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Incorporation of natural antioxidants in the extraction of sugarcane juice to control vitamin C and pH during pasteurization – Ulóngué Village – Angónia District – Mozambique

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ABSTRACT: *This research aimed to incorporate natural antioxidants into sugarcane juice to minimize vitamin C and pH losses during pasteurization. Ginger, beetroot, lemon peel, lemongrass, and hibiscus were used for this purpose. The problem is that the high temperatures used in this process eliminate many nutrients, in this case vitamin C, and alter the juice's pH. Therefore, because this is a common process practiced in Ulóngué Village, there is need to raise awareness among the population about the importance of using these foods in this process, as they have the potential to minimize oxidation and nutrient loss. For this purpose, four different formulations of sugarcane juice were produced and analysed in the laboratory, namely Ao (sugarcane juice with incorporation of ginger, beetroot and unpasteurized lemon peel), A1 (sugarcane juice with incorporation of ginger, beetroot and pasteurized lemon peel), Bo (sugarcane juice with incorporation of ginger, lemon peel, lemongrass and unpasteurized hibiscus), B1 (sugarcane juice with incorporation of ginger, lemon peel, lemongrass and pasteurized hibiscus), obtaining pairs of results for Vitamin C and pH, (1.9mg/L and 2.6), (1.7mg/L and 2.9), (1.6mg/L and 3) and (1.5mg/L and 3.3), respectively. Based on the results obtained, it was found that the incorporation of natural antioxidants contributed to minimizing vitamin C and pH losses before and after pasteurization. In addition to the values being within specifications, the reduction in vitamin C and pH changes were minimal.*

KEYWORDS - Pasteurization; sugarcane juice; Natural Antioxidants.

I. INTRODUCTION

Sugarcane juice is a liquid product obtained from pressing sugarcane (Saccharum officinarum). It is widely consumed in various regions of the world due to its sweet flavour and nutritional properties. These sugars (sucrose, fructose, and glucose) are mostly simple sugars, constituting an immediate source of energy (ALMEIDA et al., 2019). Composed primarily of water (approximately 70 to 80%), carbohydrates in the form of sucrose, fructose, and glucose, minerals such as calcium, potassium, magnesium, and iron, as well as B vitamins and antioxidants, it is widely consumed in tropical regions. Its nutritional value is complemented by the fact that it is a natural, refreshing drink rich in quick energy due to its high concentration of simple sugars (SANTOS, 2020). Socioeconomically, sugarcane juice is extremely important in many regions, especially in rural areas, where sugarcane production supports small communities and generates seasonal jobs. The sale of sugarcane juice is a significant source of income for many informal workers, particularly in developing countries. Furthermore, local production and marketing contribute to the dynamism of regional economies, minimizing transportation costs and promoting the consumption of fresh produce (OLIVEIRA et al., 2021).

Pasteurization is a fundamental process in preserving juices, eliminating pathogenic microorganisms and reducing microbiological deterioration. The method consists of heating the product to controlled temperatures, preserving its nutritional properties and increasing its shelf life (SILVA, 2021). However, this process can affect certain components of the juice, especially vitamin C and pH levels, which are key indicators of nutritional and sensory quality (CARVALHO et al., 2020). According to RAGAEE et al. (2012), the heat applied during the pasteurization process can result in significant losses of vitamin C. As PERES et al. (2020) point out, pasteurization is a technique widely used in the food industry to control unwanted microbiota, ensuring product quality and safety.

Vitamin C (ascorbic acid) is sensitive to heat and oxidation and is one of the main vitamins affected during pasteurization. Although the process helps protect the juice from contamination, it can result in significant losses of vitamin C, especially at higher temperatures or during prolonged processing. Low-intensity pasteurization (below 80°C) can minimize this degradation, maintaining a balance between microbiological safety and nutrient retention (OLIVEIRA et al., 2019).

The pH of the juice also varies during pasteurization, which can influence flavor perception and product stability. The reduction in pH after pasteurization can occur due to the formation of organic acids resulting from the degradation of compounds present in the juice. This effect can influence microbiological stability, as a lower pH helps inhibit the growth of microorganisms, but it can also alter sensory characteristics, making the juice more acidic (SOUZA et al., 2020).

