samples Below LOQ in the European Union

| **Conventional vs. Organic Samples Below LOQ in European Union** | | |
|---|---|---|
| **Year** | Conventional | Organic |
| **2012** | 54.9% | 85.1% |
| **2013** | 54.6% | 84.5% |
| **2014** | 53.6% | 86.4% |
| **2015** | 53.3% | 85.8% |
| **2016** | 50.7% | 83.1% |

(33-37)

**Figure 3.1**

Conventional vs. Organic Samples Below LOQ in the European Union




(33-37)

Impact of Pesticides on Human Health

There have been studies that demonstrate that pesticides can negatively impact human health (19). However, pesticides are regulated globally. Governing bodies indicate safe levels of pesticides. In the European Union, there are three bodies that assist in assessing pesticides: EFSA, the European Commission, and Member States (28). Prior to industries applying new pesticides, the substances must first pass through a rigorous sequence of steps involving these three partners before the substance is approved. The enterprise seeking approval must first complete an application of the active substance and submit scientific documents as supporting evidence to a Member State. Once the Member State has reviewed the request, the items are forwarded to EFSA which then peer reviews the assessment of the Member State. The European Commission and Member States analyze

EFSA's conclusions and dictate if the active substance will be authorized or not. If the active substance is approved, the company then applies to use the pesticide that contains the active substance on the market. The Member State analyzes the request and suggests a maximum residue level, or MRL, which is established for pesticides to dictate the highest concentration that is permitted in food to prevent adverse effects (12). Therefore, pesticide exposure does not indicate that humans will demonstrate toxicity because they must be exposed to unsafe amounts. If the MRL coincides with current legislation the request then passes to the European Commission. If it does not, EFSA will analyze the suggested MRL and forward their outlook to the European Commission who determines whether the proposal of the MRL will be accepted or rejected (29-37).

Within the European Union, MRL's are established by Regulation (EC) No 396/2005. Since this statute is a regulation, it is directly applicable to all member states whereas with a directive, member states have more freedom in regards to the legislation because they transpose the law in a way that meets the objectives. Thus, within the European Union, pesticide residue levels are standardized (37).

Furthermore, pesticides are continuously being monitored. Member States of the European Union must supervise pesticide application to ensure that standards are being met, such as that they are being applied to specified crops and that application does not exceed standardized limits. In addition, all Member States participate in two annual programs that focus on pesticide residue levels. EFSA also publishes a yearly report regarding residue levels in food (29-37). On the document, can be found the percentage of food that adheres to legal limits. In 2016, 84,657 samples were collected. The findings indicated that 96.2% complied with legal standards. Furthermore, 50.7% had levels inferior to the LOQ (37).

In the United States, the USDA yearly publishes the Pesticide Data Program (PDP). In 2016, the report indicated that 99.5% of food samples complied with residue standards (5). In addition, pesticide residue levels are continuously being monitored. Testing is conducted during the year and results are sent each month to the FDA and EPA (5). Thus, in the event that pesticide residue levels were reaching unsafe amounts, the agencies could act immediately.

According to the data collected by EFSA, within the last ten years, the majority of crops have complied with legal standards (28-36). The results ranged from 96.0% to 98.3% (Figures 3.3 and 3.4). Therefore, hazardous concentrations of pesticide residues on conventional crops is

not of large concern. Consequently, this diminishes the argument that organic products are superior on the premise that they contain inferior amounts of pesticides because the contamination of pesticides is not a significant danger to begin with.

