PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

ESTUDO EXPERIMENTAL DA INFLUÊNCIA TÉRMICA NO TEOR DE VITAMINA C NA PASTEURIZAÇÃO DE SUCO DE LARANJA EM DOIS TIPOS DE AQUECIMENTO

EXPERIMENTAL STUDY OF THERMAL INFLUENCE ON VITAMIN C CONTENT IN PASTEURIZATION OF ORANGE JUICE IN TWO TYPES OF HEATING

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RESUMO

Introdução: O tratamento térmico é um dos métodos mais utilizados para conservar alimentos, como o suco de laranja, aumentando sua vida útil. No entanto, pouco se sabe sobre os perfis de temperatura e velocidade durante o tratamento térmico de alimentos líquidos em embalagens comerciais. **Objetivo**: Este trabalho teve como objetivo determinar o teor de vitamina C e o coeficiente de transferência de calor por convecção na pasteurização de suco de laranja. **Métodos**: Foram realizados dois testes: no teste 1, o aquecimento começou com banho-maria a 22 ºC e foi aquecido a 80 ºC. No teste 2, o banho-maria iniciou a 80 ºC. **Resultados e Discussão**: O coeficiente de transferência de calor por convecção foi analisado na região da parede, sendo maior no teste 2. Em ambos os testes, o perfil gráfico da curva segue a mesma tendência da literatura. Em relação à vitamina C, no teste 1, houve redução da mesma. No teste 2, manteve-se constante. **Conclusões**: Estudar o comportamento térmico do suco de laranja é de extrema importância para garantir sua qualidade. Para evitar essa degradação e reduzir sua perda, é necessário que nos tratamentos térmicos seja realizado um aquecimento rápido e que o caldo tenha baixa exposição ao ar e ao calor no momento de seu preparo.

Palavras-chave: *Vitamina C. Transferência de calor. Coeficiente Convectivo. Pasteurização*

ABSTRACT

Background: Heat treatment is one of the most used methods to preserve food, such as orange juice, increasing its shelf life. However, little is known about the temperature and speed profiles during heat treatment of liquid food in commercial packaging. **Aim:** This work aimed to determine the vitamin C content and the convective heat transfer coefficient in the pasteurization of orange juice. **Methods:** Two tests were performed: in test 1, the heating started with a water bath at 22 ºC and was heated to 80 ºC. In test 2, the water bath started at 80 ºC. **Results and Discussion**: The convective heat transfer coefficient was analyzed in the wall region, and it is higher in test 2. In both tests, the curve graphic profile follows the same literature trend. Regarding vitamin C, in test 1, there was a reduction in it. In test 2, it remained constant. **Conclusions:** Studying the thermal behavior of orange juice is extremely important to ensure its quality. In order to avoid this degradation and reduce its loss, it is necessary that in thermal treatments, rapid heating is carried out and that the juice has low exposure to air and heat at the time of its preparation.

Keywords: *Vitamin C. Heat Transfer. Convective Coefficient. Pasteurization.*

1. INTRODUCTION:

The citrus industry is an extremely important sector for Brazil, as the country is responsible for 34% of the fruits and 56% of the juice produced in the world. Furthermore, the orange is the most consumed fruit by the Brazilian population, and among the different cultivars is the Pêra Rio orange (Citrus sinensis L. Osbeck) (LEONELLO; ESPERANCINI, 2019).

Heat treatment is one of the most used methods to preserve food, such as orange juice, increasing its shelf life. However, little is known about the temperature and speed profiles during heat treatment of liquid food in commercial packaging (GHANI; FARID (2001).

