

**EVALUATION OF VITAMIN C CONTENT FROM TWO VARIETIES OF MANGOES
IN MARKETS OF MBALE CITY**

BY

MUSOBO SOLOMON

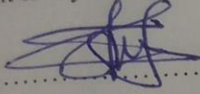
BU/UP/2020/0676

**A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF CHEMISTRY IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF
BACHELOR OF SCIENCE EDUCATION DEGREE OF BUSITEMA UNIVERSITY**

SEPTEMBER 2023

DECLARATION

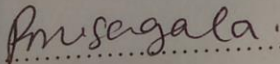
I, Musobo Solomon, declare that this research work is my own piece of work. I confirm that this work is my own and it has not been submitted before to any of the University.



MUSOBO SOLOMON

Date... 21/11/2024

This research project report has been submitted to the Department of Chemistry with the approval as supervisor:



Mr. Musagala peter

Date... 21/11/2024.

ACKNOWLEDGEMENT

I thank my father Mr. Sunguka Albert and my mother Ms. Kabai Joan who support me financially, advised me in my career for my academic success right from primary level to secondary level and eventually to university level.

I thank the Almighty God for the grace upon my life and for the lives of the following people who played a big role in helping me discover my strengths and who greatly supported me in the course of this great achievement in my academic career.

I thank my supervisor Mr. Musagala Peter for his time, support, patience, advice and diligent review of my work and all the academic and non-academic staff of the department of chemistry, Busitema University, for the cooperation put in throughout my academic pursuit.

All my friends and colleagues especially those of Musene Benjamin, Otim Nicholas, Chesang Davis and Kissa Sam who encouraged and supported me throughout my studies and my course mates for the entire cooperation we had with them.

TABLE OF CONTENTS

DECLARATION.....	Error! Bookmark not defined.
ACKNOWLEDGEMENT	ii
LIST OF TABLES	v
LIST OF FIGURES	vi
ABBREVIATIONS.....	vii
ABSTRACT.....	viii
CHAPTER ONE: INTRODUCTION	1
1.1 Background to the Study.....	1
1.2 Statement of the problem	2
1.3 Objectives of the Study.....	2
1.3.1 General objective	2
1.3.2 Specific objectives	2
1.4 Justification of the Study	2
1.5 LITERATURE REVIEW	3
1.5.1 Vitamin C and its Significance.....	3
1.5.2 Vitamin C concentrations in mangoes.....	4
CHAPTER TWO: EXPERIMENTAL	10
2.1 Apparatus	10
2.2 Materials	10
2.3 METHODS	10

2.3.1 Starch indicator solution	10
2.3.2 0.005molL ⁻¹ standard iodine solution.....	11
2.3.3 Vitamin C standard solution.....	11
2.3.4 Sample preparation	11
2.3.5 Procedure for Iodometric Titration	11
CHAPTER THREE: RESULTS AND DISCUSSION.....	13
1.1 RESULTS.....	13
3.1.2 The concentration of vitamin C in mango varieties grown in Mbale City.	13
3.1.3 Comparison of the concentration of vitamin C in each of the varieties of mangoes	14
3.2 DISCUSSION	14
CHAPTER FOUR: CONCLUSIONS AND RECOMMENDATION	16
4.1 Conclusions.....	16
4.2 Recommendations.....	16
REFERENCES	17

LIST OF TABLES

Table 1: Average volume of iodine used.....	9
Table 2: Concentration of Vitamin C in Mango Varieties.....	9
Table 3: Variations in Concentration of Vitamin C within varieties of mangoes.....	10

