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Content Comparison of Organic and Conventional Celery

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Abstract

The dispute between organic vs. conventionally grown vegetables has encouraged us to investigate using a comparative study of the chemical compositions of organic and conventionally grown celery. Celery is used in a variety of food products including soups, stews, sauces, and vegetable platters. It is full of nutrients like vitamin k, vitamin C, potassium, and folic acid along with minerals like magnesium, calcium, phosphorus, and zinc. The most recent method of consumption, juicing has been found to release flavonoids (cancer fighting antioxidants) and antifungal properties to fight infections. The major difference that separates organic from conventionally grown celery is the method farmers use to grow celery. The purpose of this article is to use a qualitative method of analysis to test for ions and functional groups, to identify different chemicals and define the pros and cons of organic celery. Value-added to organic farming industry has made it difficult to find fair scale of measurement to compare it with conventional farming. Furthermore, very few studies have been conducted specifically on celery and the debate between organic and conventional celery producers continues as to which plant is more beneficial for human consumption. This research is conducted in an undergraduate organic chemistry laboratory at Saint Augustine University. Even though significant claims are promoted for organic vegetables, our study shows no significant nutritional and food safety difference between organic and conventional celery tested in our laboratory.

Introduction

Based on the U.S. EPA's current recommendation, conventionally grown fruits and vegetables are considered safe [1]. The major difference between organic and conventional grown vegetables is the use of synthetic pesticides and mineral fertilizers. The EPA's testing requirements for pesticides used on food are more extensive than for chemicals in any other use category. They include testing targeted specifically to assess the potential risks to fetuses and children. The 2010 Pesticide Data Program Annual Summary confirms that any residues found in fruits and vegetables are at levels that do not pose risk to consumers' health. This nation's food supply continues to be among the safest in the world. Therefore, in this study, we did not see the need for additional analysis to further study the level of pesticides or other chemicals since this has been a high priority for EPA.

In our study, we use celery as a representative vegetable because of its availability and its high consumption in our area. Celery is a juicy vegetable with shallow roots and a short stem that belongs to the genus Apium and the family Apiacea. The dispute between organic and conventional celery is in the use of the type of fertilizers, herbicide, and pesticide [2]. Organic farmers use natural fertilizers to provide growth nutrition, organic herbicide to control unwanted weeds, and organic pesticide for pest control. Conventional farmers use synthetic products such as chemical fertilizers, herbicides, and pesticides to produce the plant. Efforts have been made to modify the production of organic food to be environmentally friendly, with fewer unhealthy chemical health hazards while leaving minimum pesticide and herbicide residue [3] in the final product.

The disadvantages of organic celery are its high cost of production, short shelf life, fast discoloration, and high risk of bacterial contamination. Several benefits of organic celery have been listed in the literature with 85% less synthetic chemical residue, healthy fatty acid content, more antioxidants [4], tasting better to some people, and creating more profit margin for farmers.

However as long as celery's nutritional and environmental needs are met the organic and conventional celery production is abundant. The most important nutritional [5] elements for the plant are carbon, hydrogen, nitrogen, phosphorous, potassium, sulfur and other inorganic minerals that are required for growth. Both organic and conventionally grown celery thrives in rich loose soil, pH level between 6.5 and 7.5 with 7 hours of direct sunlight temperature of around 50°C.

There is no definite method of comparing organoleptic properties of the two types of celery like the taste, appearance, color, aroma, size, and firmness. The emphasis in organic farming is to use natural products and supportive methodologies while conventional farming emphasizes the quantity of production. There is contention between the drive to go back to the old farming method by using natural fertilizers versus the drive to meet the demands of the growing world population. Because of the lack of clear demarcation between organic and conventional grown celery the choice relies heavily on individual preferences. In the case of the claim that "organic celery tastes better", the assessment method is nullified due to differing levels of phenolic compounds which repel insects by making the plant bitter. Another example is provided when comparing the concentration of nutrients like vitamin C and vitamin K, chromium, phosphorus, magnesium, iron, and nitrates in celery, findings confirm that over 95% of water in conventional celery will be more diluted.

