

RELACIÓN ENTRE EL CONTENIDO DE ÁCIDO ASCÓRBICO Y LAS CARACTERÍSTICAS ORGANOLÉPTICAS DEL JUGO DE NARANJA DULCE: UN ESTUDIO CUANTITATIVO

RELATIONSHIP BETWEEN ASCORBIC ACID CONTENT AND THE ORGANOLEPTIC CHARACTERISTICS OF SWEET ORANGE JUICE: A QUANTITATIVE STUDY

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RESUMEN

El ácido ascórbico (vitamina C) y su forma oxidada, el dehidroascórbico, son compuestos inestables que son esenciales para la salud humana. La vitamina C se oxida rápidamente, un proceso que se acelera con el aire y el calor. Aunque en el cuerpo humano esta conversión es reversible, permitiendo mantener su actividad vitamínica, el oxígeno también genera radicales libres que pueden causar daño celular, conocido como estrés oxidativo. Este fenómeno es regulado por antioxidantes tanto endógenos como exógenos, siendo la vitamina C un antioxidante clave que no puede ser sintetizado por los humanos y se encuentra en frutas como los cítricos. La investigación sobre cómo la vitamina C afecta las propiedades sensoriales del jugo de naranja es importante para la salud y la calidad del producto. Un análisis sensorial reveló que la oxidación de la vitamina C afecta negativamente el sabor, aroma y color del jugo, mientras que la cuantificación mostró una disminución en la concentración de vitamina C con el tiempo. Se utilizó ANOVA para analizar los datos, confirmando diferencias significativas en las características del jugo a lo largo del almacenamiento. Estos hallazgos son cruciales para optimizar la producción y almacenamiento del jugo de naranja, asegurando su calidad y aceptación por parte del consumidor.

Palabras clave

Vitamina C, ácido ascórbico, pruebas organolépticas, naranja

ABSTRACT

Ascorbic acid (vitamin C) and its oxidized form, dehydroascorbic acid, are unstable compounds that are essential for human health. Vitamin C is rapidly oxidized, a process that is accelerated by air and heat, although in the human body This conversion is reversible, allowing it to maintain its vitamin activity. However, oxygen also generates free radicals that can cause cellular damage, known as oxidative stress. This phenomenon is regulated by both endogenous and exogenous antioxidants, with vitamin C being a key antioxidant that cannot be synthesized by humans and is found in fruits such as citrus, research into how vitamin C affects the sensory properties of orange juice is important for the health and quality of the product, a sensory analysis revealed that the oxidation of Vitamin C negatively affects the flavor, aroma and color of the juice, while quantification showed a decrease in vitamin C concentration over time, ANOVA was used to analyze the data, confirming significant differences in juice characteristics over time. storage, these findings are crucial to optimize the production and storage of orange juice, ensuring its quality and consumer acceptance.

Keywords

Vitamin C, ascorbic acid, organoleptic tests, orange

INTRODUCTION

Ascorbic acid (vitamin C) and dehydroascorbic acid are unstable compounds that play a crucial role in maintaining human health. Ascorbic acid is rapidly oxidized to dehydroascorbic acid, a process accelerated by air and heat. In the human body, this conversion is reversible and maintains vitamin activity, although with less stability. This characteristic allows us to differentiate cellular metabolic processes from open-air combustion, since metabolic processes are catalyzed by enzymes and occur slowly in several stages (1).

Oxygen, as an oxidizing agent, is essential for energy production, but it also generates reactive intermediates or free radicals that can damage biological molecules such as proteins, lipids and nucleic acids. This phenomenon, known as oxidative stress, produces reactive oxygen species, including free radicals, which under physiological conditions are regulated by endogenous antioxidants. An example of the beneficial function of these species is the immune effect of neutrophils, related to the activity of the enzyme myeloperoxidase.

Exogenous sources of reactive oxygen species include various xenobiotic substances, such as chemicals. There are 4 million of these substances known, with 63 thousand in common use and 11 thousand that can be ingested as drugs or food additives (2). There are also 50 thousand environmental polluting elements, such as the chemicals in cigarette smoke, which include radioactive compounds such as polonium 210, associated with lung cancer. Smoking a pack and a half a day for a year exposes the smoker to radiation equivalent to 300 chest x-rays, exceeding the recommendations of the International Commission on Radiological Protection.