With this article, we aim to incorporate natural antioxidants into the extraction of sugarcane juice to minimize vitamin C losses and excessive pH changes during pasteurization in Ulónguè village. We also aim to extract sugarcane juice at home by incorporating ginger, beetroot, and lemon peel; and ginger, lemon peel, lemongrass, and hibiscus, followed by pasteurization. We then determine the vitamin C content and pH before and after pasteurization in the resulting treatments. In the end, with this article, we intend to compare the level of vitamin C losses and the excessive change in pH of the results collected with literary sources and research by other authors who developed studies without Incorporation.

II. BIBLIOGRAPHICAL REVIEW

1.1. Sugarcane juice: history and characteristics

1.1.1. Origins and First Records

The consumption of sugarcane juice has deep roots in history, dating back thousands of years. Sugarcane originated in Southeast Asia, specifically in the region that now comprises New Guinea and southern China. According to historical studies, sugarcane cultivation began around 8,000 years ago in Papua New Guinea, where early civilizations used sugarcane not only as food but also to produce a sweet and nutritious beverage from its juice (GALLOWAY, 1989).

Today, sugarcane juice consumption remains popular in many parts of the world, especially in tropical and subtropical regions where sugarcane is grown. In Brazil, for example, sugarcane juice, as it is known, is a widely consumed traditional beverage, particularly in rural areas and at street markets. In Southeast Asia and India, sugarcane juice is sold by street vendors and is appreciated for its refreshing and energetic properties (GOLDSTEIN, 2011).

1.1.2. Nutritional Composition of Sugarcane Juice

TABLE 1: Composition of sugarcane juice

Ingredients Amount per 240 ml (1 cup)	Ingredients Amount per 240 ml (1 cup)
Energy	180 kcal
Carbohydrates	45 g
Sugars	39 g
Protein	0.27 g
Total Fat	0.0 g
Fiber	0.56 g
Calcium	8.22 mg
Magnesium	85 mg
Potassium	131 mg
Iron	0.37 mg
Sodium	56 mg
Vitamin	C 1.5 mg
B Vitamins (B1, B2, B6)	Traces

Fonte: USDA National Nutrient Database. (2023). Ver em: https://usda.gov .

2.3. Antioxidant properties of hibiscus

2.3.1. The main antioxidants in Hibiscus.

TABLE 2: Antioxidant composition in Hibiscus

Component	Amount presence 1kg	Function / Property
Organic Acids		
Citric Acid	Present	Antioxidant
Malice Acid	Present	Antioxidant
Tartaric Acid	Present	Antioxidant
Hibischic Acid	Present	Antioxidant
Polyphenols		
Protocatechuic Acid	0.75 - 1.0 mg/g	Antioxidant anti-inflammatory
Caffeic Acid	Present	Antioxidant
Chlorogenic Acid	Present	Antioxidant
Flavonoids		
Quercetin	0.55 mg/g	Antioxidant, anti-inflammatory
Kaempferol	Present	Antioxidant
Anthocyanins		
Delphinidin-3-sambubioside	0.75 - 1.5 mg/g	Antioxidant, natural color
Cyanidin-3-sambubioside	0.40 - 0.7 mg/g	Antioxidant, natural color
Vitamins		
Vitamin C (Ascorbic Acid)	2.3 - 3.8 mg/g	Antioxidant, immunomodulatory

Fonte: Tsai et al. (2002); Ali et al. (2005); Mohd-Esaet al. (2010) e Da-Costa-Rocha et al. (2014), USDA (2023).

2.4. Scientific studies on the antioxidant capacity of hibiscus in food and beverages.

The antioxidant capacity of hibiscus (Hibiscus abdariffa) has been widely studied due to its potential health benefits, particularly in the prevention of chronic diseases related to oxidative stress, such as cardiovascular disease and cancer. The antioxidants present in hibiscus, such as polyphenols, flavonoids, and anthocyanins, play a crucial role in neutralizing free radicals (MOHD-ESA et al., 2010).

2.4.1. Chemical Composition of Hibiscus

Hibiscus is rich in phenolic compounds, including organic acids such as citric acid, malic acid, tartaric acid, and hibiscus acid, as well as polyphenols such as protocatechuic acid, caffeic acid, and chromogenic acid. Studies indicate that protocatechuic acid has significant antioxidant and anti-inflammatory properties (MOHD-ESA et al., 2010).

