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Is Organic Food More Nutritious?

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Organically grown food has the notion that it is healthier than its conventionally grown counterparts. There is substantial research that has been done on the effects of pesticides on produce and how these foreign chemicals have negative effects on the environment and the people consuming these chemicals. While this is a known fact, the big question is if organic food is more *nutritious* than its conventional counter parts. There is minimal research on the actual nutritional quality of organically grown produce versus conventionally grown produce. Various studies have looked at vitamins, minerals and antioxidants. There are many discrepancies among the studies looking at nutritional quality, as they did not all measure the same nutrients or use the same variables. The produce examined included the following: pistachios, chickpeas, oranges, strawberries, potatoes, tomatoes, cucumbers and onions. There were few studies that had overlaps among the nutrients that were measured. Even among the discrepancies, some conclusions can be drawn with regards to nutritional quality but a better evaluation of choosing to "go organic" should be based on a multitude of factors including time of life, the environmental concerns and income considerations. More research on nutritional quality would need to be completed for a more accurate conclusion to be drawn with regards to which type of farming produces the most nutritional fruits and vegetables. At this point in time, the decision to eat organic produce should be based on the pesticide usage.

Keywords and phrases: organic, conventional, organically grown food, nutrition,

pesticides

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Introduction

All around the world a surge toward organically grown foods has taken over marketplaces, farms, and family homes. Despite the popularity of organic, there are ongoing, conflicting arguments for and against the believed benefits of organically grown foods. Some believe there is no difference between organically grown food and its conventional counterpart, while others claim that converting to organic products is the healthier option. Still, the term ‘organic’ has become an attractive term that many consumers are drawn to within the marketplace, despite the higher cost. Perhaps the assumption that organic is better is simply a result of good advertising and somewhere along the way a minuscule success story was magnified to a massive success story.

There is considerable nutrition-related disparity within the United States: approximately 30 percent of the population is clinically obese, yet on the flip side, there are also a substantial number of individuals who are arguably nutrition and fitness obsessed. This clear divide has resulted in an overwhelming number of products and programs, each claiming to be the most successful in helping individuals discover their healthiest self. Understandably, a consumer may be left dumfounded within the marketplace not knowing what to do, what to buy, or fundamentally what guidelines to live by. In recent years, the push toward “organic” has been added to the mix of products and recommendations for healthy eating, and food selection has become more confusing than ever.

What is organic food?

Organic can be an abstract concept that many individuals do not completely understand. Some people simply use the term organic as a synonym for healthy, while others think the term relates only to the pesticides used on crops. The term first coined to refer to the farming method has now reached topics from environmental health to consumer health whether that is through what chemicals are used, how the land is prepared and taken care of, or how the food is eventually processed. In its most basic sense, organically produced food is produced in a way that is most natural to the environment, avoiding or limiting the use of unnatural methods of maintaining these products.

While the original intent of organic farming was to produce foods in a more environmentally friendly manner, there are inconsistencies among farming methods, such as certain chemicals being accepted or denied in the production of organic food, as well as what methods are used world-wide. In the United States, the USDA regulates the use of the term "organic," and for the purpose of this paper, the USDA definition will be applied. The USDA has established a set of regulations with regards to the make-up of the land being farmed, the methods of farming, as well as the handling of the resulting products. Synthetic products may still be used; however, they are unfavorable and only allowed when necessary, and thus highly regulated (USDA National Organic Program, 2015).

When determining what can be considered organic, there are three distinct standards: crop standards, livestock and poultry standards, and handling standards. Organically grow crops, in adherence with the USDA certified organic standards, are managed

through five different guidelines-soil fertility, seeds and planting stock, crop rotation, managing unwanted foreign bodies, and preventing cross contamination with conventionally grown food. Organic farmers must grow crops on approved soil that does not contain chemicals or substances that would not be naturally found in nature. The seeds used to grow crops should be organic, i.e. produced from organically grown food for which genetics have not been modified. Crop rotation is an important practice implemented to prevent disease and reduce the amount of insects by planting different families of crops in the same spot in subsequent years. Restriction to pesticides, insecticides, and weed management are what make organic farming difficult, as weeds and insects can be difficult to manage naturally. In addition to these, certain chemicals may need to be used to prevent diseases; therefore, when it is necessary, the use of chemicals is acceptable, but again, farmers and producers must strictly adhere to USDA regulations. Finally, when handling the final product, organically grown food should be kept separate from conventionally grown food to prevent cross contamination of chemicals used in non-organic farming, due to the differing farming methods (National Organic Program, 2016).

Ideally, organic produce is a product that is essentially sold "as is", in its farmed form, for example an apple remaining unaltered once picked from a tree. However, many organically grown products are processed for packaging purposes or for use in multi-ingredient products. When products are processed, the labeling must be consistent with the contents as determined by the overall proportion of organic product within a package. In order to use the label "USDA certified organic," the final product must have at least 95 percent organic contents. If a product's label states it is "made with organic ingredients,"

it must contain at least 70 percent organic contents. While all the agricultural ingredients must be organically grown, nonagricultural ingredients do not have to meet organic guidelines because there is no standard for producing them (National Organic Program, 2016). Nonagricultural ingredients include minerals, bacterial cultures, and enzymes. These do not have the same guidelines as agriculturally grown ingredients because agricultural ingredients are often those grown through farming, whereas these substances are created through non-farming methods. Gelatin, guargum, and cornstarch are examples of agricultural ingredients that would have to be organically grown due to the base of the products being produced through farming, for example corn starch is made from corn.

Environmental benefits of "organic"

Creating an environmentally friendly approach to organic farming compared to conventional farming has demonstrated clear results with regards to pesticides, insecticides and other chemicals used, as well as the effect they have on both environmental health and human health. It has been noted that only 0.1 percent of all pesticides used are actually effective in preventing pests from destroying crops, while the other 99.9 percent essentially play no role in pest prevention. This ultimately introduces the pesticides to the environment and atmosphere without serving any beneficial purpose (Crinnion, 2010).

