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EXPLORING VITAMIN C STABILITY IN FRUITS AND VEGETABLES: A COMPARATIVE UV SPECTROSCOPIC INVESTIGATION- AN OVERVIEW

[1]S. Subiksha, [2]Anjali. M

[1]M. Sc Student, [2]Assistant Professor
[1]Department of Food Science and Nutrition,
[1]Dr. N.G.P Arts and Science College, Coimbatore, India

Abstract :Vitamin C, a crucial antioxidant, is essential for human health but can be degraded during processing, storage, and handling. Factors like temperature, light, and pH can impact its stability. This review explores the biochemical basis of vitamin C stability, its molecular structure, antioxidant functions, and factors influencing its stability. UV spectroscopy offers insights into vitamin C content in fruits and vegetables. Techniques like low-temperature freezing and non-thermal processing maximize nutrient retention, while high-pressure processing and pulsed electric fields enhance nutritional value.

Keywords- Vitamin-C; Antioxidant; UV Spectroscopy; Low temperature; Stability

I. INTRODUCTION

Vitamin C has a variety of physiological benefits in addition to its well-known antioxidant properties. It is required for a range of biological processes, such as collagen stabilization, hormone synthesis, and epigenetic modifications. Vitamin C is also required for the differentiation and function of immunological and epithelial barrier cells, both of which contribute to the body's immune response. [1]

Furthermore, vitamin C has been investigated for its potential therapeutic use in cancer, with evidence indicating that high-dose intravenous vitamin C may be an effective adjuvant to conventional cancer therapy in some types of tumors. While vitamin C is generally considered safe, excessive doses should be used with caution because they can have harmful effects on some vulnerable persons. Overall, vitamin C has a wide range of applications in human health, including immune function, infection prevention, cardiovascular health, and possible cancer therapies.[1]

Understanding the factors that influence Vitamin C stability in fruits and vegetables is critical because it is susceptible to degradation during processing, storage, and handling. Temperature, oxygen concentration, and moisture content have been identified as the primary causes of vitamin C loss. [2]

As a result, understanding these aspects is critical for optimizing preservation and storage procedures, eventually improving nutrient retention throughout the product's lifecycle. Furthermore, understanding the effect of various preservation procedures on Vitamin C retention is critical for assuring the nutritious value of fruit and vegetable products. As a result, a thorough understanding of the mechanisms influencing vitamin C stability in fruits and vegetables is critical for assuring their nutritional quality and safety.[2]

The purpose of the review is to explore vitamin C stability in fruit and vegetable products, focusing on the impact of alternative preservation steps and storage conditions, and to provide a simple and reliable method for determining vitamin C content in fruits and vegetables using UV spectroscopy. It emphasises the importance of Vitamin C as a water-soluble antioxidant in plant-based products and its susceptibility to degradation during processing, storage, and handling.

II BIOCHEMICAL BASIS OF VITAMIN C STABILITY

2.1 Molecular structure and properties of Vitamin C

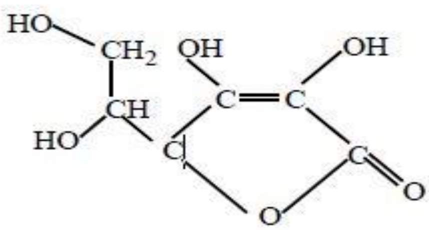

Figure-1: Structure of Vitamin-C

(Source: Akhtar, H. N., Rahman, S. M., & Muslim, T., 2010)

An essential ingredient for the body's metabolic activities is vitamin C. Since ascorbic acid cannot be produced by the human body, it must be consumed through diet.[4]

Vitamin C has been linked to antiviral effects, with in vitro studies showing its virucidal activity and potential to decrease viral load in certain viruses. It may also aid in treating viral infections by increasing interferon-alpha/beta production and downregulating pro-inflammatory cytokines. [5]

2.2 Factors influencing Vitamin C stability (light, heat, pH, etc.)

Traditional processing methods like high-temperature treatments can significantly reduce vitamin C levels. [12]

Exposure to light, oxygen, and aeration during processing can also contribute to vitamin C degradation. [12]

High temperatures and peeling can activate enzymes promoting ascorbic acid oxidation, resulting in vitamin C loss. [12]

Blanching certain vegetables before freezing may decrease water-soluble compounds and inactivate enzymes. [12]

