Journal of
Emerging Investigators

Vitamin C in Fruits: Does Organic Make a Difference?

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Summary

Vitamin C is an important compound that allows many organisms to function and live. However, there is controversy over whether organic fruits have more vitamin C than their non-organic counterparts. The purpose of this study was to evaluate whether organic fruits have more ascorbic acid than their non-organic counterparts. This analysis tested five fruits: oranges, lemons, grapefruit, strawberries, and kiwis. Using the oxidation-reduction reaction method, iodine titration was performed for each variety of organic and non-organic fruit, and the amount of ascorbic acid was calculated. The mean concentration of vitamin C in the organic variety was compared to the concentration in the non-organic variety for each fruit using a Student's *t*-test. The data showed that ascorbic acid content varies widely among these five fruits. For oranges, organic varieties had more vitamin C than their conventional counterparts (p = 0.042). However, in the grapefruit, the organic and non-organic fruits had no significant difference in vitamin C levels (p = 0.63). For kiwis, lemons, and strawberries, the organic fruits had significantly less ascorbic acid than the non-organic ones (p = 0.021; p = 0.0034; p = 0.046, respectively). The results demonstrate that the organic status of a fruit does not guarantee that it has more vitamin C than its non-organic counterparts.

Received: October 18, 2014; **Accepted:** June 13, 2015; **Published:** September 21, 2015

Introduction

Vitamin C, or ascorbic acid, is a very important water-soluble nutrient, critical for sustaining cellular function. It promotes health in a variety of ways, such as preventing scurvy, promoting bone structure and strength, reducing inflammation, and aiding the cardiovascular system through antioxidation and improving endothelial cell function (1–3). Notably, humans are among the few mammals that cannot produce their own vitamin C. Therefore, they depend entirely upon external sources for this vital nutrient (4). Some of the common sources of vitamin C for humans include chili peppers, bell peppers, citrus fruits, strawberries, and flowering vegetables (5).

The U.S. Department of Agriculture and the Department of Health and Human Services released data that suggest many people have an inadequate intake of ascorbic acid. These organizations specifically recommend that diets include products with high vitamin C levels and other important nutrients (6). Among Americans, only 42% and 60% meet the standard recommendation for vitamin C consumption for fruits and vegetables, respectively. This is important because fruits and vegetables are the most important source of vitamin C for humans. While severe vitamin C deficiency may lead to scurvy, a milder deficiency of this important vitamin still has important effects. For instance, lack of vitamin C is associated with the common cold (7). Inadequate ascorbic acid levels can lead to a lack of iron absorption and urinary tract infections in elderly people and pregnant women.

Many factors may influence the vitamin content of fruits (8). Some of these factors include the climate in which the fruit was grown, the soil conditions near the plant, the maturity of the plant when harvested, storage duration and conditions, processing, and physical damage. However, one of the factors that may also influence ascorbic acid content is whether the fruit is organic or non-organic. There is a public perception that organic fruits have more nutrients, such as vitamin C, but this has not been rigorously tested (9-11).

Worldwide, the organic industry has enjoyed dramatic growth. In the U.S., the organic industry has grown from 1 billion dollars in 1990 to almost 22 billion dollars in 2009 (12). In fact, over the last five years, sales of organic fruits and vegetables have increased by about 50% (13). Despite the higher cost of organic products, many people are willing to pay the higher price because there is a perception that these foods are healthier and safer (9-11). The urge to buy organic fruits and vegetables is partly driven by the notion that these products have more vitamin C than their non-organic equivalents, despite the lack of firm data (14). For example, investigators from Brazil showed that organic fruits had 30-60% more vitamin C than their non-organic counterparts (15). On the other hand, Stanford researchers reported that organic fruits have no more vitamin C than non-organic ones (16). Overall, there is controversy regarding whether organic fruits have more ascorbic acid than non-organic fruits, and there are few studies that have compared vitamin C concentration across a variety of organic and non-organic fruits and vegetables.

