

THE USE OF SUPERVISORY SOFTWARE AS A OPTIMIZATION TOOL FOR CAN STERILIZATION PROCESSES

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Abstract. This paper intends to present the use of numerical modelling and computational simulation of temperature profiles inside a can containing a food product which is heated by conduction. This model will be used by a computational algorithm associated with a retort control system to optimize the sterilization process.

Keywords: *Mathematical Modeling, Heat Transfer, Computational Simulation, Can Sterilization, Retort Control, Lethality Calculation.*

1. Introduction

Nowadays, thermal sterilization of canned foods in retorts has been one of the most widely used methods of food preservation. Typically, the thermal sterilization method consists of heating food containers in pressurized retorts at defined temperatures for pre-established time intervals followed by sudden cooling.

The conditions applied to the thermal processing of canned foods must be defined by specialists according to each set equipment/container/food. This system define the following process conditions: processing time, process temperature, minimal initial temperature of canned food, pressure profile and deaeration program of retort.

According to these quality and safety requirements, the processing time determination is very carefully done, including the processing time and temperature control, to avoid that the canned food will be under-processed or over-processed.

“Although the sterilization processes can be carefully defined, its application day-by-day in the industrial production has no correspondence with ideality. Operational problems like energy failure, temporary interruption of steam supply and also failure of control system hardware frequently occur and are responsible for process deviations based in the temperature variation of heating medium. Another process deviations can occur when there are basic process parameters modifications, like: canned food initial temperature, diminution of the processing time, e heating temperature medium lower. When these deviations are observed, the batch is usually reprocessed or segregated for further analysis of the process trend records by specialists that will define the batch destination. These procedures are costly, slow and when the decision is the reprocessing of the canned food, it implies in quality food product deterioration (Germer, 1997).

The purpose of this paper is present a mathematical model, which woks in real time basis and considers the operating conditions of a stationary retort. This model will receive data of retort control system and act as a software sensor for lethality determination.

2. Problem Formulation

The canned food sterilization depends, partially, of heat penetration rate inside it. When food products are packaged in to containers, that will receive heat treatment inside a retort, using steam as a heating agent, the condensation of the steam will define the rate of heat transfer to the system canned food/container. The following factors affect the heat transfer rate (TEIXEIRA et alii, 1999): (i) heat transfer coefficients; (ii) physical properties of food products and of container; (iii) temperature difference between the retort and the canned food; and (iv) container dimensions.

In this paper, we are interested in estimated the temperature profile inside of vegetal meat, packaged in cylindrical container. The vegetal meat used in this paper has the following composition: wheat gluten, soybean texturized protein, hydrolised vegetal protein, coconut fat, onion, garlic and salt. The vegetal meat used was obtained directly to the production line at a brazilian food company (SUPERBOM). For the experimental tests, were used cylindrical methalic containers with 73,3 mm of diameter and 111 mm of height.

3. Sterilization Process Control in Real Time

The use of mathematical model capable of predict the canned food characteristics as a function of process conditions alterations is fundamental to have a good performance of a real time computer controlled control systems (Akterian, 1999).

The major advantage obtained with the use of mathematical models capable of predict the temperature profile of canned food is based on the fact that we could accept retort temperature variations. For instance, when a sudden decrease in retort temperature occurs, the model will furnish the food cold spot temperature and will calculate the lethality imposed to it.

In this job, we are interested that the mathematical model works like a software sensor, used as a computer control subsystem. In his case, the model must predict the correct temperature response of canned food when the retort temperature is disturbed and the correspondent effect over the accumulated telhality (Fo) (Ryckaert, Claes and Van Impe, 1999).

The retort used is controlled by a digital control system that utilizes a microprocessed indicator and controller (SMAR, model CD-600) coupled with a programmable logic controller (ALLEN BRADLEY, SLC500). Both devices communicate with a host computer used to process supervision (AIMAX WIN). Figure 1 presents the hardware used by the retort control system.