The preparation for transition to organic farming may take years to allow the soil to rid itself of chemicals previously used through conventional farming methods. With this in mind, even with implementation of organic farming methods, produce (and other products) may still be exposed to chemicals within the soil. The amount of exposure would be related to the number and types of chemicals and the known half-life of the

chemicals as they breakdown or dissipate. Chemicals may be present in the soil from years past or from the movement of chemicals throughout the environment. With regards to insecticides being found on crops, 82 percent of conventionally grown produce have been found to have insecticide residue, whereas only 23 percent of organically grown food have been found to have insecticide residue (Crinnion, 2010).

Chemicals used in farming can negatively affect the surrounding environment by being consumed by the animals and absorbed by foliage around the area being farmed. The environment is an interconnected web and once an organism is affected by a foreign factor, such as the runoff of pesticides and insecticides used in farming, the entire environment is effected, either directly or indirectly. These chemicals increase the toxicity found within various environments which in turn impact the organism's function. All the organisms and living things in an area create an ecosystem, and once the flow of that ecosystem is disrupted, the entire ecosystem begins to change, which can be particularly detrimental considering these changes would be unnatural due to these foreign substances being used in conventional farming (Carlile, 2006). All the various aspects of the environment that are even minimally connected to that organism will be affected, whether it is the habitat, prey or predators. Biodiversity has decreased over the years as a result of increased pesticide use. Most affected are the microorganisms and algae that, while often overlooked, play an important role in maintaining ecosystems everywhere, particularly aquatic ecosystems. Not only do these microorganisms play an important role in food webs as primary producers, they also help with decomposition and nutrient cycling. If these microorganisms change, the entire ecosystem changes, in essence creating a snowball effect where, with regards to food webs, changes among

microorganisms may affect their predators which will then affect that predator's predators and so on. As can be seen, all species are intertwined in various ways, with food webs only being one example.

Pesticides and the body

As previously mentioned, research on pesticides has produced some answers with regards to their effect on environment and consumer health. In order to look at the effects chemicals have on the human body, researchers must be assured that the chemicals are in fact being incorporated into the body. One way of doing this has been to analyze the urine of individuals on various diets to determine if the chemicals are still present after traveling through body systems.

A particular study looked at pesticide contents in the urine of individuals consuming foods from both organic and conventional farming methods. Bradman executed this study by creating a diet plan for children in various households that included eating meals with conventionally grown produce for a certain number of days and a separate group of children who consumed a diet of organically grown produce. The findings of this study revealed that certain harmful pesticides found in the urine from eating conventionally grown food were absent in urine collect from the same children after consuming predominantly organic diet (Bradman et. Al, 2015). This along with other studies focusing on pesticide contents in urine show how the body receives, processes, and retains these chemicals as they are introduced through skin, respiration and ingestion (Bradman et. Al, 2015).

Around the world, there are varying degrees and numbers of acute pesticide poisonings, ranging from 2,000 to 30,000 per year (Jeyaratnam, 1990). Often those poisoned are agricultural workers due to the handling and processing of the product. The more industrialized a country is, the lower the number of acute poisonings are seen, which understandably, explains why the United States has one of the lowest rates, especially when compared to countries such as Indonesia (Jeyaratnam, 1990). Once these chemicals are inside the body, they are eventually dispelled through processes like urination, but they travel through the entire body system and interact with cells throughout the body as the cells carry out their primary functions.

While it cannot be directly stated that pesticides and other chemicals used in agriculture cause cancer, a correlation has been recognized between those with higher exposure to specific pesticides and rates of cancer. Many different pesticides have been correlated with various cancers. Diazinon is an example of a pesticide that has been linked particularly to lung cancer and leukemia (Weichenthal, 2010). With regards to the effect of the chemicals used in conventional farming that are not used in organic farming, data support that conventional farming can be harmful to both the environment and the individuals consuming those products.

Ultimately research on pesticides has clearly demonstrated the divide between organically and conventionally grown food. However, there are various aspects beyond pesticides that must be considered when determining if something is "healthy." A multitude of foods, when consumed with each other, can produce a healthy diet; however, 'healthy' is an abstract word that does not pinpoint *what* the reasoning behind health is: is it the nutrients (i.e. vitamins and minerals)? is it the fact that it is not genetically

modified? is it the degree of processing? or could it be all these things? As for the 'healthiness' of organic food, one should look beyond the data on pesticides.

Less is known about the effects of organic farming practices on the nutritional quality of various consumer goods, when compared to conventionally grown products. While the use of chemicals has been linked to possible alterations in the body from ingesting these chemicals, the impact of organic farming practices on the nutrient content of foods is less clear. The chemical content has been analyzed in the past, therefore, the purpose of this paper is to explore a nutritional realm of organic food, specifically the nutrient composition of organically grown produce. The intent is to answer the question: Is the produce of organic farming more nutrient dense than produce of conventional farming?

What about the Nutrients?

Fruits and vegetables are made up of macronutrient and micronutrient compounds, such as carbohydrates, vitamins, and minerals. A nutrient is a chemical needed for maintaining proper bodily functioning. Micronutrients are a subcategory that can then be broken down into vitamins and minerals, and several vitamins and minerals can be classified as antioxidants. Vitamins are important to help regulate various processes, such as aiding in growth and development (vitamin A) and amino acid metabolism (vitamin C). Vitamins can again be broken down into various categories, but this paper will not delve into those aspects (Schiff, 2015).