Pasteurization is a process used in foods

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when the aim is to destroy pathogenic microorganisms and denature low heat resistance enzymes present in foods. Another goal is to increase the shelf life of the food (POTTER; HOTCHKISS, 1995; JING; YONG-YAN, 2013). The process consists of heating the food to a certain temperature and time and subsequently cooling it to a temperature lower than the previous one. The literature (POTTER; HOTCHKISS, 1995) presents three types of pasteurization: the slow one, in which lower temperatures are used for a longer period (usually 65 ºC for 30 minutes); the fast one, known as HTST (High Temperature and Short Time), where high temperatures and short time intervals are used (normally 75 ºC for 15 to 20 seconds); and the very fast, known as UHT (Ultra High Temperature) or long life, where temperatures from 130 ºC to 150 ºC are used, for 3 to 5 seconds. For orange juice, HTST (High Temperature and Short Time) is used (JING; YONG-YAN, 2013).

Orange juice is an excellent source of ascorbic acid, commonly known as Vitamin C, and belongs to the water-soluble vitamins (ÇENGEL; GHAJAR, 2012). However, the quality of the juice can be influenced when it is exposed to oxygen and light, which can reduce the Vitamin C content and sensorially modify the product. To avoid vitamin C degradation and reduce loss, rapid heating and low exposure to air are recommended when preparing the juice (ROSENTHAL *et. al.*, 2018; COZZOLINO, 2012 and TEIXEIRA; MONTEIRO, 2006). Proper storage of the juice, which should be at low temperatures, helps preserve vitamin C and does not darken the juice. If the juice is kept between 15 ºC and 25 ºC, there will be a significant loss of Ascorbic Acid (COZZOLINO, 2012 and TEIXEIRA; MONTEIRO, 2006).

It is possible to find in the literature (TERUEL *et. al.*, 2003; BHUVANESWARI; ANANDHARAMAKRISHNAN, 2014 and MAHARRAMOV, 2021) studies about heat transfer during pasteurization and about food cooling. There are works (TERUEL *et. al.*, 2003) that experimentally studied the cooling of *Valência* oranges with forced air and water. In the chilled water system, cooling occurred uniformly and lasted about 57 minutes. Bhuvaneswari; Anandharamakrishnan (2014) carried out a theoretical study of temperature distribution through pasteurization for orange juice in a cylindrical container based on 3D CFD simulation. Pasteurization for orange juice was simulated at three different temperatures, and the temperature field in each was obtained. Data were compared, and an optimal computational model was obtained for this case.

Also, another author (MAHARRAMOV, 2021) studied the thermal conductivity of orange and tangerine juices in a non-steady state. The author states that all known experimental installations measure the thermal conductivity of liquids in a steady-state, even if in the production and processing of liquid food products, as a rule, the main substance is in a mobile state.

Other authors (ROSENTHAL *et al.,* 2018) concluded that high pasteurization caused significant decreases (about 7,79%) in vitamin C in orange juice. On the other hand, low pasteurization and freezing did not change the vitamin C content (ROSENTHAL *et al.,* 2018; YEBIO *et al*., 2015; NJOKU *et al.,* 2011).

This work aims to determine the vitamin C content using the iodometric method and the convective heat transfer coefficient using the method of dimensionless numbers and the experimental method.

2. MATERIALS AND METHODS:

The juice was prepared and sealed in a 200 mL cylindrical glass container. To control the temperature during the experiment, thermometers (Brax Tecnologia, model -10 + 110ºC) and a stopwatch were used. The vitamin C content was analyzed before and after the pasteurization.

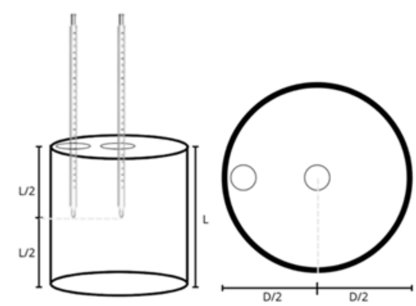

Figure 1. *Representation of the system used to control temperature and analysis regions*

The juice was heated in a water bath, and the temperature was recorded every 120 seconds. Two tests were done: in the first (test 1), heating started with a water bath at room temperature (22 ºC), and this was heated to 80 ºC, simultaneously with the juice heating. In the second (test 2), the water bath was already heated to 80 ºC when the juice was placed in the bath. In both situations, when the central region of the container with orange juice reached 74 ºC, heating was stopped.

