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EXPERIMENTAL STUDY OF THE INFLUENCE OF TEMPERATURE ON PASTEURIZATION OF *PÊRA RIO IN NATURA* ORANGE JUICE

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ABSTRACT

Background: Heat treatment is one of the most used methods to preserve food, such as orange juices, which are an excellent source of ascorbic acid. To avoid vitamin C degradation and reduce loss, fast heating is recommended. However, little is known about heat transfer during juice pasteurization. **Aim:** Therefore, this work aimed to determine the vitamin C content and the convective heat transfer coefficient in the pasteurization of orange juice. **Methods:** To perform the experiment, in the juice container, two regions were analyzed: the central region and near the wall. For the time-temperature control, thermometers were installed in the two regions mentioned. Every 120 seconds, the temperature was measured. The vitamin C content in the juice was evaluated before and after pasteurization using the iodometric method. The convective coefficient was evaluated using the method of dimensionless numbers and the experimental method. **Results and Discussion:** In pasteurization, the solution was heated to 80 °C, where heating lasted 3000 seconds and cooling for 2520 seconds. The graph showing the relationship of the convective heat transfer coefficient and temperature follows the same trend of the literature. The convective coefficient is higher in the region near the wall. As time passes and temperature decreases, the central region tends to equilibrium, and the coefficient becomes more constant. The vitamin C content remained constant before and after pasteurization. The values of the dimensionless numbers used in the calculations are in the same order of magnitude as the literature. **Conclusions:** The pasteurization did not cause ascorbic acid degradation since the heating step was fast in the heat treatment. The graphic showed that there is a dependence of the dimensionless of temperature with the dimensionless Biot and Fourier. It was noted that studying the thermal behavior in the cooling of orange juice is extremely important to ensure its quality.

Keywords: *Heat Transfer. Pasteurization. Orange Juice. Convective Coefficient.*

1. INTRODUCTION:

The citrus industry is an extremely important sector for the Brazilian economy, 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 *et al.,* 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 *et al.*, 2001).

Pasteurization is a process used in foods when the aim is to destroy pathogenic microorganisms and denature low heat resistance enzymes present in foods. In addition, another goal is to increase the shelf life of the food. 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 (Potter; Hotchikiss, 1995). The literature presents three types of pasteurization, and for orange juice, HTST (High Temperature and Short Time) is used (Jing *et al.*, 2013).

Orange juice is an excellent source of ascorbic acid, commonly known as Vitamin C, and belongs to the water-soluble vitamins. 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, fast heating and low exposure to air are recommended when preparing the juice. 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; Teixeira; Monteiro, 2006).

It is possible to find in the literature studies about heat transfer during pasteurization and about food cooling. Teruel *et al.* (2003), experimentally studied the cooling of *valência* oranges with forced air and water. In the chilled water system, cooling occurred uniformly and lasted about 3420 seconds. Jing *et al.* (2013) 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, 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.

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 in the pasteurization of orange juice.

2. MATERIALS AND METHODS:

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

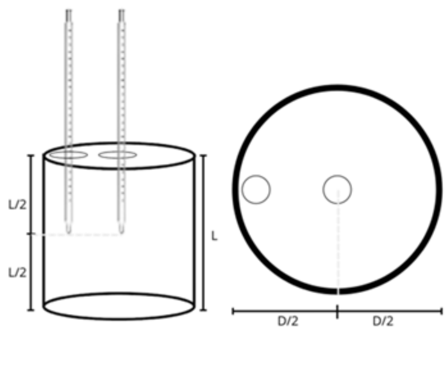

Figure 1. *Representation of the system used to control temperature and analysis regions*

The juice was heated in a water bath, and the temperature was recorded every 120 seconds.

The water bath was already heated to 80 ºC when the juice was placed in the bath. Therefore, 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 120 seconds. When the center of the juice container reached 6 °C, cooling was stopped. Next, the bath was cooled to 0 °C.

3. RESULTS AND DISCUSSION:

3.1. Temperature Profile in pasteurization

In this study, pasteurization lasted 5520 seconds, where heating lasted 3000 seconds and cooling 2520 seconds.

It is possible to observe in Figure 2 that the two regions presented practically the same temperature variation. In the literature of Bhuvaneswari (2014) and Priest; Stewart (2006), the profile of the curve follows the same trend.

3.2. Vitamin C Content

Regarding the vitamin C content, it remained constant before and after pasteurization.

3.3. Relationship between the dimensionless temperature and Biot*Fourier

According to Incropera; De Witt (2003), when the Biot number is less than 0.1, it is reasonable to assume a uniform temperature distribution in a solid at any time during a transient process. If conduction were the dominant heat transfer in the container, a non-uniform temperature distribution and Biot number greater than 0.1 would be expected. As Biot was less than 0.1, it is suggested that there is strong natural convection occurring in the container.