The pH of food can affect vitamin C degradation, with pH significantly affecting the rate of degradation in buffer solutions.[7]

Storage time also affects vitamin C levels, with oranges showing a more significant decrease after 7 days of storage compared to 3 or 1 day.[6]

2.3 Role of Vitamin- C as an Antioxidant

Vitamin C is an important antioxidant in the human body. Ascorbic acid, or vitamin C, is well-known for its antioxidant qualities, serving as a free radical scavenger and protecting cell components from oxidative damage. It accumulates in the cell's aqueous phase, where it gives protons and electrons to reduce oxidative stress. Ascorbate's hydrophilicity enables it to protect other cellular components from oxidation. Vitamin C also interacts with transition metal ions such as iron and copper, catalyzing the reduction of free metal ions, which can result in the generation of oxygen radicals.[8]

Vitamin C's pro-oxidative activity in the presence of transition metal ions is counterbalanced by antioxidants, which help maintain redox balance and prevent excessive oxidative stress. Vitamin C has been shown to promote the survival of oxidatively damaged human vascular endothelial cells in the presence of a significant molar excess of glutathione, confirming its role as an antioxidant. [8]

IIIUV SPECTROSCOPY

UV-VIS spectroscopy, which measures light intensity in the UV (10–400 nm) and VIS (400–800 nm) regions as a function of wavelength, is regarded as the oldest analytical method. It is a type of spectrophotometric technique. UV and VIS radiation wavelengths are commonly represented in nanometers (nm). The analyte only absorbs light in the UV and VIS wavelength range, and the amount of radiation it absorbs is measured. [9]

3.1 Basic principles of UV spectroscopy

The fundamental principle of UV-VIS spectroscopy is the absorption of light, whereby the quantity of light absorbed is directly proportional to the quantity of analyte contained in a sample solution. Light absorption increases linearly with an increase in analyte concentration while light transmission decreases exponentially. In the UV-VIS region, the electronic structure of the absorbing species—such as atoms, molecules, ions, or complexes—determines how much radiation is absorbed. [9]

3.2 Utility of UV spectroscopy in analyzing Vitamin C content

UV spectroscopy is a simple, fast and reliable method for determining vitamin C content in fruits and vegetables, assessing ascorbic acid concentration in various food sources. It is particularly useful for assessing vitamin C stability under different storage conditions. UV spectroscopy also helps study the effects of storage temperature and time on vitamin C content, providing valuable information for consumers and health-promoting programs. [3, 6]

3.3 Advantages of UV Spectroscopy

1. Analysis proceeds quickly. [9]
2. Sample analysis is simple. [9]
3. The absorption spectrum offers important details about the analyte's presence in the sample. [9]

3.4 Limitations of UV Spectroscopy

1. Lacking selectivity and sensitivity. [9]
2. Restricted to substances that absorb UV/VIS. [9]
3. A spectrophotometer with UV-VIS reading capability is required. [9]
4. Samples ought to be prepared as solutions. [9]
5. Mixtures of substances are hard to examine and need to be separated beforehand. [9]
6. The measurement is challenging due to matrix interference from the sample. [9]

IV COMPARATIVE ANALYSIS OF VITAMIN C STABILITY IN VARIOUS FRUITS AND VEGETABLES

4.1 Comparative analysis of vitamin C stability trends among various produce

These studies explore the impact of storage time, temperature, and packaging materials on antioxidants, particularly vitamin C in plant and vegetable juices. It highlights the need for low temperatures and glass containers to preserve vitamin C content, while high temperatures during processing and storage negatively affect its preservation. Comparative analysis of various produce reveals varying degrees of vitamin C degradation under different storage conditions, emphasizing the need for appropriate storage methods. Orange stored at room temperature experienced a more rapid decrease in vitamin C content, and orange fruits stored for 7 days showed a more significant decrease than those stored for 3 or 1 day. [10, 6]

A study evaluates the Vitamin C stability patterns of diverse produce, including oranges, pomelo, papaya, tomatoes, and watermelons. The study discovered that orange had the highest level of Vitamin C, while watermelon had the lowest. The results showed that Vitamin C in orange was the most stable, with just 19.2% loss, but watermelon had the highest Vitamin C loss of 82.1% after 7 days of storage. The results were compared to prior study, which revealed variability in Vitamin C levels according to factors such as fruit origin, processing, and storage conditions. [11]