Then, cooling was performed, where the sample was placed inside a stainless steel pan with ice. The variation in juice temperature was monitored using thermometers, which were already installed in the cylindrical container, and this was measured every 2 minutes. When the center of the juice container reached 6 °C, cooling was stopped. Next, the bath was cooled to 0 °C.

To analyze the vitamin C content, the iodometric method was used. This method determines the vitamin C concentration in a solution by a redox titration using iodine (SANTOS, et al., 2016). The redox reaction can be seen below (Eq. 1).

$$ascorbic\ acid + I_2 \rightarrow 2I^- + dehydroascorbic\ acid \quad \text{(Eq.1)}$$

3. RESULTS AND DISCUSSION:

3.1. Determination of Vitamin C

It is known (PACHECO, 2011) that 200 mL of orange juice contains 100 mg of vitamin C, so calculations were made based on this data, following Brazilian Normative Instruction No. 01, of January 7th, 2000.

Literature (ROSENTHAL *et al.*, 2018; COZZOLINO, 2012 and TEIXEIRA; MONTEIRO, 2006) says that if orange juice is kept between 15 ºC and 25 ºC, there will be a significant loss of Ascorbic Acid. As can be seen in Table 1, in test 1, there was a loss of vitamin C after pasteurization. In this test, temperatures in this interval were recorded for more than 240 seconds. On cooling down, this event lasted more than 450 seconds. Analyzing test 2, it is noted that there was no loss of ascorbic acid. The juice remained very short, between 23 ºC and 16 ºC in the cooling stage. Thus, the loss of ascorbic acid is because the juice remained at inadequate temperatures for vitamin C conservation.

3.2. Temperature Profile in Pasteurization

In test 1, the pasteurization process lasted 6360 seconds. The heating step lasted 4080 seconds and the cooling 2280 seconds. In test 2, pasteurization lasted 5520 seconds, whereas heating lasted 3000 seconds and cooling 2520 seconds. This information can be seen in Figure 2 and Figure 3.

It is possible to observe that, in both tests, the two regions presented practically the same temperature variation. The curve profile is also the same in both cases. In the literature (BHUVANESWARI; ANANDHARAMAKRISHNAN, 2014 and PRIEST; STEWART, 2006), some authors studied the same case and obtained the same profile.

3.3. Convective Heat Transfer Coefficient in Pasteurization

In this research, heat transfer was analyzed in the heating stage. The convective heat transfer coefficients were determined in the wall region. In this region, heat transfer via conduction in a transient regime was used, where the concentrated capacity method was applied, given that the number of Biot was less than 0.1.

To determine the convective coefficient in the wall region, the thermophysical properties used in the calculations were those of glass. Figure 4 presents the results of the convective coefficient in the two tests.

It is possible to observe that the convective heat transfer coefficient is higher in test 2. In the literature (PACHECHO, 2011), there are graphic profiles similar to those obtained.

The standard deviation for the convective coefficient in the wall region in test 1 and test 2 were 19.87 and 32.02, respectively. The high value for the standard deviation is justified because the regime is transient.

Based on Figure 5, it is possible to affirm that test 2 is the most favorable, given that the time used is shorter and the vitamin content is maintained without any losses.

4. CONCLUSIONS:

It was possible to notice that, in both tests, both the region of the center of the container and the region of the wall present similar temperature variations, which are in accordance with the profiles found in the literature. The convection heat transfer coefficient is higher in test 2 and tends to balance with time. It is worth noting that studying the thermal behavior in the cooling of orange juice is extremely important to guarantee its quality.