The response to oxidative stress includes endogenous antioxidants such as glutathione, superoxide dismutase, and catalase, and exogenous dietary antioxidants such as phenolic compounds, flavonoids, carotenoids, and vitamins C, D, and E. Vitamin C, a water-soluble antioxidant, is found in abundance in citrus and other fruits and is essential because humans cannot synthesize it (3). Vitamin E, a fat-soluble antioxidant, protects polyunsaturated fatty acids and proteins from oxidation, being important in the prevention of diseases related to oxidative processes. In terms of nutrition, vitamin C is essential due to its antioxidant capacity and its role in collagen synthesis and iron absorption. Research on the incidence of vitamin C on the organoleptic characteristics of sweet orange juice is crucial due to its impact on health, nutrition, product quality and consumer preferences (4).

Since orange juice is a rich source of vitamin C, it is important to understand how this vitamin affects the sensory properties of the juice, such as flavor, aroma, color and texture, which are key determinants of product acceptance. Vitamin C can act as a natural preservative, maintaining the color and fresh taste of orange juice.

However, its oxidation can alter the flavor and aroma, affecting the consumer's sensory experience (5). The growing trend towards the consumption of natural and healthy foods and drinks underlines the importance of this research. By understanding the relationship between vitamin C and the organoleptic characteristics of sweet orange juice, producers can optimize their products to meet consumer demands, improving satisfaction and potentially increasing sales.

From a scientific and technological perspective, this research can provide valuable knowledge for the food industry, helping to develop new processing and storage techniques that maintain high levels of vitamin C without compromising the sensory characteristics of the juice (6). This is crucial to ensure healthy, tasty and high-quality products for consumers, and to respond to the demand for nutritious and enjoyable foods.

Therefore, the objective of this research is to evaluate the relationship between the vitamin C content and the organoleptic characteristics of sweet orange juice during its storage, and to analyze the impact of oxidation on these properties.

MATERIALS AND METHODS

The determination of the concentration of vitamin C in different samples is an important analysis in various fields, such as the food, pharmaceutical and nutritional supplement industries. There are several analytical methods to quantify vitamin C, one of the most used being the titration method with 2,6-dichlorophenolindophenol (DCPIP) (7). The principle of this method is based on the redox reaction between ascorbic acid (vitamin C) and DCPIP. DCPIP is a blue compound that, when reacted with ascorbic acid, is reduced to a colorless form. When titrating the sample with DCPIP, the end point of the titration is reached when the color change from colorless to blue occurs, indicating that all the ascorbic acid has been oxidized (8). To carry out the quantification, first, a standard solution of ascorbic acid of known concentration is prepared. Then, an aliquot of the sample to be analyzed is taken and diluted if necessary. Both the standard

solution and the diluted sample are then titrated with DCPIP to the end point, recording the volumes of DCPIP consumed (9).

Using the following formula, the concentration of vitamin C in the sample is calculated:

$$\left(\frac{\text{mg}}{100\text{g}}\right) = \frac{V_{\text{DCPIP, muestra}} \times C_{\text{acido ascorbico, estandar}}}{V_{\text{acido ascorbico, muestra}}} \times 100$$

Where: Vitamin C =

$$\left(\frac{\text{mg}}{100\text{g}}\right) = \frac{V_{\text{DCPIP, muestra}} \times C_{\text{acido ascorbico, estandar}}}{V_{\text{acido ascorbico, muestra}}} \times 100$$

- $V_{\text{DCPIP, sample}}$ is the volume of DCPIP consumed in the titration of the sample.
- $C_{\text{ascorbic acid, standard}}$ is the concentration of the standard ascorbic acid solution.
- $V_{\text{ascorbic acid, sample}}$ is the sample volume used.

This method allows vitamin C to be quantified in a simple and precise way. It is widely used in quality control, research and development laboratories, both in industry and in academic institutions (10). It is important to keep in mind that, prior to titration, sample preparation steps must be carried out, such as extraction, filtration and dilution, depending on the matrix and complexity of the sample. In addition, good laboratory practices must be followed and calibrated equipment and trained personnel must be available to guarantee reliable results (11).