Minerals are natural elements found in rocks, sediment or water sources. There are about 15 different minerals known to play a vital role in the physiology of the body. Minerals are important for structural aspects of essential substances for bodily

functioning, such as developing and maintaining bone density, and producing enzymes and hormones. Minerals cannot be destroyed but can be manipulated by dissociating them in water to utilize their ion form, known as electrolytes. Important electrolytes are sodium, calcium, and potassium, which, for example, are critical to action potentials in neurons and therefore the function of the nervous system (Schiff, 2015).

Lastly, antioxidants play a critical role in protecting the body from harmful molecules within the body. Antioxidants, such as vitamins C and E and beta-carotene, are used in stabilizing free radicals in the body. Free radicals are unstable chemicals that take electrons from compounds to stabilize themselves. Antioxidants prevent this from happening. They take electrons from such compounds as fats or proteins, leading to instability throughout the body system. Research has connected this instability of free radicals to heart attacks, strokes and even Alzheimer's disease. By stabilizing free radicals, antioxidants can potentially prevent or slow down this process of degradation in the body and act as a sort of shield for important molecules in the body (Schiff, 2015).

Produce analysis

The previously discussed data about pesticides may provide an easy answer to "is organic food better?" However, what about the nutritional quality of that produce? Pesticides affect the consumers, the producers, and essentially anyone involved in the process of planting, growing, processing, selling and consuming the product. Holistically, there are not any studies that have comprehensively evaluated all produce, all over the world, and compared the organic and conventional counterparts for nutrient amounts. Studies have analyzed nutrient aspects of produce such as chickpeas, pistachios, strawberries, cucumbers and a few others. Across this relatively limited body of research,

nutrient measurement has not been consistent. Among the research conducted on produce, some discussed vitamins and minerals, such as vitamin C and potassium, whereas other studies only discussed antioxidant levels. While challenging, the comparison of nutrient levels among previously completed studies offers some overlap among results and allows for a few assumptions to be made with regards to nutrient levels in other produce with similar composition.

Legumes and nuts

Akbaba and colleagues evaluated chickpeas grown under both conventional and organic farming methods, analyzing the product using a wavelength disperse x-ray fluorescence (WDXRF), with a focus on the nutrient content. The chickpeas used were harvested in the same season and the same region, but were produced on different farms. The statistical analysis of the study revealed that levels of some nutrients varied by farming method, while other nutrients levels showed no difference. Twenty-two different elements were measured, with seven showing varying results. The following were more abundant in organically grown chickpeas: calcium (Ca), iron (Fe), phosphorus (P), chlorine (Cl), potassium (K), and sodium (Na). On the contrary, conventional farmed chickpeas were found to have higher amounts of aluminum (Al), nickel (Ni), chromium (Cr), and stannum (Sn) (Akbaba, 2012).

The same study was repeated, using WDXRF and statistical analysis on pistachios. This study measured 27 different nutrients and found higher levels of calcium, iron, manganese (Mn), phosphorous, magnesium, chlorine, sodium in organically grown pistachios. Aluminum was found to be lower in the organically farmed product, whereas

higher amounts of gold (Au) and strontium (Sr) were found in conventionally farmed products (Akbaba, 2012).

Fruits and vegetables

Nutritional differences have been seen in chickpeas and pistachios, as well as in select produce, including oranges, strawberries, and potatoes. While Akbaba et al. (2012) looked at the mineral content of pistachios and chickpeas, antioxidant levels were the focus in Tarrozi's (2005) study of blood oranges. Both organically grown and conventionally grown blood oranges were analyzed and the results showed a higher content of phenolic and ascorbic acid (vitamin C) in the organically grown oranges. The oranges came from the same retail outlet where organically and conventionally grown fruits were processed separately (Tarrozi, 2005).

On the other hand, strawberries produced on both organic and conventional farms in California produced differing results. With regards to minerals, phosphorous and potassium were found to be more prevalent in conventionally grown strawberries; however, with regards to antioxidants, higher levels of ascorbic acid and phenolics were seen in organically grown strawberries (Reganold, 2010).

A study comparing the two different farming methods for red potatoes found that conventionally grown products showed a higher content of sodium and iron and the organically grown counterparts had higher content of copper and magnesium. Other minerals tested, such as zinc and calcium, showed little to no difference when comparing the products (Griffiths, 2012). The study done on potatoes did state however that in order to see a truly beneficial outcome to eating the organic counterpart with the intent that the

individual will receive more of a particular nutrient, a mass, ultimately unrealistic, amount of potatoes would have to be consumed.

The examination of tomatoes' nutrient and mineral content revealed that organically farmed tomatoes had lower levels of ascorbic acid and phenolics. This study, conducted by Barrett and colleagues (2007), particularly focused on soil maintenance and soil content and will be discussed later. With regards to the farming of cucumbers, higher antioxidant levels were seen in those that were organically farmed versus those conventionally farmed (Santiago-Lopez, 2016). As with the analysis of tomatoes by Barrett (2007), the analysis of cucumbers, conducted by Santiago-Lopez et. al (2016) respectively, the soil and external treatment of the growing product was highly analyzed and will, again, be discussed later (Barrett, 2007). Finally, onions will be the last item discussed in this paper. Again, this study specifically looked at the actual farming and soil treatment in addition to nutrient contents. As was seen among tomatoes and cucumbers, the organically farmed onions contained higher levels of antioxidants (Ren, 2017).

Most of the studies measuring nutrients in produce attempted to control or eliminate discrepancies by either choosing organic and conventional produce grown under essentially the same conditions, such as in greenhouses or used guidelines that only pertained to produce grown in similar regions or on the same/similar farms. Still, comparison of the results is difficult. While the internal validity of the studies may have been maintained, external comparisons presented more difficulty due to different variables that can be applied to the environment or the chemicals used in both types of

farming. Table 1 presents the data from the previously discussed studies, summarizing the specific nutrients and results based on the analyses of each produce item.

Table 1. Nutrients found in organic versus conventionally grown produce.

