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Research Protocol

Analysis of Biochemical Changes during Food Sterilization Using CFD

Ghani A Albaali*

Princess Sumaya University for Technology, Jordan

***Corresponding Author**: Ghani A Albaali, Princess Sumaya University for Technology, Jordan.

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Abstract

The concentration profiles of bacteria deactivation and Vitamin C (Ascorbic acid) destruction in canned food during the sterilization process are presented and analyzed. Navier Stocks equations of energy, momentum, and continuity are solved for 2D cylindrical can together with the concentration equations for bacteria deactivation and vitamin destruction using Computational Fluid Dynamics CFD. Arrhenius equations are also used in the analysis of the kinetic of these biochemical changes. The natural convection is also studied for a can filled with cherry juice that was subjected to heat (saturated steam at 121°C) from all sides. The work shows clearly the effect of secondary flow on the Lowest Temperature Zone LTZ. It also shows its fluency on the biochemical changes of both bacteria and vitamins.

***Keywords:** CFD; Analysis of Biochemical; Food Sterilization*

Introduction

The sterilization process is normally using saturated steam to heat the food to a temperature sufficient to kill microorganisms [1]. The heat is transferred to the liquid food during the sterilization process are mainly by conduction and convection. Natural convection heating of the lowest temperature zone leads to its movement towards the bottom of the can [2,3] and Kumar., *et al*. (1991 and 1990).

The governing equations and boundary conditions

Transient temperature, velocity, bacteria, and vitamin concentrations, during the sterilization process in a 2D cylindrical can, are analyzed ad studied. The Navier Stocks equations of energy, momentum, and continuity are used [4], which are solved together with those for bacteria deactivation and vitamins destruction.

Concentration equation for bacteria deactivation

$$\frac{\partial C_b}{\partial t} + v\frac{\partial C_b}{\partial r} + u\frac{\partial C_b}{\partial z} = D\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial C_b}{\partial r}\right) + \frac{\partial^2 C_b}{\partial z^2}\right] - k_b C_b \qquad (1)$$

Concentration equation for vitamin destruction

$$\frac{\partial C_v}{\partial t} + v\frac{\partial C_v}{\partial r} + u\frac{\partial C_v}{\partial z} = D\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial C_v}{\partial r}\right) + \frac{\partial^2 C_v}{\partial z^2}\right] - k_v C_v \qquad (2)$$

Where C_b and C_v are bacteria and vitamin concentration in the liquid food, *r* and *z* are the radial and the vertical positions of the can used, *D* is the diffusion coefficient, *v a*nd *u* are the velocities in both radial and vertical direction, k_b and k_v are the reaction rate constant of bacteria and vitamins respectively.

The boundary conditions used are by assuming the can sitting in its upright position and heated from all sides by saturated steam and by assuming that all physical properties are constants except for viscosity and density. The effect of bacteria and vitamin diffusion is assumed constant because of the high viscosity of the liquid used. The viscosity is calculated based on the change in temperature following to a 2nd order polynomial:

$$\mu = a+bT+aT^2 \qquad (3)$$

Where *a*, *b*, and *c* are the polynomial constant and *T* is the temperature (°C)

Bacterial deactivation and vitamin destruction kinetics

The biochemical changes may include negative or positive impact. The rate of biochemical changes is usually follows (Reuter, 1993):

$$-\frac{dC_b}{dt} = k_b C_b \qquad (4)$$

$$-\frac{dC_v}{dt} = k_v C_v \qquad (5)$$

where, *Cb* and *Cv* is the concentration of the bacteria and vitamin in the can, *t* is the time of exposure to heat, k_b and k_v are the reaction rate constants, which is usually described by Arrhenius equation.

Results And Discussion

The simulation presented in this work shows the effect of sterilization for a can filled with cherry juice. Figure 1 shows the streamline and velocity profile for a mentioned can after a heating period of 1000 s. This figure shows clearly the influence of the flow on the location, shape, and size of the lowest temperature zone. Figure 2 shows the profiles of temperature, bacteria deactivation, and Vitamin C destruction for the same can and at the end of the sterilization process (2450 s). This figure shows the effect of temperature on both the deactivation of bacteria and the destruction of Vitamin C. It shows also that the lowest heating zone moved toward the bottom of the can.

