SIGMOID MODEL: APPLICATION TO HEAT TRANSFER IN VEGETABLE PRESERVES STERILIZED IN GLASS JARS

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Abstract— A sigmoid model is proposed for the simulation of food temperature evolution during the processing of preserves in batch low capacity sterilizers. Predicted results are compared against experimental data and a formula method (exponential) widely used in the simulation and control of industrial processes. The proposed model result to be simple and accurate for the prediction of thermal histories of foods of different shapes and sizes sterilized in glass jars of different sizes, and may be very useful for low volume processors. The exponential model did not provide accurate predictions for these processing conditions.

Keywords— Modelling; Heat Transfer; Glass Containers; Particulate Foods; Sigmoid Model

I. INTRODUCTION
During the last years there has been in Argentina a steady increase in the processing of low volumes of vegetable and fruit preserves at commercial level (home-made, organic, specialties, etc.), due to their much higher value (www.alimentosargentinos.gov.ar, 2006). All these products are filled into transparent glass containers which are hermetically sealed and submitted to a heat treatment to secure microbial innocuousness and to increase their shelf life (Wang et al., 2003). In these cases, visual quality (appearance) of the products - normally whole or sliced fruits or vegetables - is the main quality index that customers count on (Marra and Romano, 2001). The sterilizing effect of heat treatment is due mainly to protein denaturation, especially of those enzymes that regulate the metabolism of microbes. Nutritious components, like vitamins, are also affected by the heat treatment. All these changes are tightly related to the time-temperature history of the food during thermal processing. So, it is mandatory design process schedules that provoke the minimal changes in colour, shape and overall appearance, and nutrients content, compatible with the destruction of microorganisms. That is why it is necessary to count on simple and accurate methods to predict product temperature evolution during thermal treatment, so as to minimize the usual thermal abuse due to overprocessing. Besides, as processors work at an artisan level, dealing with small batches under poorly standardized conditions, it is usual that they change the size of the containers or that of the products sterilized. An additional complexity is that retort temperatures – in these low volume batches – generally are not constant but vary during processing, increasing up to an almost constant value.

Although sterilization is widely used for food preservation, only processing of foods packaged in cans or plastic containers and continuous aseptic processing (without containers) have been studied in depth from the heat transfer point of view. Almost no attention has been devoted to food processing in glass containers (Maroulis and Saravacos, 2003).

Few references to this subject can be found in literature. Bimbenet and Michiels (1974) presented an initial theory for heat transfer in these systems (particulate foods in a liquid medium packaged in glass containers). Some later papers that dealt with the simulation of particular cases can be found (Akterian and Fikiin, 1994; Akterian, 1995; Abril et al., 1998; Márquez et al., 1998, 2001, 2002, 2003).

In this work an easy-to-use approximate calculation method able to predict heat penetration in particulate foods of different shapes and sizes, immersed in a liquid medium, and packaged in glass containers of diverse volumes is proposed.

The method is especially useful for heat treatments with time variable process conditions (come-up period) and enables to relate the variation of heating medium temperature to food temperature and to link it to microbe destruction and loss of quality kinetics.

II. MATERIALS AND METHODS
A. Containers and Samples
To perform the tests three types of cylindrical glass containers were used (Table 1). The containers were filled with cylinders, cubes or spheres of 1.0, 1.5 and 2.0 cm of characteristic dimension CL (diameter, side and diameter, respectively). The length of cylinders was different according to the volume and height of the glass containers used, being 9.0, 11.0 and 10.0 cm for jars of 360, 660* y 660** cm³, respectively. These shapes and sizes were selected according to those of products and containers found in the markets.

As the objective was to simulate the pasteurization and sterilization of fruits and vegetables, a test material of thermal properties similar to those of fruits and vegetables was used for the samples, in this case high-density polyethylene. The amount of test material filled