	Chickpea (Akbaba, 2012)	**Pistachio** (Akbaba, 2012)	**Oranges** (Tarozzi, 2006)	**Strawberries** (Reganold, 2012)	**Potatoes** (Griffiths, 2012)	**Tomatoes** (Barrett, 2007)	**Cucumber** (Santiago-Lopez, 2016)	**Onion** (Ren, 2017)
Al		C						
Au		C						
Al	C							
Ca	O	O						
Cl	O	O						
Cr	C							
Cu					O			
Fe	O	O			C			
K	O	O		C				
P	O	O		C				
Mg		O			O			
Mn		O						
Na	O	O			C			
Ni	C							
Sn	C							
Sr		C						
Antioxidants			O	O		C	O	O
Vitamin C			C	O		C		

External Characteristics of Produce

In relation to pesticides, it is important to consider how they can be incorporated into the fruit as they grow. Anyone who has eaten fruits or vegetables knows that the external 'layer' of produce can have different textures and characteristics, such as being fleshy, or having a softer, more easily punctured covering, having a rind, or a thick membrane that is typically removed to reveal the fruit or vegetable beneath, and there are also fruits and vegetables that may have a membrane as the outer layer but is not typically removed to consume the fruit, among other types of layers that may encompass various fruits and vegetables. Many people wash or rinse their produce before consuming it, believing that this rinses any residue left from any chemicals used on the product during the growth, but that is not always true. Strawberries are a 'fleshy' fruit that do not have a peel and are not manipulated by removing any part of the fruit (excluding the stem and leaves of strawberries) to consume the fruit. Due to this fleshy characteristic, strawberries absorb the products around them as they grow and are incorporated into the fruit, meaning, you essentially cannot rid the fruit of the chemicals that may have been placed on that fruit. Peaches are similar to strawberries in that they have more of a fleshy outside; this characteristic could also be considered to include raspberries, blackberries, and blueberries. Potatoes would most likely be grouped with strawberries, as they are more of a fleshy food and the outer skin layer is very thin and permeable, making it more susceptible to absorb the chemicals used on the product during growth.

Oranges are peeled and the outer layer is most often times removed before consumption, similar to a banana. This would most likely increase the possibility of removal of pesticides before consumption because the layer that the chemicals are

directly applied to is typically removed. Tomatoes and cucumbers have an outer layer that is less permeable than that of a potato or berry fruit; because of this property, they are less likely to absorb pesticides, but more likely to have chemical residues on them when consumed compared to an orange or banana because there is not a distinct membrane removed. Finally, nut-like products, such as chickpeas and pistachios are often found in a shell, and most often, shells are not consumed with regards to nuts, and this sometimes pertains to peas. This hard, outer layer most likely decreases the amount of pesticides consumed when consuming the nut or pea.

The Dirty Dozen

The so-called 'Dirty Dozen' is a list many have heard of created by the Environmental Working Group (EWG) (Lunder, 2018). The EWG essentially created a list ranking the worst types of produce to eat based on pesticide amounts. Looking at the so called "dirty dozen," there are many overlaps among the EWG conclusions and the conclusions discussed in this paper. Per the EWG, strawberries top the list as one of the most heavily saturated produce with pesticide and chemical levels. Strawberries seem to be a more difficult specimen in reducing the amount of pesticides, as they are more likely to carry various diseases and quickly absorb the chemicals used on them as they grow. In fact, high levels of pesticide residues have been found on more than 60% of strawberries (Kovacova, 2013). Because of their fleshy property, they are more likely to incorporate the chemicals placed on them as they grow, which may relate to them being placed as the number one fruit on the well-known dirt-dozen list. Potatoes also appear on the dirty dozen list, and as discussed before may be due to the semi-fleshy texture of the outer membrane of the produce.

With regards to comparing the studies done on potatoes and strawberries, there are essentially no overlaps due to the fact that the studies did not examine the products for the same nutrient contents. In the case of these two products, the choice to eat organic or conventional counterparts pertains more to the pesticide factors rather than the nutritional factors. However, if looking at the nutritional factors and nutritional factors only, it would still appear to be more beneficial to eat organically grown strawberries due to the higher levels of antioxidants and vitamin C in the organically grown products. While higher levels of potassium and phosphorus were found in the conventional products, the antioxidants and vitamin C seem to be more important for the body to acquire through consumption. Potatoes, on the other hand, showed higher levels of copper and magnesium in the organic products and iron and sodium in the conventional products. It is hard to come to a conclusion about determining which of these nutrients may be more beneficial to the human body; however, it is pertinent to state that the higher levels of iron may sway a consumer to choose the organic counterpart, particularly if an individual has an iron deficiency or is pregnant; yet higher levels of magnesium have been linked to "reduced risk of cardiovascular disease, stroke and cancers of the mouth, pharynx, esophagus, lungs, stomach and colon" (Tarrozi, 2006).

Tomatoes and cucumbers showed differing results as well, even though they have similar properties with regards to their membrane. Tomatoes appeared to favor conventionally grown food with higher levels of antioxidants and vitamin C; however, in a study of produce in Africa, tomatoes were seen to have the highest amount of pesticide residue and they do appear on the dirty dozen list (Mutengwe, 2016). It seems that organic tomatoes did not show to be more nutritious, however if the choice to buy

organic produce considered both nutritional quality and pesticide amounts, the pesticide amounts would trump the nutritional quality. Organic cucumbers were found to have higher levels of antioxidants and also do not appear on the dirty dozen, supporting the choice to buy organic cucumbers, but not necessarily making it a critical factor, as most pesticide residues are more likely to be able to be washed off of the product.

While the dirty dozen is not based on nutrition but on pesticides, it is interesting to see how the comparison between the presented list and the research discussed in this paper show similar results. Strawberries and potatoes appear on the list, however, oranges and bananas do not. Perhaps there is a correlation between the amount of pesticides on and the nutrient composition of the harvested products. Unfortunately, no published study was located that analyzed these two aspects directly. This relationship would be an interesting topic to further explore.