The main chemical constituents of hibiscus (H. sabdariffa) with pharmacological applications are organic acids, anthocyanins, polysaccharides, and flavonoids. Furthermore, several studies have identified delphinidin-3-sambubioside and cyanidin-3-sambubioside as the main anthocyanins present in hibiscus calyx and leaf extracts. The part of the plant most used in the food sector is the calyx, from which various types of products can be made, such as teas, fermented drinks, soft drinks, jellies, ice cream, chocolates, and cakes (DA-COSTA-ROCHA et al., 2014).

2.4.2. Food and Beverage Applications

The use of hibiscus in food and beverages is widespread across various cultures, utilized for both its sensory properties and its health benefits. Studies show that hibiscus tea is a popular beverage in various parts of the world, known for its high antioxidant activity (USDA, 2023).

Research shows that including hibiscus in beverages can significantly improve their antioxidant profile. A study by MOHD-ESA et al. (2010) evaluated the antioxidant activity of different parts of the hibiscus plant and concluded that the flowers have the highest concentration of antioxidants, making them recommended for use in teas and other beverages. Additionally, hibiscus has been incorporated into juices, jellies, and baked goods to increase their nutritional value and stability, as well as to provide a vibrant, natural heat (DA-COSTA-ROCHA et al., 2014).

2.4.3. Health Benefits and Efficacy

The health benefits associated with hibiscus consumption are primarily related to its ability to reduce oxidative stress. Clinical studies indicate that regular consumption of hibiscus-based beverages can lead to a significant reduction in blood pressure in hypertensive patients, attributed to the vasodilatory and antioxidant activity of the plant's compounds (ALI et al., 2005).

Furthermore, research suggests that hibiscus may play a role in regulating lipid metabolism, helping to reduce LDL cholesterol and triglyceride levels in the blood, which is beneficial for cardiovascular health (TSAI et al., 2002).

2.5. Lemon peel acid as an antioxidant

2.5.1. Chemical composition of lemon peel acid and its antioxidants

Lemon peel is proven to be rich in antioxidants. According to USDA Food Data Central (2016), the chemical composition of lemon peel is described in the table below:

TABLE 3: Antioxidant composition in lemon peel

Component	Quantity / Presence	Function / Property
Organic Acids		

Citric Acid	6-8%	Natural Preservative, Antioxidant
Malic Acid	Present	Antioxidant, Improves Flavor
Ascorbic Acid (Vitamin C)	0.2-0.5%	Antioxidant, Immunomodulator
Polyphenols		
Hesperidin	60-80 mg/100g	Antioxidant, Anti-inflammatory
Limonene Dioxide	Present	Antioxidant, Anticancer
Flavonoids		
Quercetin	3-5 mg/100g	Antioxidant, Anti-inflammatory
Kaempferol	Present	Antioxidant, Anticancer
Carotenoids		
Beta-carotene	0.1-0.2 mg/100g	Antioxidant, Vitamin A Precursor
Essential Oils		
Limonene	2-3%	Antioxidant, Characteristic Aroma
Terpinen-4-ol	Present	Antioxidant, Antimicrobial
Others Compounds		
Pectin	30% (husk fiber)	Antioxidant, improves digestion

Fonte: USDA NationalNutrientDatabase. (2016). Ver em: https://usda.gov

III. RESEARCH METHODOLOGY

The research was conducted in Angónia District at Faculty of Agricultural Sciences. The Angónia District is located to the north and northeast of Tete Province, bordered to the north, northeast, and east by neighboring Malawi, to the south by Tsangano District, and to the northwest by Macanga District. The total area of this District is approximately 3,259 km2. It has the following coordinates: 14°42'57" south latitude 34°22'23" east longitude and an altitude of 1,650 m in the Ulónguè municipality (MAE, 2014).

3.1. Research Design

The research was conducted at Faculty of Agricultural Sciences, Zambeze University in Ulónguè village, Angónia district. The research was conducted in two phases. In the first, two sugarcane juice formulations were developed incorporating antioxidants from selected and differentiated ingredients. In the second phase, the formulations were individually separated into two parts, with one part maintaining its natural characteristics and the other pasteurized. After the process, four sugarcane juice treatments were obtained. The treatments are finally described as follows:

Sugarcane juice formulation "A" (Ginger, Beetroot, and lemon peel acid)

A0: Sugarcane juice incorporating ginger, beetroot, and unpasteurized lemon peel acid;

A1: Sugarcane juice with added ginger, beetroot, and pasteurized lemon peel acid.

