FINITE ELEMENT MODELING OF FOOD COOKING

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Abstract - **In the last few years there has been an evident rise in the production of previously cooked, ready-to-serve meals.**

At a global level, the studies on this matter have yet to develop. Heat (and mass) transfer are modeled to predict thermal histories, microorganisms destruction and, finally, the cooking time. Both the experimental and modeling problems are quite complex, due to an important contribution of the radiation in the oven to the heat transfer and the simultaneous water loss by means of evaporation, porosity and volume variation, crust formation, etc. Nowadays the modeling of the process is carried out using finite differences or finite elements, contemplating important simplifications.

To simulate the cooking of different foods in a convection oven, a commercial finite elements software (ALGOR) is used.

The three-dimensional mesh of finite elements is formed using "Brick" elements, proper of the ALGOR software heat transfer module. The thermal variable properties of the food are considered, including the specific apparent heat, which involves the evaporation of water in the superficial crust. The convective and radiation components of the heat transfer in the air-food system are also taken into account. This is done with heat transfer coefficients determined in specific experiments for the utilized oven.

The obtained results are validated against experimental data, from cooking runs of the same foods in the determined oven.

Keywords – **Cooking, Finite element, Prepared meals.**

I. INTRODUCTION

Nowadays, cooking is a relevant technological process in different food industries. It is especially important in the fast food sector, catering services and production of prepared meals (ready-to-serve). From a safety point of view, cooking may ensure the elimination of harmful pathogens (principally Escherichia coli O157:H7).

The rise on the production of pre-cooked meals throughout the whole world in recent years has been more than noticeable. These products are baked in continuous or batch equipments and are commercialized frozen or refrigerated, ready to be reheated and consumed.

One fundamental condition for the cooking stage is that it must be done with as little thermal abuse as possible. For that, a special emphasis in the study of the heat transfer is necessary in this process, to find time-temperature relations that ensure the completion of the process from the microbiological point of view without losing any of the nutritional or organoleptic characteristics of the food.

Being able to simulate the heat transfer during the cooking process is essential for the specification of the cooking conditions (cooking time, temperature and air circulation) and the study of quality factors (crusting, dehydration, general appearance).

The modeling of the cooking process is, nowadays, done by means of finite differences (FDM) or finite element models (FEM), assuming important simplifications (Nicolaï *et al.*, 1995). Most of the published models refer to regular shapes and meat products: meatballs (Hung and Mittal, 1995), meat loaves (Holtz and Skjöldebrand, 1986), deep-fat frying of chicken drum (Ngadi *et al.*, 1997), hamburger patties (Ikediala *et al.*, 1996; Zorrilla and Singh, 2000), both of them without shrinkage; chicken patties (Chen *et al.*, 1999), patties with radial shrinkage (Zorrilla and Singh, 2003), meat cooking (Salvadori and Mascheroni, 2003; Purlis and Salvadori, 2005).

Another aspect to consider is that the simulation of heat transfer in cooked food trays presents two conditions that make it considerably more difficult: the fact that food is heterogeneous and generally anisotropic, and the lack of information and complexity of determination of the physical properties that are involved (Purlis and Salvadori, 2005).

In this sense, the finite elements method is more flexible than that of finite differences, for it permits the modeling of multidimensional irregular geometries, considering volume deformation and heterogeneous, non-isotropic foods.

The objectives of the present work are:

- To study the feasibility of using a finite elements commercial software to model the cooking of different prepared foods: potato and meat pie, beef pieces and lasagna.

- To systematize the use of the prediction software by establishing standardized procedures for the