Soil and Nutrient Quality

As discussed earlier, there are various practices for maintaining soil, such as fertilizing soil, using seeds from organic crop, rotating crops, managing of foreign substances, and preventing cross contamination between organic and conventionally grown foods. Not only do external additives, such as pesticides, affect the product, the components of the soil do as well. The soil supports the plant's growth by providing it with nutrients. Without proper soil, the plant would not survive. Therefore, what is in the soil is important for and contributes to how the plant will grow and eventually the product it will produce.

It can be seen that soil quality subsequently plays an important role for the nutrients found in the products. Some studies which evaluated the nutrient quality of organic versus conventionally grown product also looked at how the soil quality may have impacted the results. The studies that discussed the soil quality having any relation to nutrient quality in the final products mainly focused on soil fertility and the types of nutrients found in the soil rather than other factors such as the types of seeds planted, crop rotation practices, or prevention of cross contamination. It is unlikely that specifically using organically produced seeds and cross contamination of the final products could affect nutrient quality, but crop rotation could have greater effects due to what products may be farmed in various seasons on the same plots. There are numerous factors that contribute to the complexities of soil quality, such as the vast differences based on geographic region in which it is found around the world, the weather patterns of an area, and even how each individual farmer chooses to cultivate the land.

With regards to a study done by Marquez and colleagues (2017), organic fruits and vegetables were produced at a lesser rate, were smaller in size, and contained fewer nutrients compared to their conventionally grown counterparts. This was attributed to fewer nutrients in the organic fertilizer, as it was watered down to prevent toxicity. However, a relationship was observed between the amount of nitrogen in the soil and the size and weight of the product, such that lower nitrogen levels produced smaller fruit (Marquez, 2017). This study went to significant efforts to maintain validity among variables by controlling as many variables as possible. It was carried out in a greenhouse where the types of fertilizers used-organic or conventional-were highly controlled. While it is unlikely that treatments would have been feasible to apply to actual plots that farmers

use, the results demonstrate a correlation between nitrogen, in this case, found in the soil and the amount of nutrients found in the fruit. Ultimately, the research supported the idea that soil quality can affect the outcome of the final product.

Another study of tomatoes was carried out in fielded plots and the variables observed included: location of the farm and history of organic farming to irrigation type, soil type and the use of fertilizer in the soil. This study drew to attention how extremely complex farming can be, but particularly focused on the differences in soil type and texture. Not only are there guidelines for organic farming, but there are many different products that can be used within the guidelines (Barrett, 2007). Various products can be used to treat soil and plants, but also the characteristics of each crop, whether that be a fruit, vegetable or nut can vary by genetics as well with regards to the size of the product and its physical qualities that may, in turn, affect nutrient quality. Oddly, in the study of tomatoes, the conventionally grown fruit contained higher levels of antioxidants and vitamin C than those organically grown. The conventional plots had a higher pH, and higher calcium, sodium, and chloride content. However, the organic plots had higher levels of elements such as phosphorus, manganese, iron and nitrogen (Santiago-Lopez, 2016). These results counters the results of the study done on cucumbers, as the higher levels of nitrogen in the soil produced higher quality fruit.

Understandably, many factors go in to the cultivation of land that is farmed on for both conventional and organic farming, such as soil characteristics, geographic location and weather patterns. Nitrogen has appeared to be a significant factor in soil quality and subsequently the fruits' nutrient contents. A study done on kiwi fruits that specifically looked at the soil quality and fertilization found that plants with higher nitrogen content

produced more fruit and had higher nutrients in the soil. It was also found that organic fertilizer efficiently produced a higher yield of fruit. The study references an increase in fruit quality; however, it does not explicitly state that the fruits' nutrient quality was analyzed (Li, 2017). It can be assumed that quality is a reference to the nutrients in the fruit but will remain unknown at this point in time. Additionally, higher nutrients in the soil can lead to higher nutrients in the fruit, as the nutrients in the soil directly affect what the plant absorbs and using in its growing process; however, again, this can not be concluded until further experimentation has been conducted.

Issues with studying organic food

Various factors pose a challenge when conducting and reviewing the research on organic farming to attempt to answer the big question: "Is organic produce more nutritious than conventionally grown produce?" Awareness of these factors can be helpful when beginning to dissect this concept. Still, they provide only a limited number of the essential pieces to the larger puzzle necessary to definitively answer the aforementioned question. First of all, this is a very complex question. There is the pesticide aspect, which arguably was the primary motivator for the development of organic farming practices-to employ more environmentally friendly methods of farming. However, there are other factors that arguably should play in to a consumer's decision to "go organic," such as the nutritional quality. While no single study could evaluate every nutrient or even a single nutrient within the abundance of fruits and vegetables produced, there are studies that have sought to measure variability of nutrient content and collected data to compare fruits and/or vegetables organically produced and conventionally produced.

In the realm of organic, typical food terms, as often the case, can be misinterpreted or even misleading such that the idea that organic food is healthier, but then we have to define what 'healthier' means. Second, it is essentially impossible to think that every single piece of produce from every single farm from all over the world can/will be analyzed. The previously discussed studies are all helpful in reaching a decision about the nutritional quality of those specific pieces of produce; however, it is difficult, at best, to compare them among each other for various reasons. They are all farmed in different parts of the world, in fact even different continents; therefore, they all have varying degrees of environmental impacts including climate, weather (patterns), and soil content. Akbaba (2012) even explained that regions might vary from one another due to different agricultural practices, soil types, differing fertilizers and chemicals used on the plants. Control of production variables is simply not practical and it is "not possible to make global statements concerning the difference between quality of organic and conventionally grown [produce]" (Barrett, 2007). The variables for this type of experimental study would literally vary too much throughout the entire world.

