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EXPERIMENTAL VALIDATION OF MATHEMATICAL PROCEDURES FOR THE EVALUATION OF THERMAL PROCESSES AND PROCESS DEVIATIONS DURING THE STERILIZATION OF CANNED FOODS

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In this article, mathematical models for the design and evaluation of in-pack sterilization processes, including the evaluation of process deviations consisting of drops in the ambient temperature, are discussed. Models for simulating conduction heating, broken heating and convection heating are considered and the methodologies used in the determination of the empirical parameters associated with the proposed methods are briefly discussed.

The methods are validated against experimental data obtained by processing three different canned foods in a retort simulator. Results for beans in tomato sauce, cream of chicken soup and peas in brine, processed in A1 metal cans (65 mm diameter × 102 mm height), meat chunks in gravy processed in UT cans (73 mm diameter × 115 mm height) and fish processed in Dingley cans (105 mm × 17 mm × 15 mm) were used in the validation trials. f_h values ranged from 4.5 min to 38.8 minutes. Both 'normal' and 'deviant' processes were considered. A good agreement between experimental and simulated data was achieved in terms of predicted temperatures and the calculated processing values agreed with experimental values within 30% for the cases presented.

Keywords: mathematical modelling; sterilization; process deviations; CTemp; canning

INTRODUCTION

In-pack sterilization still constitutes one of the most important methods for the production of shelf stable foods. While primarily designed for the destruction of micro–organisms, spores and enzymes that could otherwise spoil the food or cause food poisoning, thermal processing is also used to cook the foods and in certain cases to promote the formation of desired aromas and flavours. However, during thermal processing, there is a concomitant undesirable destruction of heat labile quality factors. A balance between the beneficial and adverse effects of sterilization must be achieved in the design of a proper thermal process by taking into account the kinetics of destruction by heat of the several components involved[1].

The General Method was the first method used for the design and evaluation of thermal processes. Originally presented in 1920[2], the General Method has since been subjected to several improvements, the most important of which was the introduction of the concept of lethal rate[3]. As used at present, the General Method basically consists of the calculation of a lethal rate curve from a time temperature curve, and of the calculation of the processing values from numerical integration of the obtained lethality curve. The main limitation associated with the General Method is the need for time/temperature data in order to evaluate a particular thermal process; no means are provided to move between different processing conditions (e.g. different initial product or processing temperature).

In order to overcome the limitations of the General Method, formula methods that use theoretical or empirical equations for the description of the temperature evolution inside the container have been developed. One of the first formula methods was proposed by Ball[4] and, in spite of its limitations, it is still widely used for the evaluation of thermal processes. Other formula methods worth referring to due to their use by the canning industry include Stumbo's[5] Gillespy's[6] and Hayakawa's[7] methods.

One major limitation of formula methods is the assumption that the external heating temperature is constant during the heating and cooling periods. Variable heating medium temperatures, e.g. deviations in the retort temperature during the holding phase, can not be handled directly using formula methods. The use of Duhamel's theorem has been proposed to handle variable retort temperature in those conditions[8,9]. Another major problem associated with formula methods is that they can only predict the temperature at a single point in the container, usually the slowest heating point.

Since 1969[10], finite difference solutions of Fourier's conduction equation have been shown to be a valuable