Accordingly, this study investigates whether or not there is a higher concentration of ascorbic acid in organic fruits. Using a variety of fruits that are noted to have high vitamin C content, this study compares ascorbic acid concentration in organic and non-organic fruits using the oxidation-reduction method to measure vitamin C levels (17). The oxidation-reduction reaction, in this case, occurs when iodine reacts with vitamin C. In this reaction, the vitamin C is oxidized by the iodine into dehydroascorbic acid and the iodine is reduced, as shown in the following chemical reaction:

$$C_6H_8O_6 + I_3^- + H_2O \rightarrow C_6H_6O_6 + 3I^- + 2H^+$$

Results

This study was designed to evaluate any differences in ascorbic acid concentration between organic and non-organic fruits using an oxidation-reduction reaction. Iodine reacts with vitamin C in a reaction where iodine is reduced and vitamin C is oxidized. Five fruits were used in this experiment. They were Organic and Non-organic (1) navel oranges, (2) lemons, (3) grapefruit, (4) strawberries, and (5) kiwis. After calculating the volume of iodine needed to titrate 20 mg of a standard vitamin C solution, the iodine from a buret was carefully added to 20 mL of a fruit juice solution. The buret was used so that there could be a precise measurement of the exact volume of iodine needed to titrate each solution. When testing each fruit, three trials were done on three separate solutions from each of the fruits. Therefore, each of the 5 different types of organic and non-organic fruits tested in this experiment had 3 independent trials. The average and standard deviations of the three trials for each of the fruits was calculated, and all statistics were performed with these calculations.

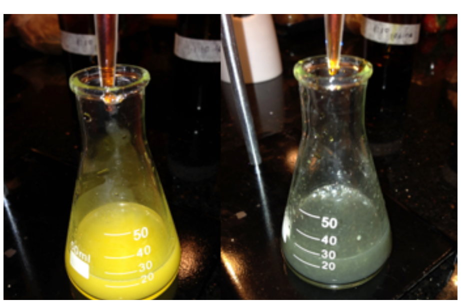

Figure 1: Orange Juice Before and After Iodine Titration. Once the iodine completes the oxidation of vitamin C, the iodine reacts with the starch to make the characteristic bluish-black color. The titration tells the investigator directly how much volume of iodine it took to completely titrate the juice. The more volume of iodine needed to titrate the juice, the less Vitamin C there was in that juice.

Standard vitamin C solution: The volume of iodine needed to titrate 20 mg of vitamin C standard solution was 6.7 ± 0.1 mL.

Navel oranges: The volume of iodine required to titrate the ascorbic acid in the non-organic and organic navel oranges was 3.8 ± 0.07 mL and 4.0 ± 0.03 mL, respectively (**Table 1**). **Figure 1** shows an example of the orange juice before iodine titration and post–iodine titration. Using the ratio shown in the Statistical Analysis section of the Methods, along with the results of the vitamin C standard solution titration, we calculated that the organic oranges had significantly more vitamin C

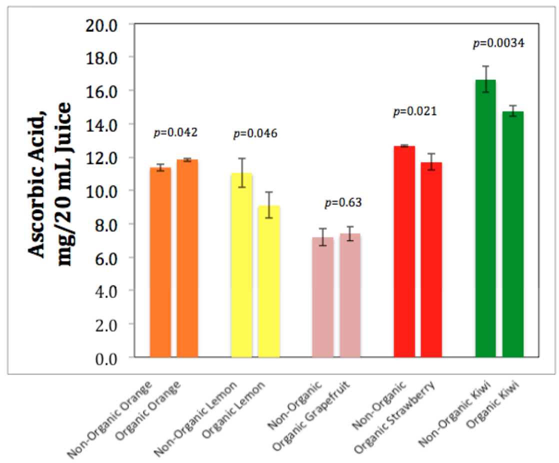

Figure 2: Non-Organic versus Organic Vitamin C Content. Organic orange fruits had more vitamin C than non-organic oranges. Organic and non-organic fruits had no significant difference in vitamin C content. Non-organic kiwis, strawberries, and lemons had more vitamin C than their organic counterparts.

than their non-organic counterparts (organic: 11.8 mg Vit C/20 mL juice; non-organic: 11.4 mg/20 mL juice; p = 0.042). The total recommended daily allowance of vitamin C is 90 mg. Therefore, 20 mL of organic oranges provides 13.1% of the daily recommended allowance, while non-organic oranges provide 12.7% of the daily recommended allowance (**Figure 2**).