LIST OF FIGURES

FIGURE 1 Alfonso Mango

FIGURE 2 Palmer Mango

ABBREVIATIONS

AA- ascorbic acid

DNA – Deoxyribonucleic acid

RNA - Ribonucleic acid

ABSTRACT

The study deals with analysis of ascorbic acid content of mangoes grown from Mbale city. Iodometric titration method was used to determine the concentrations of Vitamin C in different mango. The results indicate that the Vitamin C concentrations in Alfonso and Palmer varieties was 62.172 mg/100g and 54.34 mg/100g respectively. The results show that there was difference between concentrations of Vitamin C within the varieties of mangoes. Precisely, considering mango varieties, Alfonso variety had the highest concentration of Vitamin C per 100 g than Palmer mango variety.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Micronutrient deficiency continues to be a major challenge across low- and medium-income countries (Black, Victora et al. 2013). Notable forms of micro-nutrient deficiency include iron deficiency, anemia, iodine, zinc, and several forms of vitamin deficiency like A, B12, D, and importantly C among others (Berger, Pantet et al. 2019). These are often manifested in different forms like stunting, wasting, low birth weight, low height for age measures, and consequently overweight and obesity. Concerning vitamin C (Ascorbic acid), its deficiency which is widely known as scurvy (Schlueter and Johnston 2011) equally poses a significant challenge with far-reaching implications for public health and well-being. Women of childbearing age, the elderly, the sick, children and generally marginalized communities are the most affected persons. For instance, a cohort study by (Moya-Alvarez 2021) in the Central African Republic indicated that there's a high prevalence of Vitamin C deficiency among mothers and their infants.

The significance of Vitamin C deficiency is largely attributed to the crucial role in various physiological processes like collagen synthesis, antioxidant defense, and immune function, as well as its role as an antioxidant, regulation of gene expression, neurotransmitter synthesis, and the enhancement of iron absorption (Li and Schellhorn 2007) (Schlueter and Johnston 2011). Understanding these functions is essential for comprehending the broader impact of vitamin C deficiency on health (Harrison and May 2009). Thus, substantial deficits in the intake of Vitamin C lead to increased susceptibility to infections, impaired wound healing, and various chronic diseases (Carr and Rowe 2020).

1.2 Statement of the problem

Vitamin C deficiency poses a significant threat to public health. This is attached to the fact that deficiency of ascorbic acid is associated with the development of scurvy, certain cancers, and cardiometabolic ailments among others. In this regard, Vitamin C contributes highly towards several physiological processes like collagen synthesis, antioxidant defense, and immune function, as well as its role as an antioxidant, regulation of gene expression, neurotransmitter synthesis, and the enhancement of iron absorption. As such, vulnerable persons, especially women of childbearing age, infants, the elderly, sick, marginalized, and both poverty-stricken communities are the most affected. However, vitamin C deficiency is driven by environmental and biological factors ranging from inadequate intake of nutritious foods, infections, malabsorption, climate change, low bioavailability, and high levels of poverty among others

1.3 Objectives of the Study

1.3.1 General objective

To determine and compare ascorbic acid content in locally available varieties of mangoes in markets of Mbale City.

1.3.2 Specific objectives

- (i) To determine the concentration of vitamin C in mango varieties grown in Mbale City
- (ii) To compare the concentration of vitamin C in each of the varieties of mangoes.

1.4 Justification of the Study

Vitamin c is a vital nutrient that plays several critical roles in human health. It is an essential antioxidant that helps and protects cells from damage caused by free radicals. vitamin c is crucial

for the synthesis of collagen which is necessary for the health of skin, cartilage, ligaments and blood vessels.

1.5 LITERATURE REVIEW

1.5.1 Vitamin C and its Significance

Vitamin C also known as ascorbic acid serves as an essential water-soluble micronutrient that is vital for healthy growth. Its significance is particularly attributed to its critical contribution to the body's physiological processes such as collagen synthesis, immune function, and the absorption of non-heme iron among others (Yebio, Gebrelibanos et al. 2015). Additionally, the antioxidant properties of Vitamin C are known to combat oxidative stress and inflammation in the body (Carr and Rowe 2020). Its antioxidant significance is attributed to its effectiveness even small amounts of vitamin C can protect indispensable molecules in the body such as proteins, lipids (fats), carbohydrates, and nucleic acids (DNA and RNA), from damage of free radicals and reactive oxygen species that can be generated during normal metabolism as well as through exposure to toxins and pollutants like cigarette smoke. Vitamin C is also important in the formation and repair of bones, teeth, and collagen, the body is major building protein. In addition, vitamin C is required for the synthesis of carnitine, a small molecule that is essential for the transport of fat into cellular organelles called mitochondria, where the fat is converted to energy. The above functions partly highlight the pertinent significance of Vitamin C in maintaining good and sound health.

