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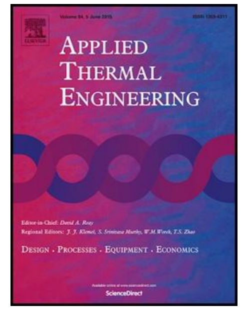

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Dynamic heat and mass transfer model of an electric oven for energy analysis

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HIGHLIGHTS

- A heat and mass transfer model for an electric oven including the load is presented.
- An expression to estimate the water evaporation rate of the load is also proposed.
- The model estimates the energy exchanges among oven components and the load.
- Parameters have physical sense, so the model is adaptable to various conditions.
- The computational effort of the model is very low.

Abstract

In this paper, a new heat and mass transfer model for an electric oven and the load placed inside is presented. The developed model is based on a linear lumped parameter structure that differentiates the main components of the appliance and the load, therefore reproducing the thermal dynamics of several elements of the system including the heaters or the interior of the product. Besides, an expression to estimate the water evaporation rate of the thermal load has been developed and integrated in the model so that heat and mass transfer phenomena are made interdependent. Simulations and experiments have been carried out for different cooking methods and the subsequent energy results, including energy and power time-dependent distributions, are presented. The very low computational needs of the model make it ideal for optimization processes involving a high number of simulations. This feature, together with the energy information also provided by the model, will permit the design of new ovens and control algorithms that may outperform the present ones in terms of energy efficiency.

Keywords: Electric oven, Thermal modeling, Lumped model, Energy analysis, Heat and mass transfer.

1. Introduction

Baking and roasting are generalized cooking methods consisting in heating the food inside an oven at a uniform temperature. In these processes, heat is transferred to the load mainly by means of radiation and convection. Although these are widely-known phenomena, complex and combined thermal, chemical, and mass transfer processes occur within the product and change its properties during the cooking. This complexity often requires the process to be supervised or even controlled by an 'expert', which usually leads to suboptimal and highly variable results in terms of food quality and energy consumption. It is then necessary to improve the understanding of the system dynamics in order to make progress in the automation and optimization of those cooking processes [1]. For this purpose, a complete model which includes both the load and the oven itself could provide a full overview of interest variables such as heat fluxes, thermal energy stored in the oven components or losses to the ambient. In short, this

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