A 2011 study was done to compare some nutritional values of juices made from organic and conventional apple, pear, blackcurrant, carrot, beetroot and celery [6]. Higher soluble solids content (SSC) for organic juices than for conventional ones was recorded for blackcurrant (14.9% and 12.5%, respectively) and beetroot (12.3% versus 8.3%). The highest organic acids content was noted for blackcurrant (3.7 g malic acid 100 g^{-1}), whereas the lowest was for celery (0.57 g 100 g^{-1} on average). Higher organic acids content was shown in apple, pear, and especially blackcurrant grown organically. Amounts of juice NH_4-N content were lower in organic vegetable juices than in conventional ones. The conventional farming method favored greater NO_3-N accumulation for beetroot (846 mg NO_3-N kg f.w.) than for organic juice (229 mg NO_3-N kg f.w.). The authors concluded that their data showed the organic juices to have polyphenols and ascorbic acid content similar to, and antioxidant activity slightly higher than, conventional juices.

Another study was published in 2004 that surveyed existing literature comparing nutrient content of organic and conventional crops using statistical methods to identify significant differences and trends in the data [7]. They reposted that organic crops contained significantly more vitamin C, iron, magnesium, and phosphorus and significantly less nitrates than conventional crops. There were non-significant trends showing less protein but of a better quality and a higher content of nutritionally significant minerals with lower amounts of some heavy metals in organic crops compared to conventional ones. The authors concluded that there appears to be genuine differences in the nutrient content of organic and conventional crops.

A similar study was done to conduct a literature-based comparison of nutrient and contaminant contents between organic and conventional vegetables and potatoes [8]. They developed detailed nutrient and contaminant databases for organic and conventional vegetables separately. Non-parametric (Mann-Whitney test) methods were used to detect significant differences between both types of vegetables. A chi-square test was used to compare the incidence of pesticide residues in organic and conventional vegetables. They reported that from a nutritional and toxicological point of view, organic vegetables and potato in general are not significantly better than conventional vegetables and potatoes. For some nutrients and contaminants organic vegetables and potatoes score significantly better but for others they score significantly worse. Therefore, they stated that it became difficult for them to justify general claims indicating a surplus value of organic over conventional vegetables and potatoes. The goal of this study is to further confirm these controversial findings by researchers in previous published reports using celery as a representative vegetable for our analysis.

Methods

In this study qualitative identification of organic and inorganic substances in celery juice was conducted through a two-step process. The first part of the test was to identify cations and anions in both the organic and conventionally grown celery of group I-V methodology. In the second part, the physical properties of both products are identified and important functional groups are used to test the presence of compounds that will difference between the two vegetables.

Chemicals and Materials used

A comparative test for the organic and traditionally grown celery was tested for Group I cations (Ag^+, Pb^{2+}, and Hg_2^{2+}), for group II cations (Hg^{2+}, Bi^{3+}, Cu^{2+}, Cd^{2+}), for group III cations (Co^{2+}, Ni^{2+}, Fe^{3+}, Mn^{2+}, Cr^{3+}, Al^{3+}, and Zn^{2+}), group IV cations (Ca^{2+}, Sr^{2+}, and Ba^{2+}), and group V cations (Mg^{2+}, K^+, Na^+, and NH_4^+). The samples are also tested for organic functional groups of olefins, alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, phenols, and amines. The samples were tested for polyatomic anions such as sulfates, nitrates, phosphates, and ammonium cation. Spectroscopic instruments like mass, infrared, NMR spectroscopy were taught in the lecture but the instruments were not available in our school therefore we chose to conduct the following experiments which turned out to be an effective end-of-semester project.