In test 1, the temperature variation affected the vitamin C content of orange juice, while in test 2, there was no degradation of ascorbic acid. Therefore, starting heating with a water bath at the maximum desired temperature is appropriate. Thus, it is pertinent to mention that in order to avoid this degradation and reduce its loss, it is necessary that in thermal treatments, rapid heating is carried out and that the juice has low exposure to air and heat at the time of its preparation. Therefore, studying the thermal behavior in the heating of orange juice is extremely important to guarantee its quality.

5. DECLARATIONS

5.1. Study Limitations

No limitations were known at the time of the study.

5.2. Acknowledgements

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5.3. Funding source

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5.4. Competing Interests

The authors declare the following financial interests/personal relationships that may be considered potential competing interests: equipment, drugs, or supplies provided by the Federal University of Mato Grosso.

5.5. Open Access

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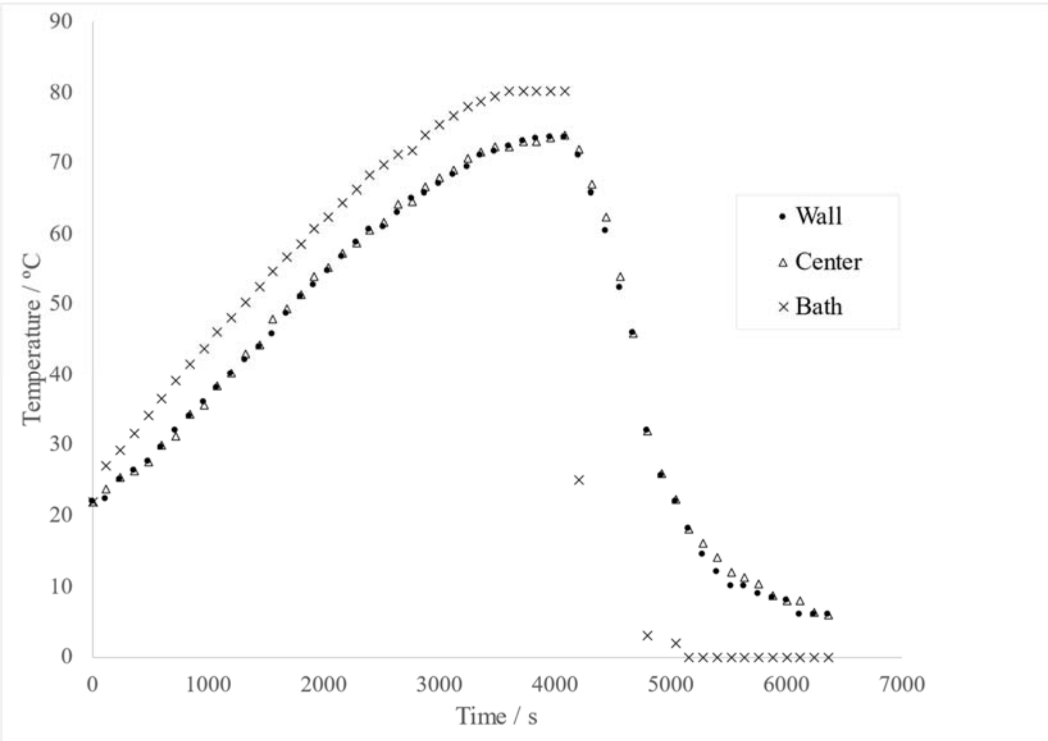