Since the human body cannot synthesize Vitamin C, one must obtain this essential nutrient from his or her daily dietary intake. Adequate consumption of diverse fruits and vegetables is viewed as the most effective way to ensure adequate consumption of Vitamin C. A balance must therefore be made in choosing which fruits and vegetables offer enough and acceptable amounts

of this essential nutrient to meet the recommended daily allowance for optimal functioning. However, this is only possible if the nutritive profiles of these fruits are readily available to guide consumers in their choice of food products. This therefore exposes people to choices of fruits and associated varieties with suboptimal concentrations of Vitamin C, - a situation that leads to inadequate consumption of Ascorbic Acid.

This exposes consumers to several health challenges, some of which have fatal implications. The most notable danger associated with Vitamin C deficiency is the development of a condition known as scurvy (Schlueter and Johnston 2011). This disease exudes symptoms like bleeding and bruising easily, hair and tooth loss, joint pain, and swelling, and resultantly leading to the weakening of blood vessels, connective tissue, and bone. Additionally, symptoms such as hemorrhages under the skin and a tendency to bruise easily, poor wound healing, chronic weakness, poor digestion, bronchial infection, and colds are also indicative of an undersupply of ascorbic acid (Muhammad, Ashiru et al. 2014).

Furthermore, other underlying consequences of Vitamin C deficiency include the onset of chronic ailments such as cardiovascular diseases like hypertension, cataract – the leading cause of visual impairments, increased lead toxicity, and certain cancers. To avert these conditions, adequate intake of diverse diets, and the addition of fruits and vegetables have been some of the viable options being explored. Thus, including mangoes and citrus fruits in the diet provides a delicious way to meet daily vitamin C requirements and promote overall health. However, there is less data available on the level of Vitamin C.

1.5.2 Vitamin C concentrations in mangoes

Mangoes, known as the "king of fruits," are not only celebrated for their rich flavor and aroma but are also recognized as a source of essential nutritional supplements (Maldonado-Celis, Yahia

et al. 2019). Mangoes are particularly known as a good source of several bioactive compounds such as Vitamin C (Rymbai, Srivastav et al. 2013). Therefore, due to its potential health benefits and contribution to overall human nutrition, the concentration of vitamin C in mangoes has been a subject of interest, attracting robust research.

However, just like citrus fruits, studies conducted have shown that several factors influence the vitamin C concentration in mangoes. These include ripeness, post-harvest handling, and environmental conditions among others (Maldonado-Celis, Yahia et al. 2019). According to (Ouma, Ambuko et al. 2014) indicate that the vitamin C content in mangoes tends to increase during the ripening process, reaching optimal levels in fully ripened fruits. Just as with oranges, different varieties of mangos exhibit variations in the level of vitamin C, with some mango cultivars demonstrating higher concentrations of vitamin C than others (Ouma, Ambuko et al. 2014). This can in part be attributed to advances in genetic and post-harvest technologies that offer promising avenues for optimizing vitamin C levels in mangoes and variations in climatic and geographic zones from which these plants are grown (Le, Viet Nguyen et al. 2022). Additionally, post-harvest processing and storage conditions can affect the vitamin C content of mangoes. For example, poor post-harvest handling methods such as exposure to heat, light, and prolonged storage can lead to vitamin C degradation in mangoes (Le, Viet Nguyen et al. 2022). This necessitated the invention of storage methods, such as controlled atmosphere storage, to preserve the vitamin C levels in mangoes during post-harvest handling (Maldonado-Celis, Yahia et al. 2019, Le, Viet Nguyen et al. 2022). Understanding these factors is crucial for harnessing the nutritional potential of mangoes and promoting their role in a healthy, balanced diet.