Sugarcane juice formulation "B" (Ginger, lemongrass, hibiscus, and lemon peel acid).

B0: Sugarcane juice with added ginger, lemongrass, hibiscus, and unpasteurized lemon peel acid.

B1: Sugarcane juice with added ginger, lemongrass, hibiscus, and pasteurized lemon peel acid.

3.1.1. Quantities of ingredients used in sugarcane juice formulations

The ingredients and their respective quantities used in the initial preparation of sugarcane juice formulations incorporating natural antioxidants are described in the table below, defined according to the methodology proposed by PRATI et al. (2005):

TABLE 4: Ingredients used in the initial preparation of sugarcane juice formulations

Formulation	Ingredient	Quantities (kg)
	Raw Sugar cane	8
	Ginger	0.224
	Beetroot	0.434
Sugar cane	Lemon Peel	0.310
	Sugar cane in nature	8
	Ginger	0.224
	Lemon Peel	0.310
Bo	Lemongrass	0.028
	Hibiscus	18

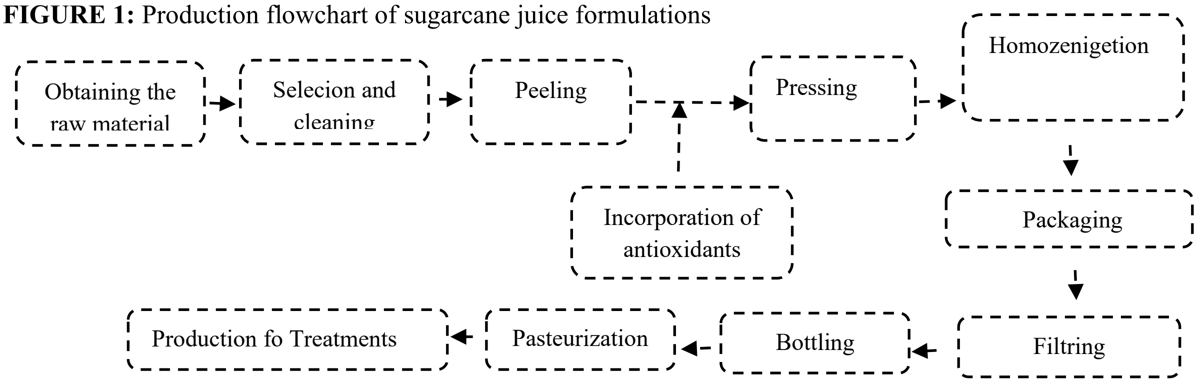
Fonte: Prepared by the authors (2024)

Both initial formulations resulted in three (3) litters of sugarcane juice with the incorporation of antioxidants.

3.1.2. Standard production flowchart for sugarcane juice formulations

The following describes the process flowchart used to prepare sugarcane juice formulations.

FIGURE 1: Production flowchart of sugarcane juice formulations



Fonte: Adapatado de FALGUERA (2011)

3.2. Type of Research

Regarding the nature of the research, quantitative research is considered by OLIVEIRA (2011, p. 24) as an investigation characterized by the use of quantification, both in the methods of collecting information and in processing it through statistical techniques.

According to MATTAR (2001), quantitative research seeks to validate hypotheses through the use of structured, statistical data, analyzing a large number of representative cases, and recommending a final course of action.
Qualitative research provides a better insight and understanding of the context of the problem, while quantitative research seeks to quantify the data and applies some form of statistical analysis. (MALHOTRA, 2001, p. 155, apud OLIVEIRA, 2011, p. 24).

The procedure that enabled the development of the research is experimental. For GIL (2007, p. 36), experimental research consists of determining an object of study, selecting the variables that would be capable of influencing it, and defining the forms of control and observation of the effects that the variable produces on the object.

3.2.1. Sample Collection

After extraction, the beverages were packaged in previously sterilized glass containers and subjected to heat treatment using a time/temperature of 70°C for 10 minutes, in a water bath, according to the methodology proposed by SINGH et al. (2002), followed by storage in a cold chamber at 4–8°C.

