Proceeding Series of the Brazilian Society of Computational and Applied Mathematics, v. 11, n. 1, 2025.

Trabalho apresentado no XLIII CNMAC, Centro de Convenções do Armação Resort - Porto de Galinhas - PE, 2024

Computational Simulation of the Alternative Cocoa Fermenter

Jorge Henrique Sales[1], Gabriel F. O. Viana[2], Claudio S. de S. Brandão[3]
Universidade Estadual de Santa Cruz, Rod. Jorge Amado, Ilhéus-Bahia/Brazil, 45662-900

In the southern region of Bahia, the cocoa culture has been a source of income and moved the economy for a long time, but the emergence of the witch's broom caused the decline of this productive sector. Given the importance of cocoa for the region, it makes sense to use it as an object of study for the development of academic research that can foster the reheating of this branch of the economy [1]. In this context, for the processing of cocoa to occur to be able to use in the manufacture of chocolate and derivatives it needs to go through 5 distinct stages, being: harvesting, breaking, fermentation, drying, and storage. The stages in question are responsible for more than 45% of the organoleptic properties of cocoa, i.e. affect the final quality of the product. Fermentation is one of the most important stages since it is through fermentation that cocoa develops most of its characteristics, such as colors, flavors, and aroma. The step by step of cocoa fermentation is to let the mass ferment, without stirring, until the temperature reaches 32°C or if it does not reach the ideal temperature, wait to complete 48h. There are cases in which temperatures can be reached between 40°C to 60°C [1]. Thus, the idea arose to create a cocoa fermenter model that could increase the efficiency of the fermentation cycle, and boost its scale and quality. Nowadays the process is done manually, requiring the worker to perform the laborious task of monitoring and stirring the cocoa mass at short intervals, in hours. This work compares four fermentation equipment through the analysis of heat diffusion. The method is theoretical with the help of computer modelling, where the propagation of heat from a source throughout the system filled with a mass of cocoa is evaluated. This study considers four possible fermenter models, making use of Fourier equations in Cartesian and cylindrical coordinates to model the diffusion of heat in space since the biochemical reactions that occur in fermentation suffer a direct influence of temperature. The methodology used in this work consisted of the analytical resolution of the Fourier equation [2] for the heat and the computational simulation of the cooling curve of the cocoa mass. The Fourier equation used to solve this problem is a second-order partial differential equation that describes the temperature variation in a constant volume; where only heat exchange occurs through thermal conduction and the regime is non-stationary, (temperature varies with time). This equation is given by:

$$\frac{\partial \Psi(r,t)}{\partial t} = \alpha \nabla^2 \Psi(r,t). \tag{1}$$

Being α is the thermal diffusivity, $\Psi(r,t)$ is the temperature, and operator ∇^2 is associated with the point of space. Considering that all models seek to establish the same initial conditions, the values of the constants will not affect the simulation as much as in the case of geometry. For both geometries in all domains, the physics is defined at an initial temperature of 20°C (293.15 K) which is considered as the ambient temperature. The heat source was assigned the value 50°C (323.15

[1] jhosales@uesc.br
[2] gfoviana.egm@uesc.br
[3] cssbrandao@uesc.br

K) which corresponds to the amount of heat of 54 KJ (for a cocoa mass of 0.5 Kg), or the heat transfer rate of for 10 min (600s). A normal mesh, standard of the program was used, was defined for a time interval of 0 to 600 seconds (10 min) at a step of 1 second. The results obtained for the simulation of the fermentation trough are presented below for the times of 0, 60, and 600s (10 min):

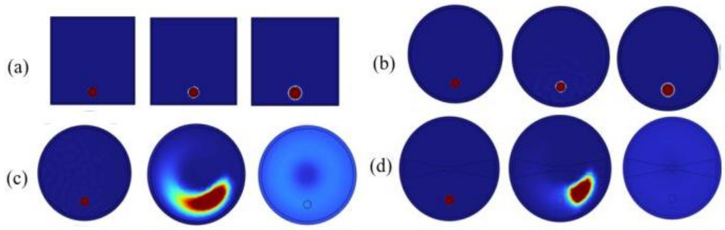

Figure 1: Fermentation models at instants 0, 60 and 600 seconds (10 min). Source : authors.

The method is theoretical where the propagation of heat from a source throughout the system filled with a mass of cocoa is evaluated. Trough computational simulation were built 4 models of fermenter, which are: a) Fermentation trough (based in common used models), b) Stationary fermenter (without stirring), c) Spin fermenter (where its applied a rotation of $\frac{\pi}{100}$ rad/s) and d) Fermenter with helix (with the same rotational speed). Both models have the same internal volume, by using the finite elements method the meshes bellow were generated. The trough system and stationary fermenter shows, through computer simulation, which a single heat source (50°C), propagates symmetrically to its isotherms, with a decrease in temperature to the limit of 20°C (cocoa mass temperature). Conversely the spinning fermenter show asymmetrical isotherms within the cocoa mass. The asymmetry favors the propagation of heat to other regions of the cocoa mass, which establishes a thermal equilibrium of around 21°C within 10 minutes. Consequently, activating fermentation at other points within the spinning drum. Resulting in more uniform fermentation throughout the system. The simulation shows that the isotherms are not well distributed by the spinning system with propellers. This traditional process is inefficient due to the non-uniform temperature distribution in the cocoa mass, thus requiring external intervention to standardize the temperature. This problem could be solved with two proposed fermentation systems: Spinning cylindrical and fermenter with helix.

Acknowledgements

Sales and Viana have CNPq support

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