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Numerical and experimental analysis of the heat and mass transfer during okara drying

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HIGHLIGHTS

► Okara in the shape of spherical pellets was dried in a fixed bed dryer.
► Governing equations of heat and mass transfer were solved by the Implicit Finite Difference Method.
► Thermophysical properties were obtained from correlations using centesimal composition.
► Numerical results when compared to experimental data show good agreement.

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ABSTRACT

The aim of this study is to model the heat and mass transfer during the okara drying. Okara, containing 77% of moisture content (w.b.), was extruded in the shape of spherical pellets and then dried in a fixed bed dryer until 3% of moisture content (w.b.). During the process, the okara moisture and temperature profiles were experimentally obtained. The governing equations of heat and mass transfer (Fourier and Fick, respectively) were solved by the Implicit Finite Difference Method. The thermophysical properties of okara which were necessary in the numerical model were obtained from correlations that require the okara centesimal composition and some variables measured during the process. The numerical results were compared to the experimental ones, presenting a reasonable adjustment.

1. Introduction

Drying operations are widely used as a method of conservation in the food industry [3,8,17,23,24,33]. Dried products have limited deterioration rates, due to the low water activity, are easily transported and stored because of the reduced volume, and have no need of refrigeration, representing energy economy. Nevertheless, important alterations on flavor, color and aroma can take place, and depending on the intensity and effect of the drying process, one can obtain the loss or inutility of the product for a determined function.

For biological materials the drying process cannot be represented by generalized models. The specific characteristics of each product, associated to the drying air properties and to the heat transfer medium adopted, determine several drying conditions [21]. Therefore, it is necessary to study the product characteristics and the drying process conditions in order to obtain the desired final product with the lower energetic demand possible.

In this context, the process modeling stands out. The mathematical models have potential to predict the drying behavior for a type of product, determining the influence of certain parameters in the process efficiency, minimizing the system operation costs and the degradation of the sensorial attributes of the product. Mathematical models which consider the product and the drying system characteristics are important tools in the development of efficient dryers [28]. The largest part of the models used in food drying problems is based on the equations of Fick and Fourier, which represent the transient phenomena of mass and heat transfer, respectively [5,7,9,13,20,22]. Such equations are solved by numerical methods, such as the Finite Volume Method (FEM) and the Finite Difference Method (FDM). There are also studies regarding to the use of analytical methods to solve heat and mass transfer equations [2,10]. Another fraction of the modeling studies uses an empirical approach, basing on models like Page, Thompson, Henderson, among others [18,25,34]. However, the theoretical modeling have better scientific acceptance because they are based on the physical phenomena of the process and the results can be extrapolated for another process conditions, beyond that used in the experiments.

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