**Table 3.2**

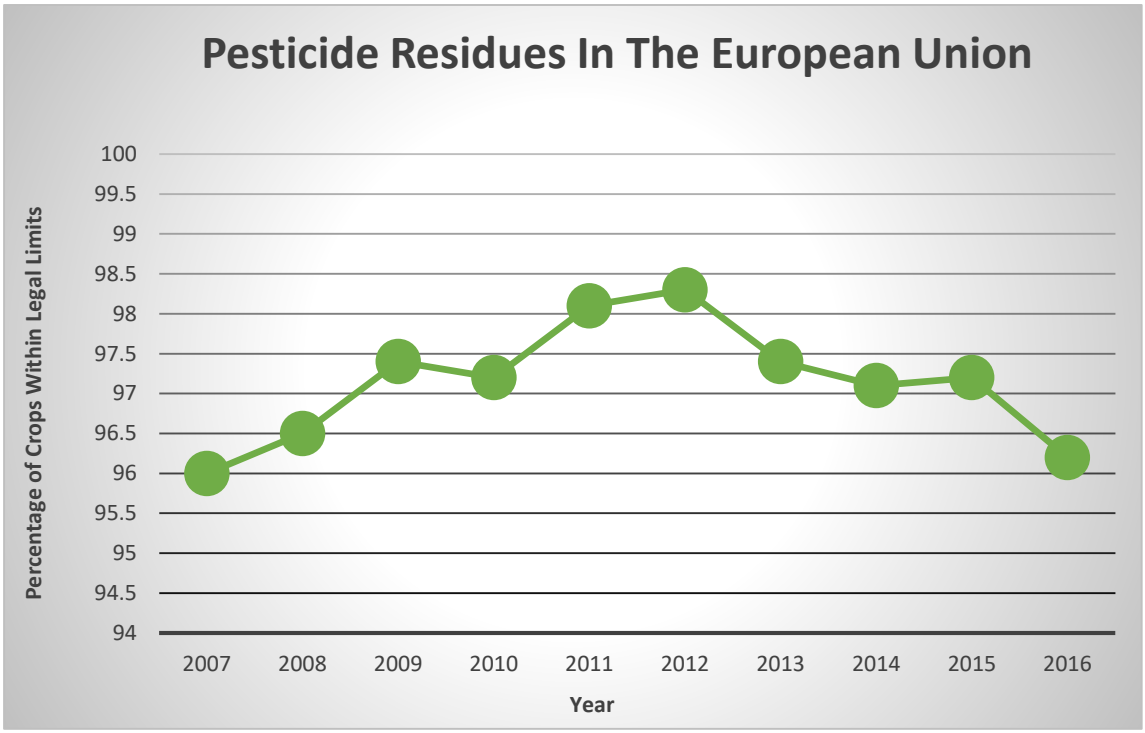
Pesticide Residues in the European Union

| **Pesticide Residues in the European Union** | |
|---|---|
| **Year** | Percentage Within Legal Limits |
| **2007** | 96.0% |
| **2008** | 96.5% |
| **2009** | 97.4% |
| **2010** | 97.2% |
| **2011** | 98.1% |
| **2012** | 98.3% |
| **2013** | 97.4% |
| **2014** | 97.1% |
| **2015** | 97.2% |
| **2016** | 96.2% |

(29-37)

**Figure 3.2**

Pesticide Residues in the European Union




(29-37)

## 3.7 Genetically Modified Organisms

Genetically modified organisms, GMOs, are prohibited in organic products (5). By definition, they are organisms that have had their genes modified. Genes can be modified to improve the quality of products, such as a longer shelf life (25). This makes it easier to distribute food to other parts of the world that lack food security and allows these populations to store food for longer periods of time (18). Also, GMOs can be utilized to produce a more nutritious product, for instance, the supplementation of vitamins (39). These foods can also be used to improve food security by distributing them to locations with inadequate nutrition. Food security is a rising concern. The escalating global population requires higher food production and urbanization is replacing farmlands. Each year, a large percentage of crops are lost to pests. Genes can be altered to create crops that are resistant to such nuisances. By 2050, the world

population is anticipated to increase to between nine and ten billion people. Former US Secretary of Agriculture, Earl Butz, once stated, “Before we go back to organic agriculture in this country, somebody must decide which 50 million Americans we are going to let starve or go hungry” (24). As a result of GMO crops, farmers will have elevated yields. Not only is it more profitable for farmers, but greater harvests are beneficial to a country’s economy because excess crops can be exported (25).