Figure 2. *Time-temperature behavior during pasteurization in test 1*

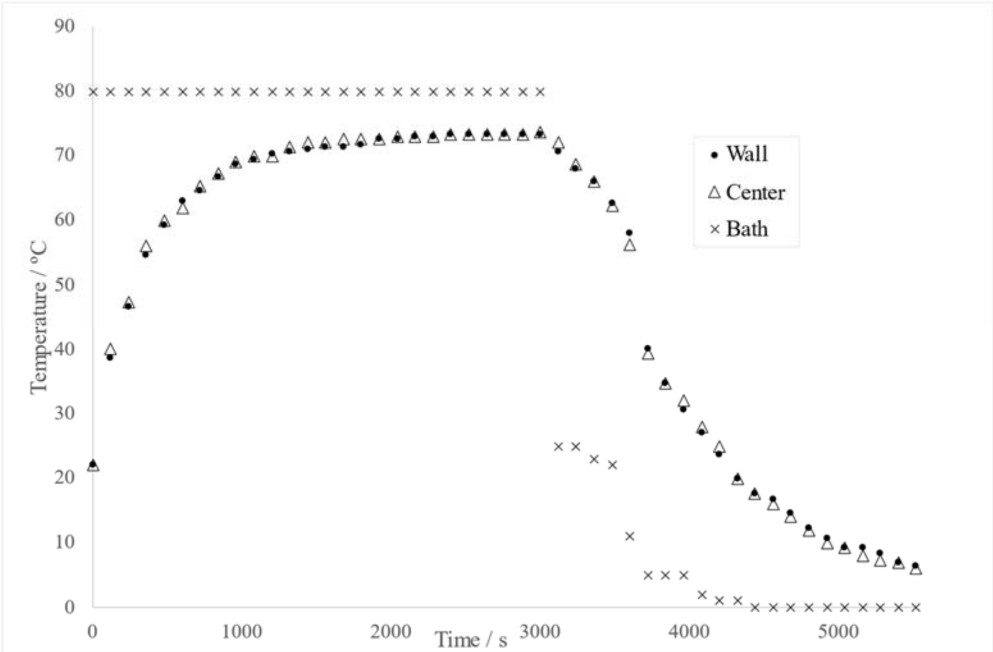

Figure 3. *Time-temperature behavior during pasteurization in test 2*

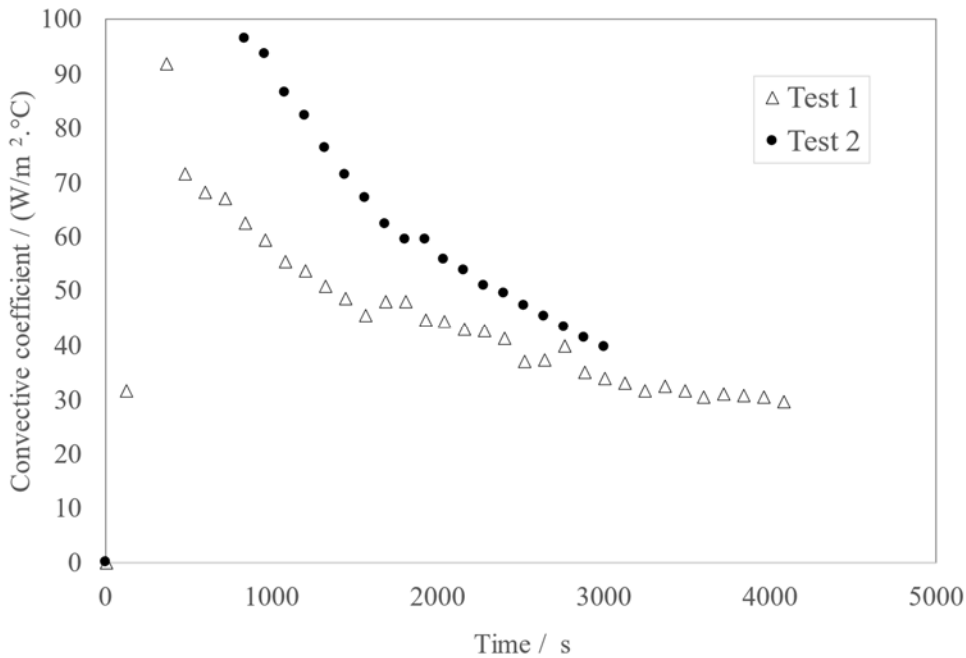

Figure 4*. Convective heat transfer coefficient in the wall region in the heating stage*

