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# Thermal Characterization and Efficiency Enhancement of Lebanese Bread Oven: A Comprehensive Experimental and Numerical Study

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The production of Lebanese bread encounters problems and challenges in the baking process. The Lebanese bread baking ovens have never been modeled yet. Also, the parameters for the baking process have never been studied. Reducing energy consumption while increasing energy efficiency requires a scientific understanding of the oven operating conditions and also the baking process kinetics.

This paper presents the first 3D CFD model developed for the Lebanese bread baking oven followed by experimental validation. Nevertheless, it develops a mathematical model that defines the kinetics of the Lebanese bread baking process.

A prototype of a typical Lebanese baking tunnel oven is designed and manufactured for study purposes. The prototype is equipped with appropriate measuring instruments to experimentally investigate the evolution of the oven temperatures and heat fluxes profiles at several points inside the baking chamber as well inside the dough through the baking process.

Computational Fluid Dynamics (CFD) was used to model the airflow characteristics inside the baking chamber and the non-premixed combustion occurring at the burner. Based on the simulation results the air velocity profile and temperature profile, as well as heat fluxes within the baking tunnel were established.

The predicted temperatures and heat fluxes values are in good agreement with the experimentally measured values and they showed a maximum deviation of 12%. The energy efficiency of the oven is estimated at around 16% and the energy used to bake 1 Kg of Lebanese bread is around 3.85 MJ.

A multi-phase mathematical model derived from the energy, mass, and momentum conservation principles is developed and applied to the baking process. This model is numerically simulated using (CFD) and the results are experimentally validated.

This paper is a crucial step toward oven design and baking process optimization. It is important to understand the heat transfer modes inside the baking chamber and through the baking process to provide some engineering insight in order to optimize Lebanese bread oven energy efficiency.