Lemons: The volume of iodine required to titrate the ascorbic acid in the non-organic and organic lemons was 3.7 ± 0.26 mL and 3.1 ± 0.29 mL, respectively (**Table 1**). The organic lemons had significantly less vitamin C than the non-organic lemons (organic: 9.1 mg Vit C/20 mL juice; non-organic: 11.0 mg/20 mL juice; p = 0.046) (**Figure 2**).

Grapefruit: The volume of iodine required to titrate the ascorbic acid in the non-organic and organic grapefruit was 2.4 ± 0.17 mL and 2.5 ± 0.14 mL, respectively (**Table 1**). There was no significant difference between the organic and non-organic grapefruits (organic: 7.4 mg Vit C/20 mL juice; non-organic: 7.2 mg/20 mL juice; p = 0.63) (**Figure 2**).

Strawberries: The volume of iodine required to titrate the ascorbic acid in the non-organic and organic strawberries was 4.2 ± 0.02 mL and 4.0 ± 0.07 mL, respectively (**Table 1**). The organic strawberries had significantly less vitamin C than the non-organic strawberries (organic: 11.7 mg Vit C/20 mL juice; non-organic: 12.7 mg/20 mL juice; $p = 0.021$) (**Figure 2**).

Kiwi: The volume of iodine required to titrate the ascorbic acid in non-organic and organic kiwi was 5.5 ± 0.11 mL and 5.0 ± 0.09 mL, respectively (**Table 1**). The organic kiwi had significantly less vitamin C than non-organic kiwi (organic: 14.8 mg Vit C/20 mL juice; non-organic: 16.7 mg/20 mL juice; $p = 0.0034$) (**Figure 2**).

Discussion

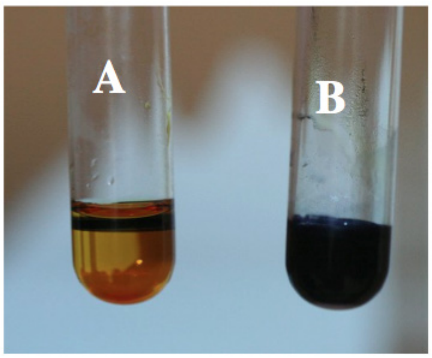

Figure 3: Before and After Iodine Mixes with Starch. A shows the solution before the iodine titration. B shows the solution after the iodine has completely titrated the ascorbic acid and reacts with starch to make the distinct black and blue color.

This study investigated whether or not organic fruits have more vitamin C than their non-organic counterparts. There were two major findings in this study. First, vitamin C content varied widely among fruits. Specifically, kiwis and strawberries had the most ascorbic acid content of any other fruit tested in this experiment. On the other hand, grapefruit and lemons had the lowest vitamin C levels and oranges were in between these two extremes. Other studies report similar results (18). Second, there was variation in the relationship between ascorbic acid content and whether or not a fruit was organic. In some fruits, such as oranges, organic varieties had significantly more vitamin C. In other fruits, including kiwi, lemons, and strawberries, the non-organic varieties had more ascorbic acid, and for grapefruit, there was no significant difference between organic and non-organic varieties. Our findings add to the current controversy regarding whether organic foods have more vitamin C content. Our study suggests that this relationship is variable depending on which fruit is being studied, but there were no consistent trends across all fruits. Our findings are similar to those reported by researchers from Stanford (16).