3.3. Treatment Arrangement and Analysis Variables

The parameters to be analyzed are described in the table below:

TABLE 5: Treatment Arrangement and Analysis Parameters

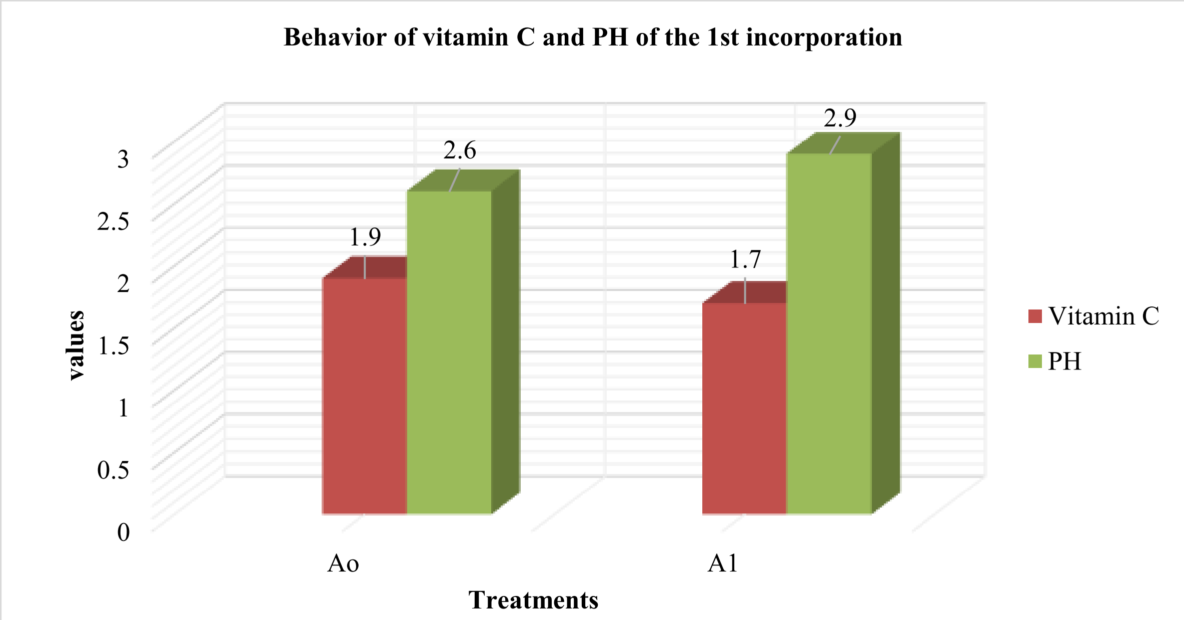
Treatments	**A0**	**A1**	**B0**	**B1**
properties	• Vit. C content	• Vit. C content	• Vit. C content	• Vit. C content
Analytical	PH	PH	PH	PH

Source: Prepared by the authors (2024).

IV. PRESENTATION AND DISCUSSION OF RESULTS

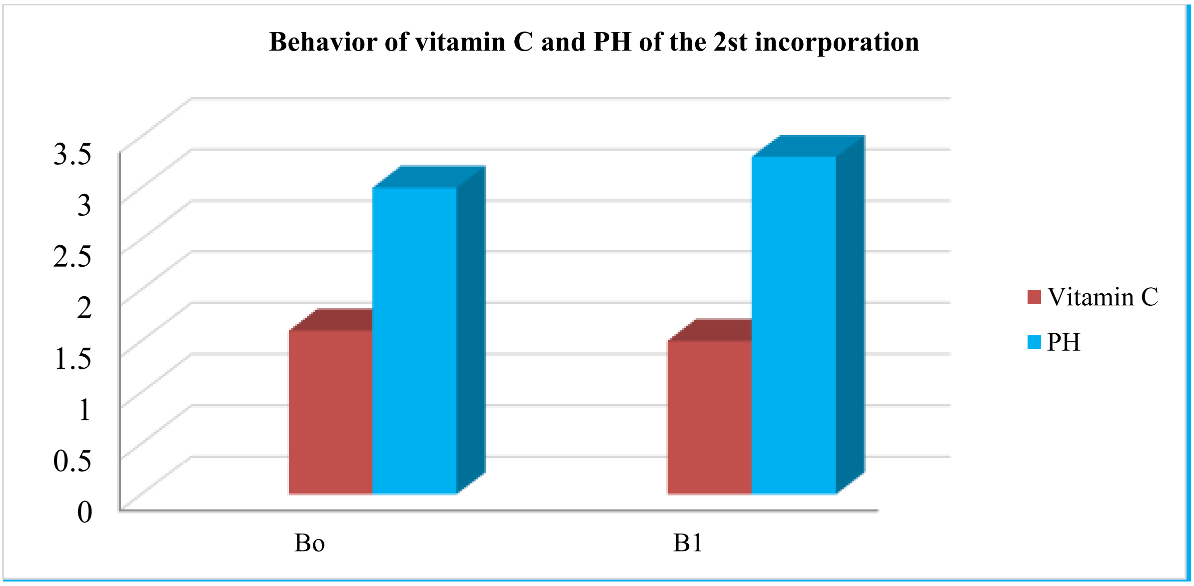
The results presented in Graph 1 indicate an increase in pH values and a reduction in vitamin C levels in all formulations after pasteurization. These changes are consistent with the known effects of pasteurization on the chemical composition and nutritional properties of juices.