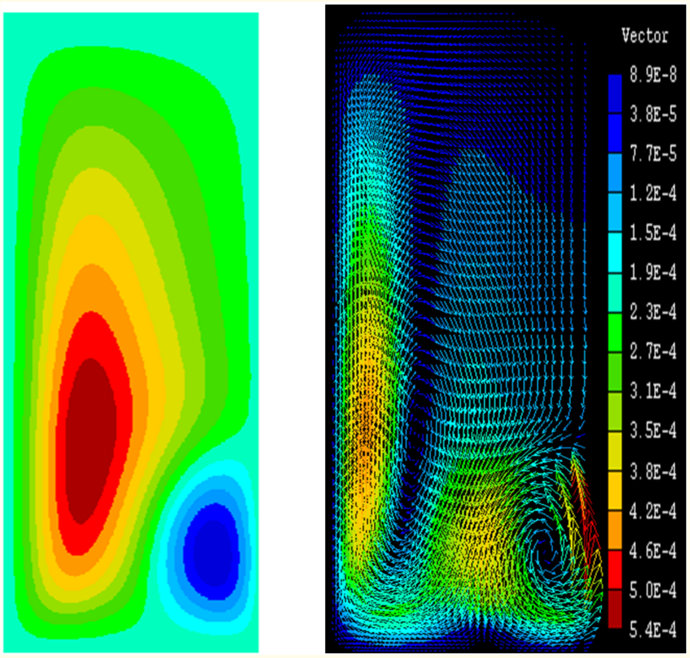

Figure 1: *Streamline and Velocity Profile of Cherry Juice in a 2D Can Heated by Steam After 1000s.*

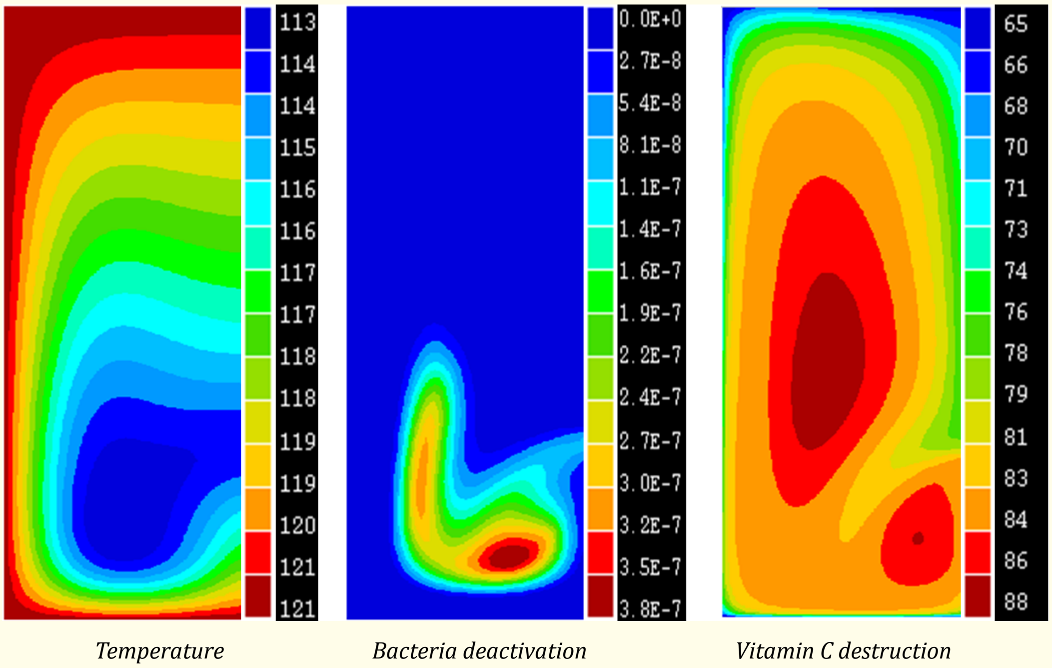

Figure 2: *Profiles of Temperature, Bacteria Deactivation, and Vitamin C Destruction in a can Filled with Cherry Juice After 2450 s of Heating.*

Conclusions

Sterilization of cherry juice in a 2D cylindrical can heated from all sides has been presented and analyzed. The Navier Stocks equation is solved numerically together with the concentration equation for bacteria and Vitamin C. Arrhenius equation was used to describe the kinetics of the deactivation of bacteria and the destruction of Vitamin C. The results of the simulation show the recirculating flow inside the can and the formation of a secondary flow. It also shows the movement of the lowest heating zone towards the bottom of the can. It is also found that bacteria and vitamin concentrations are depending on the flow pattern and the temperature distribution.

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