The graphical behavior presents a straight line, with $R^2 = 1$, whose equation is:

$$y = 0.0667x \quad (1)$$

This behavior shows that there is a dependence of the dimensionless of temperature with the dimensionless Biot and Fourier. The graph for Equation 1 can be seen in Figure 3.

3.4. Convective Heat Transfer coefficient in pasteurization

In this research, heat transfer was analyzed in the cooling stage. Under these conditions, the concentrated capacity method is applied. In the wall 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. In the central region of the container, Newton's theory of cooling was used. In both regions, the convective heat transfer coefficients were determined.

To determine the convective coefficient in the wall region, the thermophysical properties used in the calculations were those of glass. To determine the convective coefficient in the central region, the thermophysical properties of the fluid were used, in this case, the orange juice.

It is possible to observe in Figure 4 that the convective heat transfer coefficient is higher in the region near the wall, and there is a sharp drop in the convective coefficient curve in the wall region. This is because the temperature is very high at this moment, as it is the period when cooling starts, so the value is lower. As time passes and temperature decreases, the central region tends to equilibrium, and the coefficient becomes more constant. The standard deviation for the convective coefficient in the central region and in the wall region were 3.99 and 16.74, respectively.

3.5. Dimensionless numbers used in the calculation of the heat transfer convective coefficient in the central region

It is observed, in Table 1, in the order of magnitude of the dimensionless numbers, the occurrence of laminar regions, which remain stable over time. In their study, Fujii *et al.* (1970) obtained values in the same order of magnitude.

4. CONCLUSIONS:

It was possible to observe that both the region of the center of the container and the region of the wall have similar temperature variations, which agree with the profiles found in the literature. The convective heat transfer coefficient is higher in the wall region and tends to equilibrium over time.

It was seen that the dimensionless number of temperature has a dependence relation with the dimensionless numbers of Biot and Fourier. Still, the order of magnitude of the dimensionless numbers used to calculate the convective heat transfer coefficient indicates the occurrence of laminar regions, which remain stable over time, which was expected.

It was observed that the pasteurization did not cause ascorbic acid degradation since the heating step was fast in the heat treatment. In order to avoid this degradation and reduce its loss, it is necessary that in thermal treatments, fast 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 cooling 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, which 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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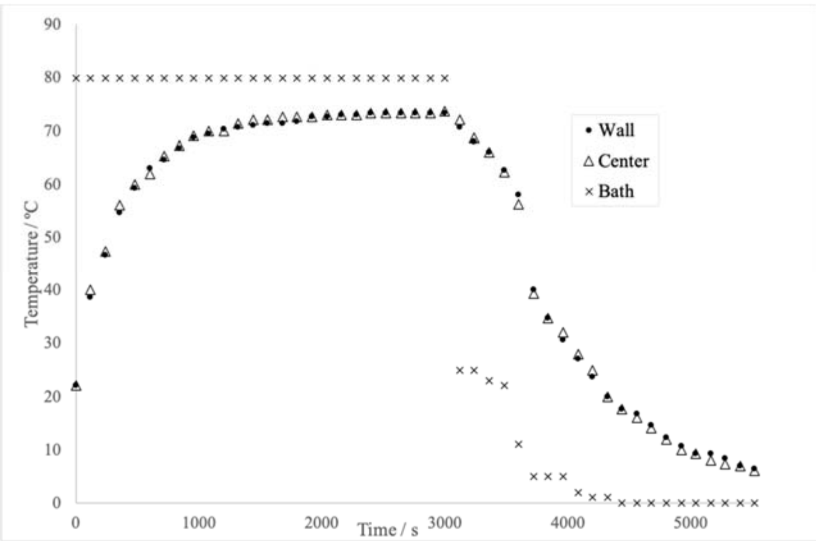