GRAPH 1: Results obtained for pH and vitamin C in sugarcane juice formulations



Fonte: Adapted by the authors (2024).

Graph 2: Results obtained for pH and Vitamin C in sugarcane juice formulations



Fonte: Adapted by the authors (2024).

According to KUNITAKE (2012), a pH below 4.6 classifies sugarcane juice with added passion fruit as an acidified beverage. This condition hinders the development of a large number of bacteria, as well as the activity of the polyphenol oxidase enzyme, whose optimal pH for activity is 7.2.

The increase in pH after pasteurization can be explained by the degradation of organic acids, which are sensitive to heat (PEREIRA et al., 2018). During the pasteurization process, some volatile acidic compounds can be lost, resulting in an increase in pH values, as observed in the formulations from Ao to A1, and also from Bo to B1. The increase in pH can also occur due to chemical reactions that promote the partial neutralization of the acids present, such as the acid from lemon peel, incorporated into the formulations.

The reduction in vitamin C content in pasteurized samples is a widely documented effect. Vitamin C is highly sensitive to heat and can be degraded during heating. In the formulations from Ao to A1, and also from Bo to B1, a decrease in vitamin C content was observed, which is expected due to exposure to heat during the pasteurization process, as it is converted into inactive compounds during heating. The addition of ingredients such as ginger, lemongrass, and hibiscus to the formulations can influence the stability of the nutritional components, but pasteurization, as observed, has a greater impact on vitamin C degradation than the simple incorporation of ingredients (CARVALHO et al., 2020).

The main form of vitamin C degradation in processed products basically involves non-enzymatic aerobic and anaerobic reactions. Studies have shown that in fruit products with a pH < 4.0, non-enzymatic browning occurs primarily due to the degradation of ascorbic acid. The rate of degradation depends on factors such as vitamin concentration, pH, oxygen content, storage temperature, and processing (OLIVA, 1995).

Aerobic conditions are provided by the incorporation of air during the extraction, filtration, mixing, and packaging filling stages. In the presence of oxygen, ascorbic acid is oxidized to hydroascorbic acid, which is then hydrolysed and oxidized to diketogulonic acid and oxalic acid. The rate of aerobic oxidation depends on the pH, with an alkaline environment being the most favourable (OLIVA, 1995). However, the pH values found are considered satisfactory because they comply with regulations, where the maximum for juices is 4.6. In the case of vitamin C, although there was a decrease of approximately 0.2 and 0.1 mg/L in A and B, these values are considered satisfactory because they are within the recommended range.

3.4. Vitamin C and pH Control

The control of vitamin C and pH in artisanal sugarcane juice with the incorporation of antioxidant ingredients (hibiscus, ginger, lemon peel acid, beetroot, and lemongrass) is directly related to the characteristics of each of these ingredients and the impact of pasteurization on their chemical composition.

Hibiscus, for example, contains phenolic compounds and organic acids that can influence both vitamin C stability and juice pH (SANTOS et al., 2019). During the pasteurization process, these compounds can help partially protect vitamin C from degradation caused by heat.

3.4.1. Vitamin C

Vitamin C is highly sensitive to pasteurization, resulting in its reduction in pasteurized samples. Vitamin C retention is therefore limited, and heat certainly caused vitamin C losses, even in the presence of antioxidant ingredients. According to MENDES and GOMES (2020), ascorbic acid is extremely sensitive to heat and is rapidly degraded during thermal processes such as pasteurization. However, the aforementioned authors also note that the presence of antioxidant compounds can slow this process, preserving some of the vitamin C. This is due to the ability of antioxidants to scavenge free radicals before they attack vitamin C, contributing to its stability.