A. Vitamin C quantification

The levels of ascorbic acid, dehydroascorbic acid and vitamin C were measured on the same day of pulping using the HPLC technique. 20 μL of sample or standard was injected into a stainless steel RP-18, Lichrosorb, 5 μm column, operated at room temperature. The mobile phase consisted of 0.2 M KH_2PO_4 adjusted to pH 2.4 with H_3PO_4 , at a flow rate of 0.5 mL/min. A UV-vis detector was used at 254 nm and 30 $^\circ\text{C}$. The calibration curve was constructed with ascorbic acid at concentrations of 10 to 50 mg/L, using 1 mg/mL of DTT (12). To extract vitamin C from sweet orange and apple fruits, 2.0 g of puree were weighed and mixed with 8.0 mL of HPLC grade water, stirring magnetically for 5 minutes. The extracts were centrifuged at 1,493 x g for 15 minutes at 4 $^\circ\text{C}$ and the supernatant was filtered with a 0.45 μm Millipore filter. To quantify ascorbic acid, the extract diluted with HPLC grade water was injected into the HPLC, ensuring that the reading was within the calibration curve. To quantify vitamin C (ascorbic acid + dehydroascorbic acid), mL of the diluted extract was taken, 1 mg of DTT was added and allowed to react in the dark for hours before being injected into the HPLC. Dehydroascorbic acid was calculated by subtracting the ascorbic acid content

from the total vitamin C (13).

B. Determination of the state of maturity of the orange for sensory evaluation.

For this purpose, the sweet orange tree was used following CODEX STAN 245-2004, which objectively classifies the raw material according to its maturity criteria due to its color and minimum juice content (14). This standard defines the maturity states in two categories I and II, allowing us to evaluate how the maturity state influences the content of bioactive compounds. We worked specifically with both categories, since this represents an intermediate state, suitable for the production of industrial products from this fruit. Immature fruits were not used because they do not develop the sensory characteristics desirable for the consumer, nor were overripe fruits because they do not withstand the heat treatment necessary for the pasteurization of the preserve (15).

RESULTS

Sensory analysis of orange juice

The sensory analysis of orange juice was carried out to evaluate how the oxidation of vitamin C affects the organoleptic characteristics of the product. To this end, various tasting tests were carried out with a panel of trained judges. The parameters evaluated included the flavor, aroma, color and texture of the juice in different states of conservation.

Flavor evaluation

The flavor of orange juice showed significant variations as vitamin C was oxidized. Judges described the fresh juice as featuring a vibrant, sweet citrus flavor. However, as the oxidation of vitamin C progressed, an increase in acidity and a decrease in sweetness was observed, which is attributed to the formation of acidic compounds during the oxidation of ascorbic acid.

Aroma evaluation

The aroma of orange juice was also affected by the oxidation of vitamin C. Initially, the fresh juice gave off a fresh, characteristic orange aroma. With time and oxidation, the aroma became less intense and was described as slightly rancid by the judges, suggesting that the volatile compounds responsible for the fresh aroma degrade during oxidation.

Color evaluation

The color of the orange juice remained relatively stable in the first days of storage. However, with the progressive oxidation of vitamin C, a slight discoloration was observed. This phenomenon is due to the degradation of the carotenoid pigments present in the juice, which are sensitive to oxidative processes.

Texture evaluation



The texture of orange juice did not show significant changes during the study period. However, some judges reported a slight sensation of increased viscosity in juices stored for longer periods, which could be related to the precipitation of solids as the components oxidize and degrade.

Vitamin C quantification

Vitamin C quantification was performed using the 2,6-dichlorophenolindophenol (DCPIP) titration method. This method is widely recognized for its precision and simplicity. The results showed a constant decrease in the concentration of vitamin C over time, indicating its progressive oxidation.

Titration results

The values of vitamin C concentration in the orange juice samples are presented in Table 1. Initially, the average concentration of vitamin C in the fresh juice was 45 mg/100 mL. After 7 days of storage at room temperature, this concentration decreased to 32 mg/100 mL, and after 14 days a concentration of 20 mg/100 mL was recorded.