Because our study focused only on vitamin C content, it did not address the other potential health benefits of organic fruits. A recent report published in the British Journal of Nutrition analyzed several studies together and found that organic crops have higher levels of antioxidants and lower pesticide levels than non-organic crops (19). However, another study published in 2012 found that there is little evidence to argue that organic products are more nutritious, indicating that this debate may continue for some time (16).

There were a few limitations to this study. This study did not take into account where the fruit came from, except that the oranges were from California. Furthermore, it didn't consider how ripe the fruits were when they were picked, how mature they were, how long they were sitting in the store, or if any physical damage had been done to the fruit during processing. There was also no knowledge of the details about how the fruits were grown and what kinds of pesticides may have been used for the non-organic fruits. Since our major finding was that ascorbic acid content depends on more than just organic versus non-organic, these factors may affect the vitamin C levels in fruits. Further studies will be needed to evaluate the role of other factors upon ascorbic acid content.

Methods

Iodine Solution

An iodine solution was created to titrate the ascorbic acid. A 1:10 solution was made by diluting 30 mL of Lugol's Iodine with 270 mL of distilled water. This solution was stored in amber glass bottles.

Starch Solution

After the entirety of the ascorbic acid was titrated, the iodine reacted with starch to create a dark blue color (**Figure 3**). To indicate the titration of ascorbic acid, a 0.5% starch solution was made by dissolving 1 g of soluble starch into 200 mL of boiling distilled water.

Vitamin C Standard Solution

In order to measure how much iodine was needed to titrate a standard amount of ascorbic acid, a vitamin C standard solution was prepared. A 250 mg vitamin C tablet was dissolved in a total volume of 250 mL of distilled water. This resulted in a 1 mg/mL vitamin C solution.

Juicing Fruits

Fruits were purchased at a local grocery store called Giant Eagle. The fruits in this study included non-organic and organic navel oranges from California (1), grapefruits (2), lemons (3), strawberries (4), and kiwis

(5). These fruits were selected because they are easy to juice and have a high content of vitamin C. Using a clean and dry juicer, the fruits were juiced and strained to separate the pulp from the juice. A total of three individual trials were done for three different samples of the same type of fruit. Each sample included 20 mL of juice. For oranges, grapefruit, and lemons, only one fruit was needed to collect the 20 mL needed for one sample. Four strawberries were needed to collect the 20 mL of juice. Additionally, three kiwis were needed to collect the 20 mL of juice. All samples were fresh and the titration reaction was done within 15 minutes of collection.

Oxidation-Reduction Titration of Vitamin C Solution

A 50 mL buret was set up on a ring stand. The 1:10 iodine solution was poured into the buret. A 20 mL volume containing 20 mg of ascorbic acid of the standard vitamin C solution was poured into a 50 mL Erlenmeyer flask. Ten drops of starch indicator solution was added into the flask and stirred. The iodine was added drop by drop into the flask until the iodine completed its titration of the ascorbic acid. The completion of the titration was indicated by the solution turning a distinctive blue/black color, which occurs when there is no further ascorbic acid to titrate and the iodine reacts with the starch. Because the iodine has a strong affinity with the ascorbic acid, it first reacted with the ascorbic acid. Once all the vitamin C had been oxidized, the iodine reacted with the starch. The volume of iodine required to titrate the 20 mg of vitamin C was recorded. This step was repeated for a total of three trials for each of three samples of juice.

Oxidation-Reduction Titration of Fruit Juices

The fruit juice samples were titrated as described above, using 20 mL of each fruit juice. The volume of iodine required to titrate the vitamin C was measured using the buret and recorded. This step was repeated for a total of three trials for each of the three samples for each fruit, non-organic and organic separately.