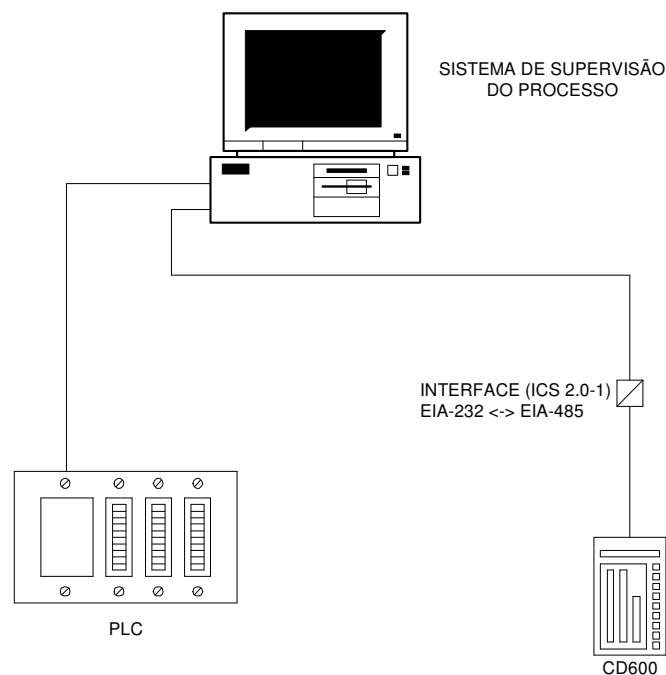


Figure 1 – Hardware of the retort control system.

The temporization of exhaust and the heating temperature periods are executated by the programmable logic controller. After this step be concluded, the control system allow the beginning of the cooling step, introducing cooling water into the retort. At this point is very important the retort pressure control, to avoid damage to the food containers.

The temperature and pressure inside retort are controlled by the CD-600 controller. This equipment is able to control up to four feedback control loops.

The retort interlock is executated by the SLC-500 programmable logic controller and don't allow the retort operation if the position switch located at the top of the retort is not locked. Also, the interlock will interrupt the retort operation in case of sudden increase in the operation pressure.

The retort is equiped with five temperature sensors, which can mounted over the container of canned food product. These sensors are important to obtain data that permits the construction of the heat penetration curve. The pressure and

the temperature measurement use microprocessed electronic transmitters that furnish readings more accurate of these process variables (Stephanopoulos, 1984).

4. Mathematical Model Development

The heat transfer to the vegetal meat packaged in a cylindrical container of height H and radius R , with constant thermal diffusivity α is governed by the following differential Equ. 1.

$$\frac{\partial T}{\partial t} = \alpha \left[\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} + \frac{\partial^2 T}{\partial y^2} \right] \quad (1)$$

where;

- T = canned food temperature;
- t = processing time;
- r = radial direction quota ;
- y = axial direction quota;
- α = thermal diffusivity of canned food

Figure 2 shows an typical schema of cylindrical container that utilizes the coordinates presents below.

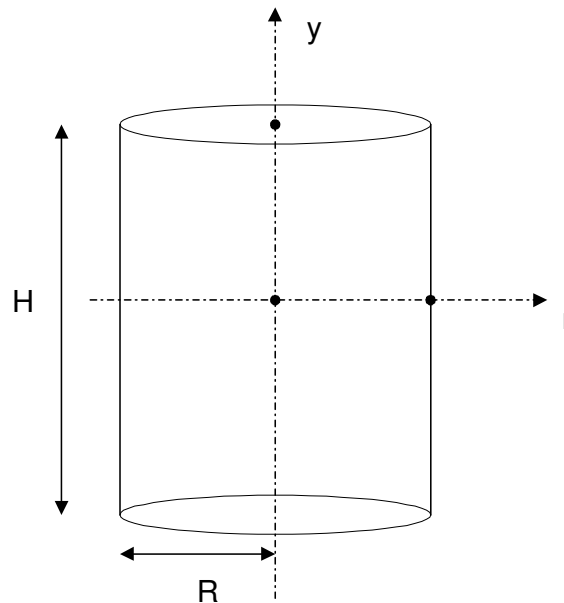


Figure 2 – Coordinates system for a cylindrical container

The accumulated lethality (F_o), Eq. 2, is presented in the sequence.

$$F_o = \int_0^{t_f} \frac{1}{10^{\frac{T_r - T}{z}}} * dt \quad (2)$$

Where:

- T_r = reference temperature for a specific canned food;
- T = canned food temperature;
- t_f = final time of thermal processing; and
- z = temperature difference required to reduce the time spent for 10 times diminution of microorganism population.