In addition, the use of GMOs eliminates the need for fertilizers, which are harmful to the environment (25). They contain toxins, such as metals (i.e. arsenic and mercury) which accumulate in the environment and enter the food supply. Consequently, humans ingest these substances and it can lead to toxic effects (1). Diminishing the need for fertilizers also benefits employees who would no longer be exposed to these chemicals (25).

Arguments against genetically modifying foods include fears that altering DNA can result in unintentional nutritional changes. Inserting genes can result in the coding of new proteins which may interfere with other substances in food. For instance, contaminants and allergens may be produced. Also, introducing new genes can cause mutations which can disable or modify the expression of naturally occurring genes (25).

Many opponents of GMOs argue that altering food is unnatural and causes adverse effects in humans (20). However, just because something is natural does not indicate that it is benign. An example of this is cyanogenic glycosides, which are naturally occurring in many plants and fruit seeds such as apple seeds. When hydrolyzed, they produce a highly potent chemical known as hydrogen cyanide (22).

In recent years, the question of whether or not foods produced using GMOs such be labeled has been raised. Adding such a distinction provides consumers with the impression that these products are inferior to Non-GMO foods. For instance, on July 29, 2016, the United States Senate adopted legislation that would require products to declare that they used GMOs (labeling can also be done using a barcode that would lead to an electronic link) (25).

## 3.8 Organic Consumers Versus Conventional Consumers

There are studies that demonstrate superior health benefits in consumers who opt to purchase organic foods (2, 3). However, there are other factors that can contribute to improved health. Bénard et. al investigated the behavioral differences between consumers who purchase organic foods compared to those who select conventional foods. Questionnaires were distributed to thousands of participants to determine the Consideration of Future Consequences, CFC, which is a measure of the degree that people consider future events result from current behaviors. The participants with a higher CFC were more likely to consume organic foods. Thus, it can be inferred that consumers who chose to buy organic options tend to be more health conscious and are therefore, more likely to engage in other healthful activities, such as consuming more fruits and vegetables or exercising (2). Consequently, their health status could result from other lifestyle choices.

In another study, participants who claimed that they frequently consumed organic foods had healthier lifestyle factors. For instance, it was more probable that they regularly engaged in physical activity, it was less likely that they smoked, and they consumed less processed or red meats (3).

Frequently, consumers that favor organic products chose this lifestyle because they believe that the restriction of chemicals in their products offer healthier and safer foods (14). However, studies demonstrate contradictory results. Bradbury et. al investigated organic food as a tactic for reducing the risk of cancer. The premise was that occupational exposure to pesticides was linked to a higher incidence of cancer. The research included 623,080 participants who self-reported their intake of organic foods. They were followed throughout 9.3 years to determine if they developed any type of cancer. The results indicated that there was no significant difference between the prevalence of cancer among the two groups with the exception of Non-Hodgkin Lymphoma (3). Thus, it can be inferred that conventional products contain limits below what would cause carcinogenic effects. Like any chemicals, there is a limit that a person must be exposed to in order for toxicity to occur (3). However, there was room for error. For instance, the participants could have developed cancer once the study was concluded. In addition, another study conducted regarding organic foods and cancer also demonstrated that organic foods may

decrease the risk of Non-Hodgkin Lymphoma (2). Research in this area is still lacking, but it should be further studied to validate if there is any connection.

Furthermore, consumers who purchase organic products often select this option because they have a notion that it is more nutritious (14). Ironically, genetically modifying food, which is not permitted in organic production, can actually increase the nutrition of foods (28). Beneficial substances can be added to foods, such as vitamins. An example of this is Golden Rice, which is the name attributed to rice that is genetically modified to increase the content of beta-carotene, which is a predecessor to vitamin A. It can be lifesaving to areas that suffer from vitamin A deficiency, which is a major cause of childhood blindness in third world countries (39).

Lastly, consumers that favor organic products tend to consume more fruits and vegetables compared to those who purchase conventional foods. This is a factor which has been associated with longevity (2).