Procedure and Results

1. Chemical Properties

Functional Groups	Test Name
Test for Unsaturation	Baeyer's test
	$R\text{-}CH{=}CH\text{-}R + 2H_2O + 2KMnO_4 \rightarrow R\text{-}CH(OH)\text{-}CH(OH) + MnO_2 + K_2MNO_4$
	$R\text{-}C{\equiv}C\text{-}R + 2H_2O + 2KMnO_4 \rightarrow R\text{-}CH(OH)\text{-}CH(OH) + MnO_2 + K_2MNO_4$
Test for 1^0, 2^0 & 3^0 alcohol	Lucas Test
	$RCH_2OH + ZnCl_2 + HCl(aq) + \Delta \rightarrow RCH_2Cl + H_2O + HCl(aq)$
	$R_1(R_2)CH\text{-}OH + ZnCl_2 + HCl(aq) \rightarrow R_1(R_2)CH_2Cl + H_2O + HCl(aq)$
	$R_1(R_2)(R_3)C\text{-}OH + ZnCl_2 + HCl(aq) \rightarrow R_1(R_2)(R_3)CCl + H_2O + HCl(aq)$
Test for Aldehyde	Tolen's test
	$R\text{-}C(O)H + AgNO_3(aq) + NaOH(aq) + NH_4OH(aq) \rightarrow$
	$R\text{-}C(O)OH(aq) + Ag(S) + 4NH_3(aq) + 2H_2O(l)$
Test for Ketones	Iodoform
	$2R\text{-}C(O)CH_3 + I_2 + 2NaOH(aq) \rightarrow 2CH_3I(aq) + 2R\text{-}C(O)O^- Na^+(aq)$
Test for Carboxylic acid	$R\text{-}C(O)OH(aq) + NaHCO_3 \rightarrow R\text{-}C(O)O\text{-}Na+ + CO_2 \uparrow$
Test for Phenolics	$Phenol + 3Br_2 \rightarrow PhenolBr_3 + 3HBr$
Test for Esters	$R_1\text{-}C(O)R_2 + CH_3CH_2OOH + H_2SO_4 + \Delta \rightarrow$ Fruity smell
Test for Acetyl chloride	$R\text{-}C(O)Cl + CaSO_4 + 3NH_4OH(aq) \rightarrow$
	$R\text{-}C(O)OH(aq) + Cu(OH)_2(aq) + (NH_4)2SO_4 + NH_4Cl\uparrow$
Test for Ammonium group	Litmus paper → Red to blue
Test for Carbonyl amine	$R\text{-}C(O)NH_2 + KOH(s) +$ Ethanol + Chloroform $\rightarrow R\text{-}C{\equiv}N\uparrow + ...$

2.Physical properties

The organic and conventional celery juice was soluble in water and the organic compounds were dissolved in dichloromethane. The pH of celery was between 5.7- 6.0 and the density of centrifuged celery was 1.0137 g/cm^3. The boiling points of the juices were in the range of 100.0 ± 2.0^{0}C.

Analysis

The functional groups that play an important role in the identification and characterization of celery juice are unsaturated hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids, esters, and amides. The presence of carbon-carbon double and triple bonds in organic molecules found in celery was tested using Baeyer's test by adding dilute potassium permanganate as an oxidizing agent. The evidence for the reaction was the discoloring of the purple $KMnO_4$ which becomes clear for alkenes as well as for alkynes; alkenes will also form glycols. The presence of the double bonds was detected in both the organic and the conventional samples. $3H_2C{=}CH_2 + 2KMnO_4 + 4H_2O \rightarrow 3CH_2(OH)CH_2(OH) + 2MnO_2 + 2KOH$.

The second experiment performed to differentiate between organic and conventional celery was the test for primary, secondary, and tertiary alcohols. $3C_3H_8O(l) + 2CrO_3(s) + 3H_2SO_4(aq) \rightarrow Cr_2(SO_4)_3(s) + 3C_3H_6O(l) + 6H_2O(l)$.

Primary and secondary alcohols were tested using the Lucas test in concentrated hydrochloric acid and zinc chloride. Tertiary alcohol reacted immediately with the samples while secondary alcohol took a few minutes to turn cloudy and the primary alcohol required heating of the sample before the appearance of white precipitation. Both the organic and conventional celery samples responded the same way to the Lucas test.

The third experiment performed was a test for an aldehyde using the Tollens' test. Silver nitrate in NaOH formed a silver oxide precipitate which presented as a dark brown solid in the solution. Addition of NaOH and NH_4OH dissolved the silver oxide and when the aldehyde was added to the solution, Ag_2O was reduced to solid silver metal. The aldehyde was oxidized to carboxylic acid and left behind a silver mirror in the glass container.

R-CHO + Ag_2O → R-COOH + Ag(s)

The fourth experiment uses a ketone test known as the iodoform test and was conducted by adding sodium bicarbonate to the two samples. The chemical reaction was as follows:

RCOR' + $NaHCO_3$ → $RCOO^-$ Na^+ + CO_2 + H_2O. The carbon dioxide gas was an indication that ketone has been oxidized to carboxylic acid.

The test for the phenolic compounds is the Lieberman test. This test was performed for a group of phenol compounds by using bromine water as the reagent. The reaction is an electrophilic substitution reaction in which the hydroxide electron-donating group enhances ortho- and para- substitution of the hydrogen atom by bromine forming a polybromide molecule.