Equation 2, show us that accumulated lethality of the canned food that receive the thermal treatment is based on temperature profile of canned food, since the beginning of the sterilization.

In this paper, were employed the following simplified hypothesis (Teixeira et Alii, 1999): (i) the temperature of canned food is uniform at $t = 0$; (ii) the cylindrical container temperature is uniform after $t = 0$ (there is no variation between to distinct points); (iii) the external heat transfer coefficient is high (the thermal resistance of the surface is very small); (iv) the thermal difusivitty doesn't vary with the time, the temperature, and spatially inside canned food; and (v) there is no headspace inside the container.

The mathematical model was developed using the discretization of the system container/canned food with a finite number of volume elements, admitted isothermics (WELT et Alii, 1997). Figure 3 presents the typical discretization utilized, where are showed the node "I" connections with respect to the neighborhood.

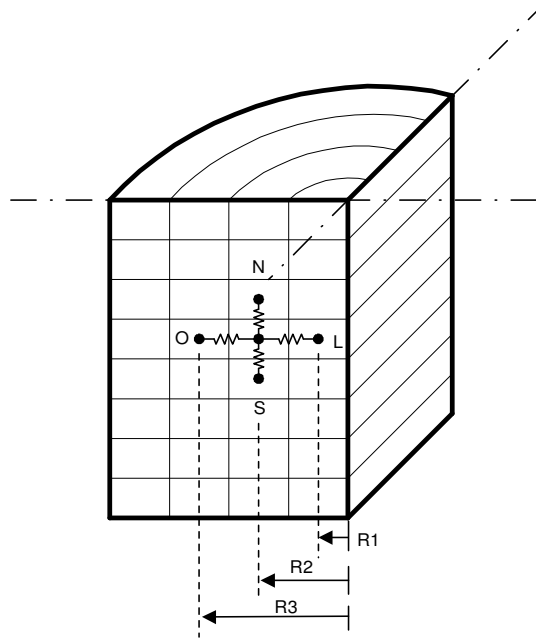


Figure. 3. Typical discretization of system container/canned food

The global energy balance equation applied to the node "I" is presented in the sequence:

$$C_I \frac{dT_I}{dt} = G_{IN}(T_N - T_I) + G_{IS}(T_S - T_I) + G_{IL}(T_L - T_I) + G_{IO}(T_O - T_I) \quad (3)$$

The thermal capacitance is calculated by using the expression: $C = \rho V_i C_p$, where ρ is the density and C_p is the specific heat of canned food. The thermal conductances between the nodes are classified into: radial conductance (G_r) and axial conductance (G_a). These conductances are defined by the equations 4, 5 and 6.

$$G_{I,N} = G_{I,S} = \frac{\pi K (R_2^2 - R_1^2)}{4dz} \quad (4)$$

$$G_{I,L} = \frac{2\pi K dz}{\ln \frac{R_2}{R_1}} \quad (5)$$

$$G_{I,D} = \frac{2\pi K dz}{\ln \frac{R_3}{R_2}} \quad (6)$$

Where K represents the thermal conductivity of canned food, R_i is the radius of the node considered and dz is the node height (in the axial direction of system container/canned food).

The equations obtained were solved with the academic version of the computational code EES – Equation Engineering Solver (Klein, 2003).

5. Considerations About the Accumulated Lethality Calculations

The computational algorithm that executes the optimization of the sterilization process based on lethality calculations is executed in conjunction with the programs AUTOMATE® and EXCEL®.

The human operator executes the program AUTOMATE® that are responsible for obtain the data stored in the supervision host computer (by the AIMAXWIN supervision software) and copy it into the electronic data sheet of EXCEL®. In the sequence, the program AUTOMATE® transfer these data to the EES and starts it. The EES solve the mathematical model and presents the results to the human operator, which will be responsible to take the decisions about the continuation or not of sterilization process.

The AUTOMATE® software is a macro manager, executing automatically all the steps cited below.

The block diagram presented in the figure 4 shows the flow of the information that is verified within the computational algorithm (Larousse and Brown, 1997).