Statistical Analysis

The mean and standard deviation of the three samples were calculated for the titration of the standard vitamin C solution and each of the fruit juice titrations. A ratio was used to convert the volume of iodine required to titrate the juices into the ascorbic acid content. This ratio used the volume of iodine needed to titrate the vitamin C standard solution. The ratio is below:

$$\frac{\text{20 mg Vitamin C standard}}{\text{mL Iodine to titrate Vitamin C standard}} = \frac{\text{mg of Vitamin C in Juice}}{\text{mL Iodine to titrate Vitamin C in Juice}}$$

After calculating the number of milligrams of vitamin C from each of the fruits, a comparison of the means of the organic variety of the fruit versus the non-organic variety was performed using a Student's *t*-test. A *p*-value of <0.05 was considered to be statistically significant. All statistical tests were performed using Microsoft Office Excel (Version 2011).

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		Non-Organic Orange	**Organic Orange**
Sample 1	Trial 1	3.7	3.8
	Trial 2	3.9	4.0
	Trial 3	4.0	4.1
Sample 2	Trial 1	3.9	3.9
	Trial 2	3.8	4.1
	Trial 3	3.8	4.0
Sample 3	Trial 1	3.7	3.9
	Trial 2	3.7	3.9
	Trial 3	3.8	4.0
Sample 1 Mean		3.9	4.0
Sample 2 Mean		3.8	4.0
Sample 3 Mean		3.7	3.9
Mean±SD (3 Samples)		**3.8±0.07**	**4.0±0.03**
		Non-Organic Lemon	**Organic Lemon**
Sample 1	Trial 1	3.2	2.7
	Trial 2	3.4	2.9
	Trial 3	3.5	2.7
Sample 2	Trial 1	3.9	3.2
	Trial 2	4.0	3.2
	Trial 3	3.8	3.4
Sample 3	Trial 1	3.7	3.1
	Trial 2	4.0	3.0
	Trial 3	3.8	3.3
Sample 1 Mean		3.4	2.8
Sample 2 Mean		3.9	3.3
Sample 3 Mean		3.8	3.1
Mean±SD (3 Samples)		**3.7±0.26**	**3.1±0.29**
		Non-Organic Grapefruit	**Organic Grapefruit**
Sample 1	Trial 1	2.4	2.4
	Trial 2	2.6	2.5
	Trial 3	2.8	3.0
Sample 2	Trial 1	2.3	2.5
	Trial 2	2.2	2.3
	Trial 3	2.3	2.3
Sample 3	Trial 1	2.2	2.3
	Trial 2	2.5	2.5
	Trial 3	2.4	2.5
Sample 1 Mean		2.6	2.6
Sample 2 Mean		2.3	2.4
Sample 3 Mean		2.4	2.4
Mean±SD (3 Samples)		**2.4±0.17**	**2.5±0.13**
		Non-Organic Strawberry	**Organic Strawberry**
Sample 1	Trial 1	4.2	3.8
	Trial 2	4.1	3.7
	Trial 3	4.4	3.7
Sample 2	Trial 1	4.0	4.0
	Trial 2	4.2	4.1
	Trial 3	4.5	4.1
Sample 3	Trial 1	4.1	4.1
	Trial 2	4.4	4.0
	Trial 3	4.3	3.8
Sample 1 Mean		4.2	3.9
Sample 2 Mean		4.2	4.1
Sample 3 Mean		4.3	4.0
Mean±SD (3 Samples)		**4.2±0.02**	**4.0±0.07**
		Non-Organic Kiwi	**Organic Kiwi**
Sample 1	Trial 1	5.6	4.9
	Trial 2	5.8	5.0
	Trial 3	6.2	4.7
Sample 2	Trial 1	5.5	5.1
	Trial 2	5.4	4.9
	Trial 3	5.6	5.2
Sample 3	Trial 1	5.3	5.0
	Trial 2	5.4	4.9
	Trial 3	5.4	4.8
Sample 1 Mean		5.6	4.9
Sample 2 Mean		5.5	5.1
Sample 3 Mean		5.4	4.9
Mean±SD (3 Samples)		**5.5±0.11**	**5.0±0.09**

Table 1: Volume (mL) of iodine needed to titrate 20 mL of juices.