## 4. Conclusions

There are various factors that can lead to chemical contamination of food that are not influenced by the methods of production. For instance, pollution plays a large role. Over time, industrialization has exponentially been depositing pollutants into the environment. Chemicals that are leached into the air can make their way into the soil and contaminate water sources. Also, as fresh bodies of water are becoming limited, some areas of the world have had to rely on waste water to irrigate crops.

Additionally, food packaging is a step after production which can lead to the chemical contamination of products. Research has demonstrated that food contact materials contain chemicals that can leach into food. Although in recent years, studies have been conducted to determine the safety of food contact materials, recent research has demonstrated that alternatives can also contaminate foods.

The use of genetically modified organisms is forbidden in organic agriculture. However, it provides various benefits. In the long run, conventional farming may have a superior impact on

the environment. Organic farming has an inferior crop yield and consequently, more land is necessary to produce the same amount of crops. Genetically modifying foods is a tactic that can be used to combat world hunger. Genes of foods can be modified to create more resistant crops. Consequently, less will be lost to environmental factors, such as wind and rain. Also, foods can be altered to increase shelf life. This can facilitate the transportation of products to countries around the globe with inadequate nutrition. Fruits and vegetables for example are vital components of a diet because they contain various vitamins and minerals. They are also extremely perishable, thus, facilitating distribution can assist in these areas with inadequate nutrition. Those in favor of organic products may argue that chemicals found in pesticides have potential negative impacts on human health, however, vitamin deficiencies and starvation can have a direct impact on humans, such as death.

Although there are studies that indicate that organic products have superior health advantages, the study design should be considered when determining the validity of the research. For instance, dosages used in the studies should be taken into account. Often, higher doses of pesticides are used which is unrealistic when comparing the amount of pesticides that foods contain. Although pesticides can have toxic effects, toxicity occurs after the exposure of a certain concentration.

The major difference among organic and conventional products is that organic products contain less pesticides. Thus, consumers who favor organic products are exposed to less amounts of pesticides. However, pesticides in conventional products are regulated. These chemicals undergo thorough assessment. Among such testing, are trials conducted on animals. Maximum residue levels, or MRL's, are established for pesticides which dictate the highest concentrations that are permitted in food that have been treated with pesticides. In the United States, the Environmental Protection Agency (EPA) regulates pesticides and evaluates whether or not they are safe to be used. Also, the Food and Drug Administration (FDA) has imposed limits in regards to the levels of pesticide residue that is permitted on vegetation. Like any chemical, humans must be exposed to a certain amount in order for toxicity to occur. Thus, exposure to pesticides does not indicate that humans will demonstrate adverse effects.

While searching for publications, it was evident that there is significantly more data on biological contamination compared to chemical contamination. Thus, in order to draw a more

conclusive argument, further studies need to be conducted that focus on chemical contamination or organic products. However, the results indicate that there is little difference between the risk of chemical contamination of organic products compared to conventional foods.

## 5. Future Research

One flaw of the research was that the samples gathered by EFSA included conventional and organic products. Considering that organic products have restricted exposure to pesticides, these products likely skewed the data. The percentage of crops that fell within legal limits was likely increased by organic products. However, the majority of the samples consisted of a small percentage of organic products. For example, in 2016, 6.5% of the data was retrieved from organic sources and in 2015, 6.4% (35, 36). Future studies should include research that contain only conventional products to gather a certain percentage that pertains specifically to them.

There are two studies that show a possible correlation between the consumption of organic products and a decreased risk of Non-Hodgkin Lymphoma (2, 3). Thus, more studies should be conducted to explore this correlation. However, many factors need to be considered when selecting the study group because there are many lifestyle factors that can increase the occurrence of cancer, such as smoking.

Furthermore, more studies should be conducted to investigate the impact that organic products have on human health. The organic industry is still a fairly new trend and we are still unable to determine the effects that these products have on humans. For instance, in the United States, the Organic Foods Production Act (OFPA) was only passed in 1990 which defined the standards for products to gain an organic certification (5). Thus, more studies should be conducted that follow the subjects for longer periods of time. For instance, in the study Bradbury et. al, the group was only followed for approximately nine years (3). Thus, it is possible that the subjects developed cancer later on in life.

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