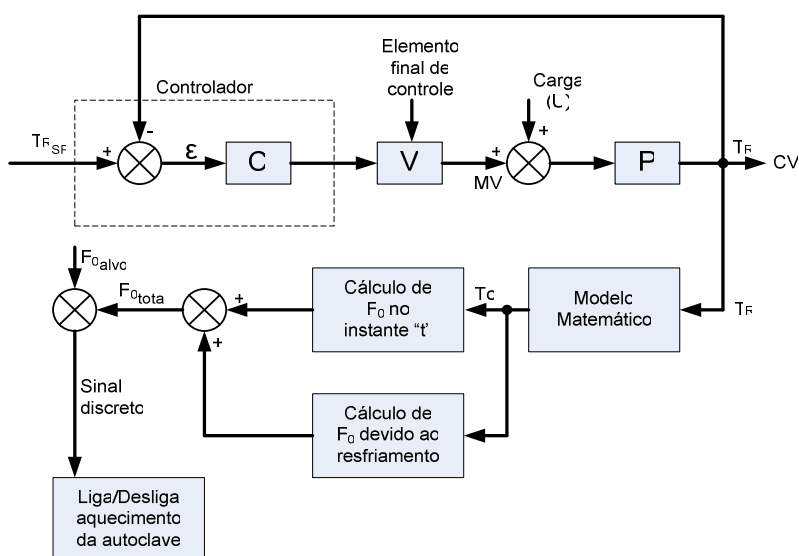


Figure 4 – Generic block diagram for model temperature prediction

6. Results and Discussion

The use of computational algorithm, presented in this paper, allow the temperature measurement of canned food (vegetal meat) without the use of traditional temperature sensors. The validation of the mathematical model was realized by the comparison of the results obtained by computational simulation against that one obtained by direct measured with a typical temperature sensor. It was utilized the same retort temperature profile to execute the mathematical model. Figures 5 and 6 present the results obtained.

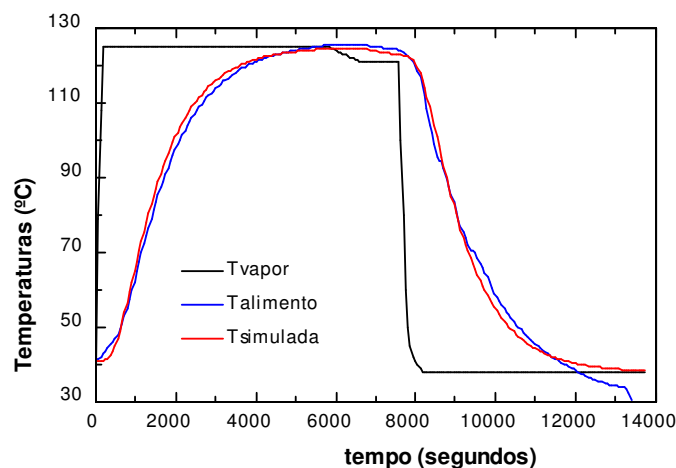


Figure 5 – Temperature profiles for measured and simulated cases

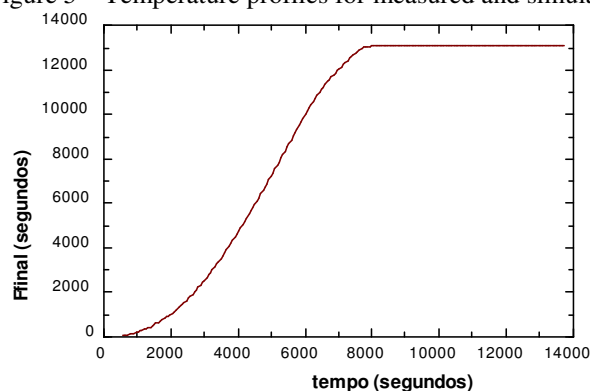


Figura 6 – Results obtained for accumulated lethality

7. Conclusions

The mathematical model is adequate for use in optimization of sterilization process of canned foods heated by conduction. The results obtained suggest that the temperature simulated is very close to that measured by thermal sensor. This model could be executed in real time, using the professional version of the EES computational software. This version don't require the use of the programs AUTOMATE® and EXCEL®.

8. References

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