Figure 2. *Time-temperature behavior during pasteurization*

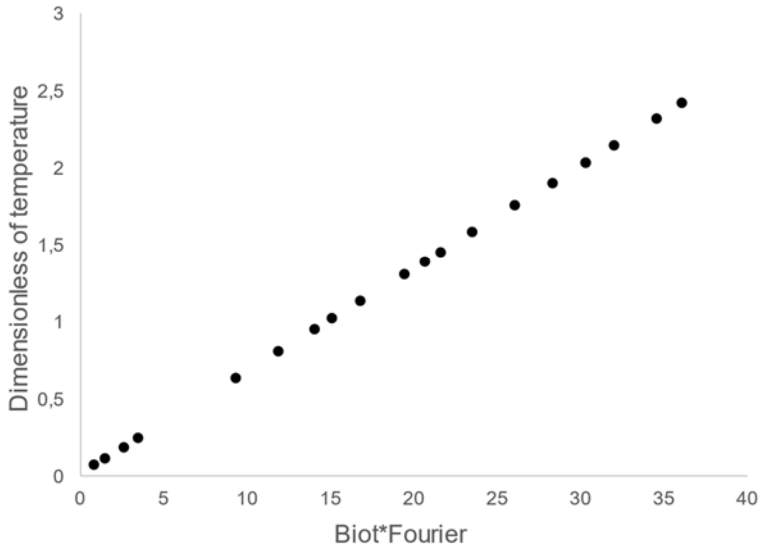

Figure 3. *Relationship between the Dimensionless of Temperature and Biot*Fourier*

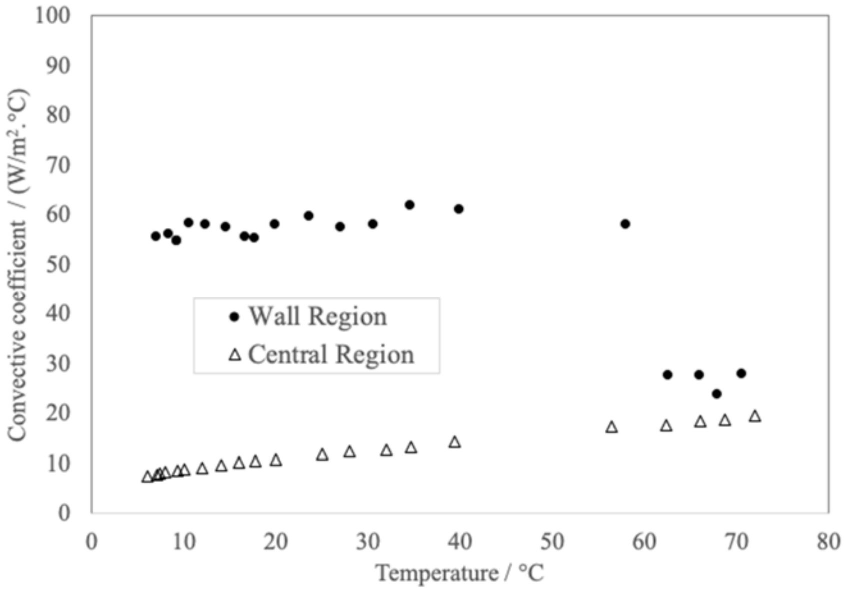

Figure 4. *Convective heat transfer coefficient in the cooling stage*

Table 1. *Dimensionless numbers used in the calculation of the heat transfer convective coefficient in the central region*

Time (s)	Temperature (ºC)	Pr	Gr	Ra	Nu
120	72.00	4.31	$8{,}90.10^8$	$3{,}84.10^9$	146.85
240	68.67	4.47	$7{,}76.10^8$	$3{,}47.10^9$	143.22
360	66.00	4.64	$7{,}17.10^8$	$3{,}33.10^9$	141.74
480	62.33	4.94	$6{,}02.10^8$	$2{,}97.10^9$	137.79
600	56.33	5.57	$5{,}52.10^8$	$3{,}07.10^9$	138.92
720	39.33	8.28	$2{,}01.10^8$	$1{,}66.10^9$	119.17
840	34.67	9.26	$1{,}41.10^8$	$1{,}30.10^9$	112.13
960	32.00	9.87	$1{,}14.10^8$	$1{,}12.10^9$	108.02
1080	28.00	10.84	$9{,}25.10^7$	$1{,}00.10^9$	104.99
1200	25.00	11.62	$7{,}52.10^7$	$8{,}74.10^8$	101.43
1320	20.00	13.00	$4{,}83.10^7$	$6{,}28E.10^8$	93.39
1440	17.67	13.69	$4{,}09.10^7$	$5{,}59.10^8$	90.74
1560	16.00	14.20	$3{,}46.10^7$	$4{,}91.10^8$	87.83
1680	14.00	14.83	$2{,}79.10^7$	$4{,}14.10^8$	84.17
1800	12.00	15.47	$2{,}21.10^7$	$3{,}42.10^8$	80.26
1920	10.00	16.14	$1{,}71.10^7$	$2{,}75.10^8$	76.00
2040	9.33	16.37	$1{,}55.10^7$	$2{,}54.10^8$	74.48
2160	8.00	16.83	$1{,}26.10^7$	$2{,}13.10^8$	71.25
2280	7.33	17.06	$1{,}13.10^7$	$1{,}93.10^8$	69.51
2400	7.00	17.18	$1{,}06.10^7$	$1{,}83.10^8$	68.61
2520	6.00	17.53	$8{,}79.10^6$	$1{,}54.10^8$	65.73