Furthermore, the variations in Vitamin C content therefore underscore the importance of selecting mango varieties with optimal nutritional profiles for maximizing vitamin C intake.

However, there is a scarcity of data profiling the nutritive quality of these precious fruits, especially about Vitamin C concentrations. Further targeted research must be conducted to ascertain the levels of Vitamin C in different varieties of mangoes consumed by locals, if any headway is to be made in ensuring that vulnerable persons are particularly protected from the likely consequences of Vitamin C deficiencies.

1.5.3 Fruit ripening

Ripening is the process by which mangoes and oranges attain their desirable flavor, quality, colour, palatable nature and other textural properties. Ripening is also associated with the change in composition that is conversion of starch to sugar. An important factor of ripening is the natural plant hormone ethylene (C₂H₄), which is produced by the fruit itself and released as a gas into the surrounding atmosphere (Thakur and Kumar 2017). The released ethylene accelerates the ripening and senescence processes, making the fruit react very strongly to it. Exposing immature fruit to ethylene can trigger this autocatalytic response, causing premature ripening and result in fruit with poor eating quality which may cause health problem (Sharma, Negi et al. 2023).

The predominant pathway of vitamin C degradation in aqueous water systems entails the oxidation of ascorbic acid to dehydro ascorbic acid, which itself promptly degrades. Vitamin C degradation depends slightly on the temperature in a range of 27-36°C for mangoes (Vu, Nguyen et al. 2023).

Above this temperature there is a high rate of loss in vitamin C concentration.

1.5.3 Roles of vitamin C in mangoes

1.5.3.1 Cancer

Cancer is a global public health problem with increased mortality levels. Though there are many types of cancers, the review presents a general picture of the role of ascorbic acid in cancer. Vitamin C is effective in protecting against oxidative damage in tissues, and also suppresses formation of carcinogens like nitrosamines (Walingo 2005). Despite progress against some rare forms of cancer, the overall death rate has increased. Though Vitamin C is cytotoxic to tumor cells but non-toxic to normal cells, conventional medicine favors more powerful and toxic chemotherapeutic agents (Isola, Gammeri et al. 2024).

1.5.3.2 Blood pressure

Elevated blood pressure is a powerful determination of cerebro-vascular and coronary disease. Great efforts have been made towards the detection and treatment of hypertension. Some of the observed decrease in cardiovascular disease over the period has been attributed to better control of blood pressure among diagnosed hypertensives (Meissner 2016). The importance of nutrition in control of blood pressure is well documented. Obesity, dietary sodium and alcohol are associated with lower or higher blood pressure. Higher intake of polyunsaturated fatty acids and magnesium have also been linked with lower blood pressure (Joffres, Reed et al. 1987).

1.5.3.3 Immunity

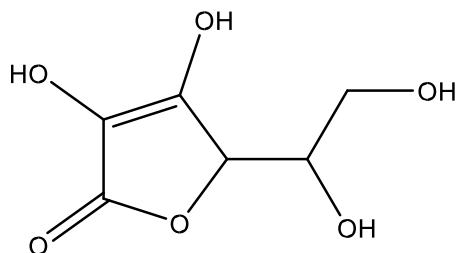
In stressful situations adrenal glands react by releasing hormones that trigger the “fight or flight” reaction. It has been indicated that 200mg of vitamin C a day may reduce the levels of stress hormones. Stress suppresses the immune system (McCabe, Lisy et al. 2017). Mega doses of vitamin C increase the levels of antibody that fights against germs and viruses in both stressed and unstressed rats, with greater antibody increase in the unstressed rats. Stressed animals may

need larger vitamin C doses for proper function of the immune system (Dawood and Koshio 2018).

1.5.4 Structure of Vitamin C

Vitamin C is an important human micronutrient. It has many vital biological functions in human health and the molecule of vitamin C was optimized and energy band gaps were determined using DFT and HF methods. Currently play a significant role in physical chemistry spatially. The observed vibrational frequencies are assigned and the computational calculations are performed and the corresponding results are displayed. The structure analysis of the present molecule was investigated by NMR (^{13}C NMR & ^1H NMR) (Ahmed and Omer 2020).