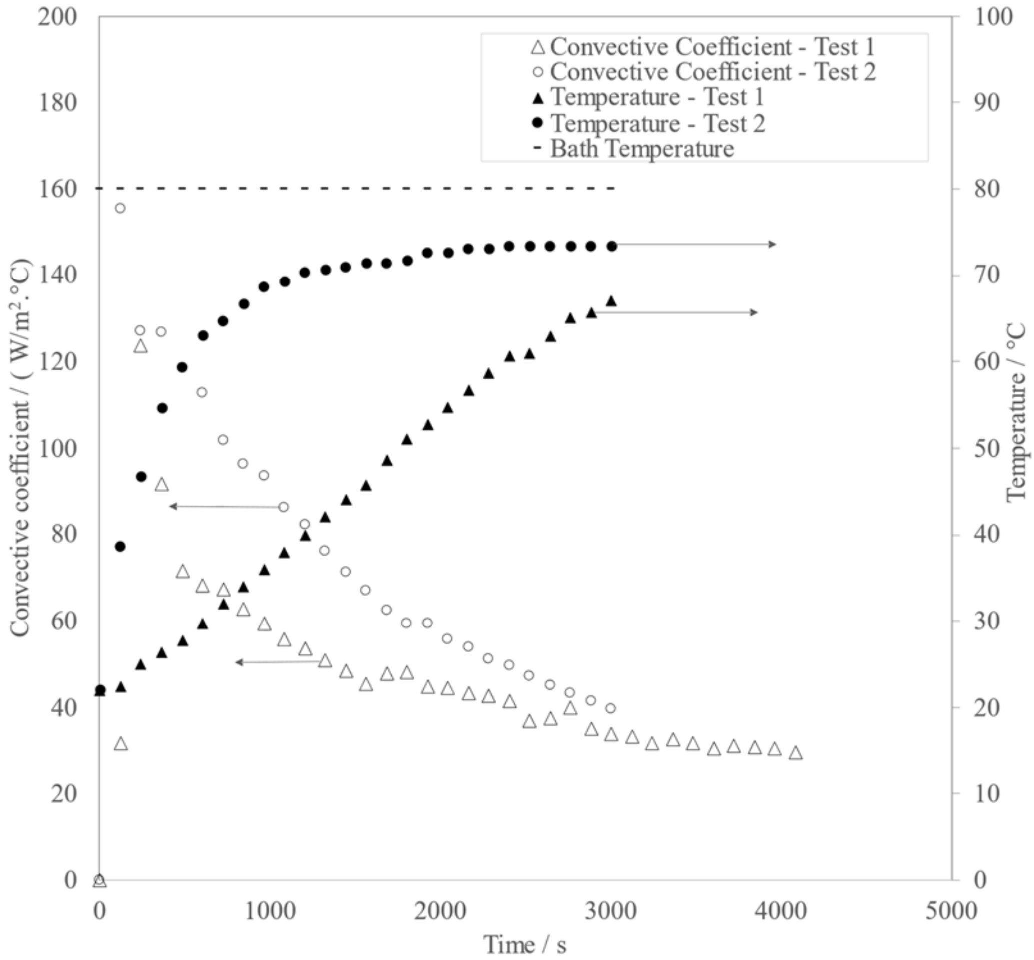

***Figure 5**. Relation time-temperature-convective coefficient*

***Table 1.** Vitamin C content and volume of 1% iodine alcoholic solution spent in the titration of each sample*

Sample	Volume of 1% iodine alcoholic solution / mL		Vitamin C content / (mg/100 mL)	
	Test 1	Test 2	Test 1	Test 2
Juice before pasteurization	0.4	0.4	42.55	42.55
Juice after pasteurization	0.2	0.4	21.27	42.55