4.2 Factors contributing to differences in stability among fruits and vegetables

Factors such as storage time, temperature, light, oxygen, pH, trace metal ions, the inherent qualities of the product, and packing materials all have an impact on vitamin C stability. Vitamin C's water-soluble nature makes it prone to leaching, resulting in large losses during food preparation and handling. It shows that vitamin C content drops more quickly at higher storage temperatures and for longer periods of time. Fresh produce has a limited shelf life due to cellular respiration, microbes, enzymatic activities, and oxidation. When preserved in glass containers, red pepper juice has the highest content of vitamin C, followed by white pepper juice in second place. The type of container and the conditions under which it is stored also influence vitamin C concentration. [10, 11, 6]

V EFFECT OF PROCESSING AND STORAGE ON VITAMIN C STABILITY

5.1 Impact of processing techniques (e.g., blanching, freezing) on Vitamin C stability

Freezing has been found to be the greatest way for preserving vitamin C because it helps retain nutrient content quickly after harvesting. However, blanching before freezing, which inactivates enzymes, may reduce water-soluble chemicals. The review also underlines how the effects of processing, storage, and cooking on vitamin C stability vary greatly across commodities. It states that, while canned goods are frequently considered as less nutritious than fresh or frozen ones, research shows that this is not necessarily the case. A study found that both high and low temperatures can have an unfavourable effect on vitamin C stability, with frozen samples losing nearly 30% of their vitamin C content after one week at -16°C, whereas boiling for 15 minutes resulted in a loss of more than 50%.[12]

5.2 Influence of storage conditions (temperature, humidity) on Vitamin C retention

Vitamin C is sensitive to temperature and storage conditions, with degradation during hot air drying directly proportional to processing time. Drying temperature and time also affect ascorbic acid concentration in guava slices, with freeze-dried samples showing the highest retention. Storage conditions, particularly temperature and humidity, significantly affect vitamin C retention in fruits and vegetables. Factors like extended storage, higher temperatures, low relative humidity, physical damage, and chilling injury can enhance vitamin C loss. Temperature management is crucial for extending shelf-life and maintaining freshness, as delays in processing at higher temperatures can lead to loss in vitamin C content. [12, 13]

5.3 Strategies for maximizing Vitamin C retention during processing and storage

Low-temperature freezing technology is the best method for preserving vitamin C in fruits and vegetables. [12]

Non-thermal processing technologies like high-pressure processing, high-pressure homogenization, ultrasounds, and pulsed electric fields can increase nutritional value and preserve vitamin C. [12]

High-pressure processing (HPP) and high-pressure homogenization (HPH) are non-thermal processing methods. These technologies increase nutritional value and preserve vitamin C in processed fruits and vegetables. High-pressure processing preserves vitamin C in juices. [12]

Pulsed electric field technology retains health-promoting compounds, including vitamin C. [12]

Ultrasounds increase vitamin C bioavailability in juices. [12]

Non-thermal processing methods inactivate oxidative enzymes, preserving vitamin C's active form and bio accessibility. [12]

VI CONCLUSION

Understanding the factors that affect vitamin C stability in fruits and vegetables is critical for preserving their nutritional value. Temperature, light, storage conditions, and processing processes all have a substantial impact on the retention of this vital vitamin. Traditional methods such as high-temperature treatments, exposure to light, and oxygen can cause vitamin C deterioration, emphasizing the significance of proper preservation methods.

UV spectroscopy emerges as a valuable tool for assessing and monitoring vitamin C content in fruits and vegetables, offering a quick and reliable method for analysis. While UV spectroscopy has its limitations, its advantages in simplicity and speed make it a preferred choice for studying vitamin C stability under different conditions.

Comparative analyses of vitamin C stability across different produce highlight the variability in retention levels influenced by storage time, temperature, and packaging materials. Strategies such as freezing, non-thermal processing technologies, and optimal storage conditions are essential for maximizing vitamin C retention during processing and storage, ensuring the nutritional quality of fruit and vegetable products.

In conclusion, safeguarding the stability of vitamin C in fruits and vegetables is vital for preserving their nutritional value and enhancing consumer health. By employing appropriate preservation techniques and storage practices, it is possible to maintain the integrity of this essential nutrient, contributing to overall well-being and dietary health.

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