STRUCTURE OF VITAMIN C



1.5.4 Methods for determining the concentration of vitamin C in mangoes

Many analytical methods have been used for the determination of vitamin C content. These include conventional titration method, fluorimetry, spectrometry, chemiluminescence, enzymatic methods, capillary electrophoresis, electrochemical methods, amperometry, HPLC are the most common (Skrovankova et al, 2015).

Use of titration method determines the concentration of vitamin C content in solution by redox titration using iodine. Vitamin C commonly called ascorbic acid, is an essential antioxidant

needed by the human body. As iodine is added during the titration, ascorbic acid is oxidized to dehydroascorbic acid, while the iodine is reduced to iodide ions (Meyiwa 2020).

In spectrometric method, the total amount of vitamin C (Ascorbic acid + Dehydroascorbic acid) is determined in mangoes by using UV spectrophotometer. Here bromine water is used which oxidizes the ascorbic acid to dehydroascorbic acid in the presence of acetic acid. Vitamin C is able to absorb UV rays (Desai and Desai 2019) .

Another method is simple fluorimetric method, for determination of AA which is based on the condensation reaction between AA and O-phenylenediamine (OPDA) (Arya et al, 1998). For the oxidation of AA to DHA and reaction with OPDA, the oxidant (DCPIP,N-bromo succinimide and iodone) is used. The sensitivity of common OPDA method is low due to blank effect of the oxidant. Wu and his co-workers (Wu et al, 2003) develop OPDA method when AA can react with OPDA in the absence of the oxidant at PH 9.4, so the sensitivity of the determination is better and the detection limit is lower. Fluorimetric method with 2,3-Diamy nonaphthalene (DAN) at PH 10.2 to 10.5 and cyanoacetamide at PH 12.9 to 13.3 could be used for AA analysis.

Ascorbic acid could also be evaluated by flow injection analysis (FIA). There are many modifications of this technique (Boroumand, Chamjangali et al. 2017). Its versatility, simplicity, and reasonable costs, and possible combination of the FIA method with spectrophotometry, chemiluminescence, electrochemical methods, potentiometry, are advantageous parameters for many different analytical measurements.

CHAPTER TWO

EXPERIMENTAL

2.1 Apparatus

Conical flasks, measuring cylinders, plastic beakers, burette, electronic balance, pipette, mortar and pestle were obtained from Busitema University laboratory, Faculty of Science and Education, with the help of Department of Chemistry.

2.2 Materials

Vitamin C standardized solution, standard iodine solution, potassium iodide, starch indicator solution, deionized water were of analytical grade **(was obtained from Busitema University laboratory, Faculty of Science and Education, with the help of Department of Chemistry).**

Two varieties of mangoes, which include; Alfonso and Palmer got from Mbale city.

2.3 METHODS

2.3.1 Starch indicator solution

The starch indicator solution was prepared by dissolving starch powder (1g) added 10 ml of distilled water, stirred well and then transferred to 100 ml boiling water.

2.3.2 0.005M standard iodine solution

The standard iodine solution was prepared by dissolving potassium iodide (2g) into 250 ml volumetric flask and iodine (1.3g) was added into the same flask. 50 ml of water was added swirled for a few minutes until the iodine dissolved.

2.3.3 Vitamin C standard solution

Vitamin C standard solution was prepared by dissolving vitamin C (0.25g) with 100 ml of water in a beaker.