Table 1. Vitamin C concentration results in 0, 7 and 14 days

Vitamin C Concentration (mg/100 ml)	Day
45mg	0 days
32mg	7 days
20mg	14 days

These results corroborate the hypothesis that vitamin C is oxidized over time, thus affecting the organoleptic characteristics of orange juice.

Statistical analysis

To analyze the data obtained, analysis of variance (ANOVA) was used with a significance level of 95%. The results of the ANOVA showed that there are significant differences in the concentration of vitamin C and in the organoleptic characteristics of orange juice in different storage periods ($p < 0.05$).

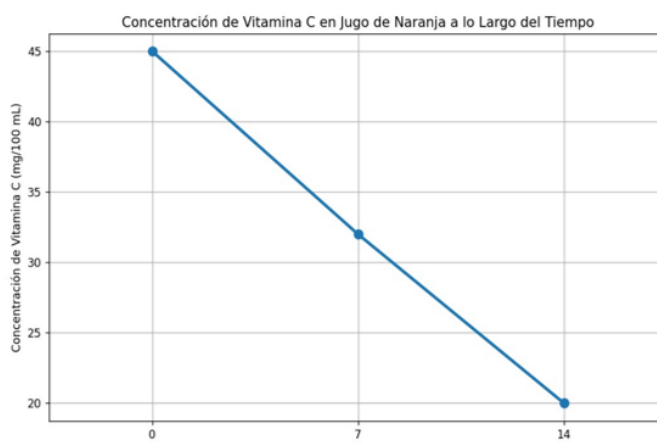


Figure 1. Illustration of the results presented in the ANOVA on the concentration of vitamin C in orange juice

DISCUSSION

(7) studied the stability of vitamin C in fruit juices and its impacts on sensory characteristics. They concluded that vitamin C is destroyed by oxidation, which significantly affects the flavor and aroma of the juice. However, they indicated that oxidation can be reduced using airtight packaging and refrigeration (6) conducted a similar study on bioactive compounds in fruit juices, confirming that oxidation of vitamin C degrades flavor and odor, and suggested the use of natural antioxidants to prevent degradation without affecting organoleptic properties. (6) correlated the vitamin C content with the organoleptic characteristics of several juice samples, highlighting that oxidation is also responsible for juice discoloration.

(4) also reported that advanced packaging techniques, such as the use of modified atmospheres, could maintain the sensory quality of the juice. (1) examined the sensory quality of tropical juices and found that vitamin C oxidation also decreases sensory quality, suggesting that controlled heat treatments could minimize this process (1).

The oxidation of vitamin C in orange juice has a direct negative effect on the organoleptic properties of the juice in terms of flavor, aroma and color. The phenomenon is well explained in current literature. During the oxidation process, vitamin C breaks down into dehydroascorbic acid, which is also very unstable and can be responsible for some unpleasant tastes and odors.

(24) The oxidation of vitamin C, as we observed in our study and in the comparative study, provides acidity and eliminates sweetness. All this affects the overall taste perception, and the product is less acceptable. Odor is another characteristic property that is influenced by the oxidation of vitamin C. Previous studies and our finding show that the decomposition of fresh volatile compounds, together with the formation of oxidation compounds, causes a rancid or unpleasant odor. This effect may be significant enough to discourage consumers from purchasing the product.

The color is quite stable at the beginning of storage, but begins to decompose with oxidation of the vitamin. Recent literature also supports this fact and states that



discoloration is a visual phenomenon that indicates the quality of the final product and has effects on consumers' perception of the quality and freshness of the orange juice. Incorporating natural antioxidants into juice supplementation may be one of the viable strategies, as suggested by (6), to increase shelf life and preserve sensory properties.