Not only can the external variables not be controlled for a study that takes in to account the entire world's production of produce, but the actual analysis of the produce for nutritional content would be a stipulation of the study. The actual procedure to analyze the produce was different in nearly every study reviewed. For example, Akbaba and colleagues (2012) used the WDXRF for analyzing the nutrients in chickpeas and pistachios, whereas Barret and colleagues (2007) analyzed tomatoes using a system of extracting the juice and different techniques involving microwaving. Each type of produce may have to be processed in a way that enables analysis of it contents (whether

there is the presence of a peel or some type of membrane); however, only utilizing certain parts of the product will not create a complete overview of the nutrients the product has to offer either. In addition to the method of analysis, it may also be nearly impossible to analyze for every single nutrient. As can be seen in Table 1, there was very little overlap of nutrients analyzed across the studies reviewed.

A final issue with conducting a comprehensive analysis and comparison of organic and conventionally grown produce is how the product is prepared for consumption. Yes, an individual could simply eat a tomato right off the vine, per se, but what if that is not the circumstance? What if the tomato is sautéed, baked, or juiced to create a specific dish? What happens to the nutrient contents then, and how is that affected by the method of farming? Tomatoes are a particularly versatile product; however, like most products of organic farming tomatoes can be prepared by the consumer in any number of ways that may affect their nutrient content and quality. Additionally, there are other complexities to the 'states' of the product, beyond raw, pureed, or how it is cooked, including how long may it had been stored and if it has been frozen, packaged or canned?

The studies discussed were also inconsistent in a sense that they are used differing internal variables as well. Some studies used greenhouses with highly controlled environments for both conventional and organic farming; some used actual farms but were not in control of the growing of the products; while others simply went to the grocery store and picked up one conventionally grown, and one organically grown product.

Consumer Considerations

Various aspects as well as the background of organic farming have been discussed. This information can then be used to help guide a consumer's educated decision on whether or not to purchase organically grown produce. The following categories are profound in making this decision: time of life, diagnoses and conditions, concern for the environment and the 'big picture.'

Time of Life

As many individuals may already know, a fetus receives nutrients from the mother through the placenta. It is much easier for a child to receive nutrients from the placenta because the child's body is not responsible for maintaining homeostasis, whereas once it leaves the protection of the uterus, is it responsible for all biochemical maintenance for its own body (Forbes, 1987). Understandably, a pregnant woman's body changes in order to support the child in-utero. The changing body with regards to the demand of various nutrients is complex and will not be discussed in this paper; however, it can be understood that there is enhanced absorption of ingested nutrients during pregnancy in order to support essentially two organisms.

Aside from how the nutrients themselves are related to growth and development, there is also the consideration of pesticide absorption with regards to age and how the body absorbs them from contents consumed. Foreign, toxic chemical exposure in the early years of life when development, particularly of the brain, is most progressive has been linked to various neurodevelopmental abnormalities, such as autism and attention-deficit

hyperactivity disorder (Rauh, 2016). While these linkages show minor changes in development, even minor changes may cause detrimental outcomes long term.

Children are particularly vulnerable to chemical exposure as compared to adults, because they are developing rapidly, meaning they have higher metabolic rates and consume more food and liquids in proportion to their bodies versus the consumption of adults. In addition to this increased metabolic rate, a child's body is less efficient at separating, breaking down and excreting toxic materials within the body (Rauh, 2016). Certain pesticides also have the ability to diffuse across the amniotic membrane in utero and directly disrupt normal neuronal cell growth and organization. Critical development periods include pre-natal through early childhood (around seven years of age), and in some cases longer, up to 15 years of age. The study conducted by Rauh (2016), found correlations between consuming organic foods and the cognitive function of the child. A correlation between chemical exposure, including pesticides, has been linked to minor changes in IQ and behavior that often have large consequences later in life because of these cognitive deficits. Liu (2012) found similar results in that prenatal development seems to be the most affected by exposure foreign chemicals; however it was argued that the exposure through consumption is really only *detrimental* up until 24 months of age.

Interestingly, it was also found that children in school with higher levels of metabolic enzymes tended to have mental disabilities, this is perhaps consistent with the idea that high metabolic rates support increased absorption of the harmful chemicals ingested while in utero and through postnatal growth (Rauh, 2012). While this evidence provides substantial conclusions with regards to pesticide exposure, it is possible that other factors could have been involved in the processes that resulted in this conclusion, as it is

correlation, not causation. However, it can not be denied that because children have higher absorption and metabolic rates, they are more susceptible to absorbing other substances, such as pesticides, that are present in their food supply.

While all nutrients are important for growth and development, it appears that calcium and iron hold particular importance in development for both in utero development and childhood development. With regards to Table 1, the studies reviewed showed that both organic chickpeas and pistachios presented higher levels of calcium and iron (Akbaba, 2012). Further, in a different study, conventional potatoes exhibited higher levels of iron (Griffiths, 2012). With regards to the studies discussed in this paper, these were the only two sources that analyzed and discussed levels of iron and calcium. While there are limitations to the reliance on a mere two studies, organically farmed chickpeas and pistachios both exhibited higher amounts of calcium, iron, phosphorus, chlorine and potassium. Unfortunately, this makes it difficult to create a definitive conclusion on whether or not organic or conventional produce should be consumed with regards to specifically calcium or iron. Relying on one study is not reliable in applying the results to the real world.

Considering the important roles of calcium and iron in development, consuming organically farmed nuts may be more beneficial for a pregnant woman or for a child, particularly in the early years of life, when going through important stages of growth and development. With this being said, organic nuts and legumes (pistachios and chickpeas) seem to represent an overall trend that supports the organically farmed products being more nutritious and may be worth consuming during pregnancy or childhood. Perhaps

future research will expand these results to include other legumes or treenuts, such as peanuts and walnuts.