2.3.4 Sample preparation

The fresh collected variety of mangoes were washed thoroughly using normal tap-water. 100g sample of the varieties was cut into small pieces and grinded in a mortar and a pestle. 10 ml portions of distilled water is added several times while granting the sample, each time decanting off the liquid into a 100 ml volumetric flask

Figure 1 Alfonso mango



Figure 2 Palmer mango



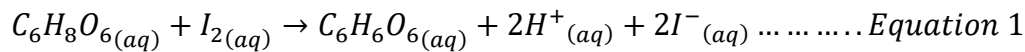
2.3.5 Procedure for Iodometric Titration

20 ml sample solution was pipetted into a 250ml conical flask and starch solution 3 drops of 0.5% was added into the flask. The burette was rinsed with a small volume of iodine solution and then filled up to the mark and the initial volume was noted. The sample solution from a specific variety of mangoes was then titrated against the iodine solution until the endpoint was reached

(dark blue-green color) that persisted after 20 seconds of swirling the solution. The final volume of the iodine solution was noted and recorded. The procedures were repeated twice until consistent results were obtained and recorded.

2.3.6 Data analysis

To determine vitamin C content in mango and orange varieties respectively, by titration method using iodine solution, it is imperative to keep in mind that despite iodine being almost insoluble in water, it is a weak oxidizing agent, and it would only oxidize vitamin C as far as desired. As a result, Vitamin C reacts with iodine according to equation 1.



Based on equation 1, the concentration of Iodine, - I_c used was calculated using equation 2.

$$I_{2c} = \frac{(\text{Concentration of Iodine solution used} \times \text{Average volume of Iodine Solution used})}{1000} \dots \dots \text{Equation 2}$$

From these, the concentration of Iodine used is equivalent to the concentration of Vitamin C (V_{c1}).

This implies that $I_{2c} = V_{c1}$.

Thus, using results from Equation 2, - (V_{c1}) and referring to Equation 1, the standard concentration of Vitamin C, V_{c2} in each variety of mangoes was calculated using Equation 3.

$$V_{c2} = \left(\frac{\text{Concentration of Vitamin C (Vc1)} \times 1000}{\text{Pipette Volume (20 ml)}} \right) \dots \dots \text{Equation 3}$$

With the weight (g) of each fruit variety known, the concentration of Vitamin C ($Mc2$) in milligrams per 100g of the fruit was calculated from Equation 4.

$$Mc2 = \left(\frac{\text{Standard Concentration of Vitamin C} \times 1000}{\text{Weight of the sample}} \right) \dots \text{Equation 4}$$

CHAPTER THREE

RESULTS AND DISCUSSION

1.1 RESULTS

3.1.1 Volume of iodine used in the determination of the concentration of vitamin C by titration method.

Table 3: Average volume of iodine used

Fruit Category	Fruit variety	Average volume of iodine used (cm ³)
Mango variety	Alfonso	14.13 ± 0.08
	Palmer	12.35 ± 0.05

3.1.2 The concentration of vitamin C in mango varieties grown in Mbale City.

The results of concentrations of Vitamin C in mango varieties are shown in Table 2.

Table 4: Concentration of Vitamin C in Mango Varieties

Mango variety	Concentration of Vitamin C in moles per liter (mol/L)	Concentration of Vitamin C in milligrams per 100g (mg/100g)
Alfonso	3.5325×10^{-3}	62.172

Palmer	3.0875×10^{-3}	54.34
--------	-------------------------	-------

The results indicate that the Vitamin C concentrations in Alfonso and Palmer varieties was 62.172 mg/100g and 54.34 mg/100g.

3.1.3 Comparison of the concentration of vitamin C in each of the varieties of mangoes

The results of comparing concentrations of Vitamin C within respective varieties of mangoes, and concentrations of mangoes are presented in Table 3.

Table 3: Variations in Concentration of Vitamin C within varieties of mangoes

Mango variety	Concentration of Vitamin C in milligrams per 100g (mg/100g)	Weight percent (%)
Alfonso	62.172	62.2
Palmer	54.34	54.3

The results show that there was a significant difference between percentage weights of Vitamin C within both the varieties of mangoes. Precisely, considering mango varieties, Alfonso variety had the highest percentage of Vitamin C per 100g than Palmer mango variety.