According to LOPES et al. (2020), antioxidants act as protectors of vitamin C, slowing its oxidation during thermal processing and storage. Without antioxidants, vitamin C is more susceptible to degradation, especially under heat and air exposure. Antioxidants such as phenolic compounds and organic acids neutralize free radicals, which would otherwise attack vitamin C, accelerating its loss.

The prepared formulations suffered a loss of vitamin C of approximately 10.5% (A) and 6.25% (B) when pasteurized. In comparative studies of the level of vitamin C loss in pasteurized juices with and without the addition of antioxidants, LOPES et al. (2020) observed a 25% loss of vitamin C in juices with added antioxidants and a 45% loss in juices without the addition of antioxidants. Also along these lines, SILVA et al. (2019) and MENDES and GOMES (2020) observed losses of 30% and 20% in juices with the addition of antioxidants and losses of 50% and 40% in juices without the addition of antioxidants, respectively. Thus, the incorporation of antioxidants contributes to the control of vitamin C losses during pasteurization.

3.4.2. pH

The pH, on the other hand, tends to increase after pasteurization. This increase may be related to the degradation of acids present in the formulation, such as citric acid from lemon peel, which is also heat-sensitive (PEREIRA and LIMA, 2018). Pasteurization causes the loss of volatile acids and slight neutralization, resulting in an increase in pH in heat-treated samples.

Beets and lemongrass, although they contribute nutrients and bioactive compounds, have little impact on pH retention during heat treatment, but they can influence the flavour and heat of the final product (SILVA and MENDES, 2020).

Furthermore, PEREIRA and LIMA (2018) argue that antioxidants such as citric acid, present in lemon peel, and phenolic compounds from hibiscus, can positively influence pH retention by acting as buffers. These compounds help minimize sudden pH changes during heat treatment, contributing to greater stability of the final product. In this study, both the A0 and B0 formulations showed a 0.3 pH increase after pasteurization. In a study on the influence of pasteurization on the pH of fruit juices by PEREIRA E MENDES (2018), it was observed that pasteurization resulted in an average increase of 0.3 pH units compared to unpasteurized juices. This was attributed to the degradation of volatile organic acids during the thermal process. A study on the effects of pasteurization on acidic beverages revealed that the pH increased by 0.2 to 0.4 units after heat treatment. The study concluded that the loss of volatile acids and the partial neutralization of organic acids contribute to the increase in pH.

CARVALHO et al. (2020), in a study evaluating the pasteurization of vegetable juices, recorded a 0.5 pH increase in the samples after pasteurization. This increase was associated with the decomposition of acids during heating and the formation of less acidic compounds.

Therefore, while natural ingredients may contribute to the retention of some nutritional components, the pasteurization process inevitably causes partial degradation of vitamin C and an increase in pH, as observed in the laboratory results.

V. Conclusion

After conducting the research, it was found that the main constituents of homemade sugarcane juice extraction were ginger, beetroot, lemon peel, lemongrass, and hibiscus. These raw materials were derived from unusable parts, in this case the peel, pulp, and leaves of native plants.

The determination of the ingredient quantities for sugarcane juice formulations incorporating natural antioxidants was based on the methodology proposed by FALGUERA (2011), based on the volume of the ingredients, which were used to determine the quantities in question. Therefore, two versions of sugarcane juice were formulated, to which antioxidants were added to ensure vitamin retention and pH. Compared to the literature, the loss of vitamin C of 10.5% (A0 to A1) and 6.25% (Bo to B1) is below the most documented and analysed in this study. Similarly, the pH showed an identical variation (an increase of 0.3 units) for both treatments.

Therefore, it can be concluded that the incorporation of antioxidants during juice extraction minimizes vitamin C losses and pH changes during pasteurization.

In future research of the same nature, we suggest that studies without the incorporation of antioxidants involving pasteurization be conducted in comparison with this study to verify vitamin C and pH stability.

Sensory analysis of this type of juice should be performed, as well as a study of the physicochemical stability of the formulations under different specific pasteurization conditions. The community and sugarcane juice sellers are encouraged to extract and incorporate natural antioxidants to control vitamin C and pH losses, ensuring product and consumer safety.

Acknowledgments

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