Based on the metabolic rate alone, the importance of consuming foods with low levels of chemicals is very important. With regards to the elderly population, the same ideas may be implied, but for different reasons. While children have higher metabolic rates, elderly individuals are more likely to have chronic diseases than that of children. Arguably, one of the most common chronic diseases is cardiovascular disease. This can be linked to a multitude of other various medical problems, including obesity, which can then be related to an individual's diet and exercise. While exercise cannot be necessarily correlated with organic food, diet can. Consuming foods rich in nutrients is very important for those whose bodies are already subpar due to a chronic disease. Not only is it important to consume a 'healthy' diet rich in nutrients, but it would be smart to avoid as many foreign substances and chemicals being put into the body, such as pesticides. Perhaps, the most important stages of life to consume organic would be in childhood as well as later adulthood, or whenever one's body begins acquiring various chronic conditions, such as cardiovascular disease and cancer.

Diagnoses and Conditions

As with the evaluation of life cycle stage and organic food consumption, the relationship between disease and organic foods can also be separated into the effects of the nutrients and the effects of the pesticides. Nutrients are essential to bodily functions, providing fuel for energy and regulating thousands of processes necessary to sustain life. Individuals should try to attain most of their nutrients from their diet rather than relying on supplements, because they are in their most natural form when taken in from foods,

such as produce. From birth and throughout the entire life span, the body needs to be supplied with the correct components to fire neurons, so the brain can work, manipulate calcium for muscle contraction and use vitamin C for immunity, among many, many other important processes in the body. While the body can synthesize some nutrients for functional use, the production of vitamin C by the body is vestgial, meaning the body does not make its own vitamin C and it must be supplied through the diet or supplements. Considering that vitamin C is an important factor in maintaining immunity, this helps show that produce with higher nutrients may be beneficial for someone who has an autoimmune disorder, or a weaker immune system, yet is beneficial for all humans considering no one enjoys being sick!

Organic diets have been correlated with various medical conditions, an obvious one being cancer; however, a correlation between organic diet and other health conditions have also been reported in the literature. Lower incidence of pre-eclampsia in pregnant women and eczema in children under two years of age have been observed among those that predominantly consumed organically grown produce (Mie, 2017). A study done by Csizmadi (2013) compared activity level, energy expenditure and nutrient levels among individuals aged 35-69 years old and without a previous diagnosis of cancer. Dietary adequacy and physical attributes were both assessed. With regards to nutrients, they found that those who had to use supplements or those who had an inadequate supply of various nutrients were at higher risks for chronic diseases including cancer. Not only does the activity level of individuals contribute to long term health benefits but receiving essential nutrients through the diet can also be an important factor. Therefore, consuming

foods that have higher levels of nutrients associated with health enhancing properties would give the body a better chance at absorbing them through the diet.

The studies that looked at antioxidant levels found overall that organically grown foods had higher antioxidant levels. Antioxidants are important for prevention and treatment of chronic diseases and are important for bioactivities such as promoting healthy functioning of the heart to prevent or slow down heart disease. They have also been linked to having anticancer and anti-aging properties as well as offering some protection against cardiovascular disease, diabetes, and other chronic diseases (Zhang, 2015). As discussed earlier, there are potential benefits for consuming organically produce in early stages of life; however, there may also be benefits for the elderly. While research is still limited, a correlation has been demonstrated between antioxidants and the prevention of cognitive decline in the elderly (Rafnsson, 2013). The few studies discussed in this paper (Tarozzi, 2006; Reganold, 2012; Santiago-Lopez, 2016; Ren, 2017) consistently showed higher levels of antioxidants in organically farmed produce. Because there seem to be more antioxidants in organically farmed produce, there would seem to be a better chance at consuming higher levels of those antioxidants that could result in better health, particularly mental health.

Concern for the environment

Not only is there a divide among those who obsess over living a healthy lifestyle and those who are not concerned with doing so or even disregard health information, there is also a divide between the environmentally conscious, often deemed ‘tree huggers’, and those who seem to have little concern for the environment. While concern about the environment does not directly relate to the nutritional quality of produce, the effect that

pesticides have on the environment may still be an important consideration in choosing to buy organically grown produce. As discussed previously, pesticides and insecticides and essentially any chemical or product placed on produce being farmed is destined to either remain on the product that will be consumed or make its way in to the surrounding environment and ultimately the ecosystem. This in turn has been shown that there is less biodiversity in conventional farming areas versus organic farming areas (Haas, 2001). It is true that there are environmentally friendly pesticides; however, the fact is, they are still for synthetic product.

The market for pesticides is constantly changing in response to pests adaptation and resistance to the pesticides as well as the failed introduction of new formulas with the intent to manage the resulting invasive species of pests. Not only is the market ever changing, but it is hard for specialized smaller market products to be used, because it may not be cost effective for the farming companies. In the end, it all comes down to placing foreign chemicals, no matter how "green" they are deemed, into the environment (Goldson, 2015). Such practices lead to changes in the environment and changes in the foods grown-conventionally and organically. The biggest difference is that organic farming methods are implemented with the intent to employ more environmentally friendly strategies for production. Individuals who understand the impact that these chemicals have on the environment want to consume organic food. While this aspect is not directly related to the nutritional value of the produce, it is an important factor to consider when deciding whether or not to consume organically grown produce.

What is the 'Big Picture?'

Finally, for a consumer reading these results and then observing the prices of organic food versus conventional foods, the question still exists: *Should I purchase organic foods?* At best, the responds is vague: *It depends*. The following section outlines key points and questions to help the consumer navigate the marketplace of conventional and organic produce.