3.2 DISCUSSION

Findings on the weight of vitamin C content in Table 2 above show that Alfonso weighed 62.172mg per 100g of sample, Palmer 54.34mg per 100g of sample of vitamin C in mango

varieties. This means that the Alfonso variety had the greatest weight and the palmer had the least weight between the two mango varieties and this may be due to high degradation of vitamin C during ripening.

The weight of the vitamin C standard solution was 50mg per 0.250g. This means that the mango varieties had the weights in comparison with the vitamin C standard solution of Alfonso

The above results show that about 3-5 mangoes should be eaten per day and this number is very high as compared to what health experts recommend. Usually, the concentration of vitamin C decreases with ripeness because of the oxidation of vitamin C.

The variability in vitamin C content of various mangoes and their products is also influenced by variety, cultural practice, maturity, climate, fruit quality, fresh fruit handling, processing factors, packaging, and storage conditions.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATION

4.1 Conclusions

Vitamin C is important in the health of humans and many species need a dietary source to stay healthy. Two fruit varieties of mangoes were used and their weights were expressed in weight percent of vitamin C in their samples, which were determined by titration method. The results of the two varieties were as follows; Alfonso 62.2% of the sample, and Palmer 54.3%, were samples of vitamin C in mango varieties.

The recommended daily amount for vitamin C is 15-75mg for children, 75mg per day for women, and 90mg a day for men. This implies that approximately 3-5 mangoes should be eaten per day.

4.2 Recommendations

All the two varieties of mangoes are rich in vitamin C and should be eaten when they are just ripening. Alfonso mango variety should be eaten to avoid some health problems like; cancer, and coronary heart disease among others since they contain much vitamin C compared to other varieties.

REFERENCES

1. Ahmed, L. and R. Omer (2020). "Spectroscopic properties of Vitamin C: A theoretical work." Cumhuriyet Science Journal **41**(4): 916-928.
2. Berger, M. M., et al. (2019). "Micronutrient deficiencies in medical and surgical inpatients. Journal of Clinical Medicine, 8(7). <https://doi.org/10.3390/jcm8070931>."
3. Black, R. E., et al. (2013). "Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet, 382(9890), 427–451. [https://doi.org/10.1016/S0140-6736\(13\)60937-X](https://doi.org/10.1016/S0140-6736(13)60937-X)
4. Boroumand, S., et al. (2017). "Double injection/single detection asymmetric flow injection manifold for spectrophotometric determination of ascorbic acid and uric acid: Selection the optimal conditions by MCDM approach based on different criteria weighting methods." Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy **174**: 203-213.
5. Carr, A. C. and S. Rowe (2020). "Factors affecting vitamin c status and prevalence of deficiency: A global health perspective. Nutrients, 12(7), 1–19. doi.org/10.3390/nu12071963."
6. Dawood, M. A. and S. Koshio (2018). "Vitamin C supplementation to optimize growth, health and stress resistance in aquatic animals." Reviews in Aquaculture **10**(2): 334-350.
7. Desai, A. P. and S. Desai (2019). "UV spectroscopic method for determination of vitamin C (ascorbic acid) content in different fruits in south Gujarat Region." International Journal of Environmental Sciences & Natural Resources **21**(2): 41-44.
8. Harrison, F. E. and J. M. May (2009). "Vitamin C function in the brain: Vital role of the ascoebate transporter SVCT2. Free Radical Biology and medicine 46 (6), 719-730."

9. Isola, S., et al. (2024). "Vitamin C Supplementation in the Treatment of Autoimmune and Onco-Hematological Diseases: From Prophylaxis to Adjuvant Therapy." International Journal of Molecular Sciences **25**(13): 7284.

10. Joffres, M. R., et al. (1987). "Relationship of magnesium intake and other dietary factors to blood pressure: the Honolulu heart study." The American journal of clinical nutrition **45**(2): 469-475.

11. Le, T. D., et al. (2022). " Supply Chain Management of Mango (*Mangifera indica* L.) Fruit: A Review With a Focus on Product Quality During Postharvest. *Frontiers in Sustainable Food Systems*, doi.org/10.3389/fsufs.2021.799431." ().