$3B_2$(aq) + C_6H_6O → $C_6H_3Br_3O$ (2,4,6-tribromophenol) + 3HBr.

Discussion

Functional groups are a reliable source of identification for distinctive chemical and physical properties of molecules. The functional groups in this study to identify the inorganic cations and anions and the test for functional groups in organic and conventionally grown celery showed no difference in the results. When it comes to choosing which product to use the following recommendation is provided to help with the decision. Organic producers assure the public that they implement the use of a minimal amount of herbicide, pesticide, fertilizers, and genetically engineered organisms. Regarding GMO there is no evidence that celery is genetically engineered to modify its DNA to fight insects or to repel chemical insecticides. USDA has realized and removed unnecessary regulations on farmers that produce conventional celery so that their profitability exceeds their production cost. In both cases, celery is safe from GMOs but the health risk comes from the overuse of pesticides to protect the celery stocks from being attacked by organisms.

More than 95% of animals that are used for meat and dairy products consume GMO foods like corn and the resulting manure from these animals are used in organic farming. It is reasonable to assume the manure that comes from the GMO fed animals will have modified bacteria, antibiotics, and growth hormones in their compost. When considering compost that comes from other animals it has been noted that farmers use arsenic to strengthen the eggshells of chicken, and horses freely graze on grounds where the grass has been sprayed with pesticides. Organic fertilizers have several issues to consider before declaring composts supplied by farms and GMO fed animals are safe to use as fertilizers.

The defense for conventional farming methods and the challenges of producing organic celery need a standardized method of comparison. Organic certification requires farmers grow crops with restricted synthetic fertilizers, a limited amount of pesticide, and yearly crop rotation. Recent studies show that organic crops are expensive as they need 25% more farmlands, with low product yield and labor-intensive farming. These may result in less antioxidants, and low vitamins or minerals. On the positive note organic farming produce 7% more phosphorous in celery and farmers benefit from these lucrative businesses. The young and the affluent consumer prefer organic celery while the older population and low-income families prefer conventional celery. Presently, the following two organizations offer the latest information about vegetables.

1. The United States Department of Agriculture (USDA) in 2017 declared that the food supply in developed countries is among the safest in the world; this includes conventionally grown celery. USDA has studied more than 600 pesticides and among those that are found in conventionally grown vegetables, the amount is below the FDA tolerance level. Furthermore, scientific community agrees that the toxicity of these chemicals greatly outweighs the benefits and they recommend to include ample amount of vegetables in every ones daily diet. Others are concerned about the serious health risk of male sterility, early female puberty, and rising cancer rates. However, there are not enough research to scientifically correlate the growing cancer to the consumption of synthetic pesticides in vegetables.

2. On the other side of the spectrum The Environmental Working Group (EWG), is an American activist organization that promotes healthy living from published scientific research and by holding producers accountable to avoid harmful chemicals. EWG has listed conventional celery as one of the dirty dozen vegetables in 2021 and it is listed as the 11th most dangerous vegetable to consume. While their list is impressive, they promote organic farming and their list is considered biased by many conventional farmers. USDA and EWG has website that provide valuable research information and the choice between organic and conventional celery is left for the consumers.

Based on our findings, similar to the study done by Hoefkens et al [8]. we were not able to find any significant difference in their content or type of organic molecule content, food safety issues, and nutritional difference between the two products tested in our study. One of the limitations of the study was the fact that we did not test for presence of pesticide or any other chemicals residues.

Conclusion

In conclusion, the experiment to find the difference between organic and conventional celery gave a multilevel platform to instill hands-on training for organic chemistry students while they were solving real-world problems. The project promoted scientific and experimental inquiry while encouraging student independence and innovation when they were performing their wet experiment, writing their report, and doing their oral presentation. Even though significance claims are promoted for organic vegetables these study shows no significant nutritional and food safety difference between organic and conventional celery. The conclusion that was reached from this study is threefold: to encourage organic farmers to produce harmless celery specially for those that are sensitive to ingesting minute amounts of synthetic pesticide and herbicide; to reassure conventional American farmers who are currently meeting the standards of EPA regulations to continue mass production, and to encourage the consumers to thoroughly wash celery stems with water and baking soda before consumption.

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