This paper has discussed the effects of pesticides, described the findings of various studies which analyzed nutritional content organic foods, discussed discrepancies within and among studies, and is now presenting factors to consider when deciding to consume organically grown food, particularly produce. The 'big picture' essentially involves what specific types of produce may be the most beneficial to consume. When considering whether or not to purchase organic food, the factors can vary both in what they are and how they relate to each other. Consider for a moment probability and the many different scenarios that could play out, making this decision a lot tougher than it may initially seem. For example, maybe an individual is pregnant and concerned about the health and development of the developing child, however is not so concerned about the environment. Different considerations can be brought together that apply differently to different people's lives.

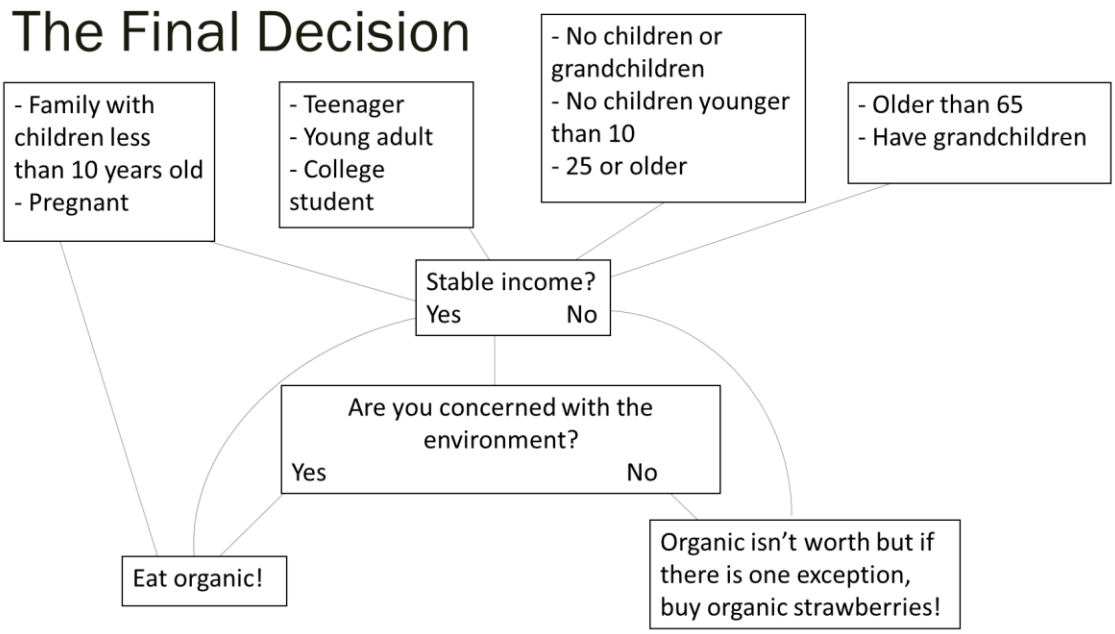
Consider the aforementioned scenario in more detail: a pregnant woman walks into the grocery store with the intent to purchase produce. Organic strawberries are two or three dollars more expensive than their conventionally grown counterpart. The woman is middle class, so is not necessarily "scraping pennies" out of her bank account but would also rather not spend the extra money if she does not have to. She is ambivalent with

regards to agriculture and the environment. Due to the fact that she is pregnant and ideally creating the most beneficial environment within her body for the fetus to develop, she should strongly consider buying the organically grown produce, despite the additional cost. If given this advice, it would probably be brought to attention that two or three dollars per product adds up quickly, especially when purchasing many different types of produce. At this point, she could pick and choose which produce to purchase-organically or conventionally grown. However, based on the presented data presented in the paper and specifically in reference to the dirty dozen list, it would make sense to purchase organically grown strawberries as one of the most pertinent items to consume. In accordance with this idea about strawberries, similar organically grown fleshy fruits may be wise choices for organic purchase versus the conventional counterparts. On the other hand, fruits with a thick membrane that can be removed, such as oranges or bananas, may not be as pertinent to purchase as organic products, and therefore not necessarily worth the extra couple of dollars. These and other factors discussed in this paper can be evaluated using the decision flow chart in the next section.

Making the Decision

Presented is a chart to help the consumer decide if organic produce is the "way to go" based on what has been discussed in this paper.

Figure 1. Making the final decision.



Conclusion

As can be seen, the complicated question of whether or not organic food is more "nutritious" (contain more nutrients) may quite possibly never have a definitive answer. This is particularly due to discrepancies in external validity, such as the inability to properly compare products from various regions of the world under the exact same conditions. The studies also did not measure the nutrients of the produce in the same manner or for that matter the same nutrients. Another issue in making claims about the nutrient content of organic produce is the state of the product when consumed. However, aspects of the existing research do shed light to certain products being "worth" the higher price. The findings of this paper are as follows: it does not seem particularly pertinent to eat organically grown produce based solely on the nutritional quality. The contributing

factors are multifaceted; perhaps a series of follow-up questions allow for a better response when answering the "organic or not" question. These follow-up questions pertain to nutritional quality, environmental concerns, and the lifecycle stage of the consumer. These ideas all seem to go hand in hand. For individuals who may be on their own and/or have a limited food budget, such as a college student, it may not be worth consuming organic produce, with *possibly* the exception of a few items, like strawberries. For individuals supporting a family with children and/or a woman who is pregnant, organic is the way to go (assuming the food budget allows) because of the decreased pesticide exposure and increased nutritional quality. Even if the nutritional quality is not exuberantly better in organic food, it increases the potential of consuming more nutrients because the idea is that better farming methods grow products in a healthier way that allows the produce to grow more efficiently. Finally, for those reaching older age and acquiring chronic conditions, organic produce may be a safer route, again assuming there is financial security.

Various factors go in to the decision to "go organic," however it does not seem that the nutritional quality is the single determining factor. It is imperative that if this topic is to uncover more well-rounded or definitive answers that future research include studies which analyze as many different kinds of produce as possible, under the same conditions, in various regions all around the world, using the same methods in each location, and with consistent measurement of nutrients.

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