12. Li, Y. and H. E. Schellhorn (2007). " New developments and novel therapeutic perspectives for vitamin C. *Journal of Nutrition*, 137(10), 2171–2184
<https://doi.org/10.1093/jn/137.10.2171>."

13. Maldonado-Celis, M. E., et al. (2019). " Chemical Composition of Mango (*Mangifera indica* L.) Fruit: Nutritional and Phytochemical Compounds. *Frontiers in Plant Science*. [doi.org/10.13040/IJPSR.0975-8232.IJP.2\(2\).88-92](https://doi.org/10.13040/IJPSR.0975-8232.IJP.2(2).88-92)

14. McCabe, D., et al. (2017). "The impact of essential fatty acid, B vitamins, vitamin C, magnesium and zinc supplementation on stress levels in women: a systematic review." JBI Evidence Synthesis **15**(2): 402-453.

15. Meissner, A. (2016). "Hypertension and the brain: a risk factor for more than heart disease." Cerebrovascular diseases **42**(3-4): 255-262.

16. Meyiwa, B. (2020). "Iodometric and iodimetric titration methods." Journal Wetenskap Health **1**(1): 5-8.

17. Moya-Alvarez, V., Koyembi, J. C. J., Kayé, L. M., Mbecko, J. R., Sanke-Waîgana, H., Djorie, S. G., Nyasenu, Y. T., Mad-Bondo, D., Kongoma, J. B., Nakib, S., Madec, Y., Ulmann, G., Neveux, N., Sansonetti, P. J., Vray, M., & Marteyn, B. (2021). "Vitamin C levels in a Central-African mother–infant cohort: Does hypovitaminosis C increase the risk of enteric infections? *Maternal and Child Nutrition*, 17(4), 1–11
<https://doi.org/10.1111/mcn.13215>."

18. Muhammad, I., et al. (2014). " Effect of ripening stage on vitamin C content in selected fruits. *International Journal of Agriculture Forestry and Fisheries*, 2(3), 60–65.
<http://www.openscienceonline.com/journal/ijaff>

19. Ouma, L., et al. (2014). " Comparison of quality attributes of mango fruits produced from two contrasting agro-ecological zones of Kenya. RUFORUM Fourth Biennial Conference, Maputo, Mozambique, 19-25 July 2014, July, 235–240. <https://www.cabdirect.org/cabdirect/abstract/20173009500>."
20. Rymbai, H., et al. (2013). " Bio-active compounds in mango (*Mangifera indica* L.) and their roles in human health and plant defence - A review. *Journal of Horticultural Science and Biotechnology*, 88(4), 369–379. <https://doi.org/10.1080/14620316.2013.11512978>."
21. Schlueter, A. K. and C. S. Johnston (2011). " Overview and update. *Complementary Health Practice Review*, 16(1), 49–57. <https://doi.org/10.1177/1533210110392951>."
22. Sharma, M., et al. (2023). "Fruit ripening under heat stress: The intriguing role of ethylene-mediated signaling." *Plant Science*: 111820.
23. Thakur, K. and S. Kumar (2017). "Fruit maturity and ripening." *Fruit Science: Culture and Technology*: 358-373.
24. Vu, N. D., et al. (2023). "Effects of pH, total soluble solids, and pectin concentration on color, texture, vitamin C, and sensory quality of mango fruit bar." *International Journal of Food Science* **2023**(1): 6618300.
25. Walingo, K. (2005). "Role of vitamin C (ascorbic acid) on human health-a review." *African Journal of Food, Agriculture, Nutrition and Development* **5**(1).
26. Yebio, A., et al. (2015). "Comparison of Vitamin C Content in Fresh and Packed Juices of Orange and Mango. *International Journal of Pharmacognosy*, 2(2), 88–92. [https://doi.org/10.13040/IJPSR.0975-8232.IJP.2\(2\).88-92](https://doi.org/10.13040/IJPSR.0975-8232.IJP.2(2).88-92)."