Antioxidants, such as phenolic compounds and flavonoids, may also function by preventing the oxidation of vitamin C. The authors (4) also highlight the need to apply advanced packaging techniques, for example, the use of modified atmospheres, which, among other things, could allow less exposure of the juice to oxygen and therefore a slower rate of oxidation. The technique can also be applied in conjunction with the use of airtight containers and barrier materials to obtain effective results. Refrigerated storage is a common technique recommended to reduce the oxidation of vitamin C. Reducing the temperature of orange juice slows down the activity of oxidants and increases the shelf life of the product without sacrificing organoleptic properties for longer. The implications of the experiment, as well as comparative literature, for the food industry are enormous. Being able to track vitamin C oxidation and changes in the organoleptic properties of orange juice can help producers make the quality of their products superior and therefore meet consumer needs.

Storage and handling techniques that reduce the oxidation of vitamin C are of great importance to obtain quality products. There are many innovations that can be used to improve the stability of orange juice, including the use of natural antioxidants, better packaging methods, and proper storage efficiency. Understanding the relationship between vitamin C and the organoleptic properties of orange juice can also be applied in the development of new products that have greater stability and sensory quality. The target market for this type of product would be consumers who want healthy and natural products in terms of food and beverages, and this will contribute to sales and customer satisfaction.

CONCLUSIONS

The oxidation of vitamin C negatively affects the organoleptic characteristics of orange juice, which highlights the importance of developing effective conservation techniques. This study has shown that the oxidation of vitamin C results in a less sweet juice, with a more acidic flavor and a less intense aroma, accompanied by slight discoloration. These changes are caused by the formation of acidic compounds and the degradation of carotenoid pigments sensitive to oxidation, which significantly impacts consumers' perception of the product. Since organoleptic characteristics are key to juice market acceptance, it is crucial to implement strategies that minimize oxidation and maintain sensory quality. The use of refrigerated storage, airtight containers and the incorporation of natural antioxidants are presented as effective solutions to preserve both the levels of vitamin C and the sensory properties of the juice. Thus, the food industry can use these findings to optimize its processing and preservation methods, offering higher quality products that meet consumer expectations in terms of freshness, flavor and nutritional value.

The implementation of advanced processing and conservation techniques allows maintaining high levels of vitamin C and the sensory properties of the juice, responding

to the demand for natural and healthy products. The results of the study suggest that the combination of refrigerated storage, the use of packaging materials that act as an oxygen barrier, and the addition of natural antioxidants such as phenolic compounds and flavonoids is essential to extend the shelf life of juice without compromising its quality. These practices not only slow down the oxidation of vitamin C, but also help preserve the flavor, aroma and color of orange juice, improving the consumer experience. Furthermore, these strategies respond to the growing demand for healthier and more natural foods that maintain their nutritional value without the need for artificial additives. In this sense, scientific and technological research can be key for the food industry, as it provides a comprehensive conservation approach that benefits both producers and consumers, helping to develop high-quality products and meet current market expectations.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my colleague and mentor for their constant support and guidance throughout this study. Their valuable feedback and experience have been key to the success of this research. I also wish to acknowledge the Escuela Superior Politécnica del Chimborazo, whose institution provided the essential resources to carry out this work. Without their support, many aspects of the project would not have been possible. In addition, I deeply value the patience and understanding that my family gave me throughout this research process. stage, I appreciate every advice and every moment shared, your presence has been a fundamental pillar in my career, I am truly grateful for all the support received.

DECLARATION OF INTEREST

I affirm that there are no conflicts of interest associated with this research, each of the authors has participated equally and has reviewed the manuscript, we have not received funding or support from any entity that could affect the results or the interpretation of the data presented, the integrity of the study has been maintained without external influences, all aspects of the work have been addressed with transparency, this commitment ensures the objectivity and validity of our conclusions, the research has been carried out with the highest ethical standards, therefore, we guarantee impartiality in the development of the article.

AUTHOR CONTRIBUTIONS

All authors have made significant contributions to this study, both were responsible for the research design and writing of the manuscript, they also actively participated in the collection and analysis of data, as well as in the exhaustive review of the content, each of them contributed to the interpretation of the results and the formulation of the conclusions, in addition, they ensured that the citations and references were accurate and complete, this work is the result of the collaborative effort of all the participants, each author has brought their specific experience and knowledge to the project, the cooperation between the authors has been essential to achieve the established objectives, the synergy generated has enriched the development of the research, without a doubt, this joint effort has been key to the success of the study.



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