MODELING VOLUME CHANGES IN FOOD DRYING AND HYDRATION

R.J. AGUERRE†, M. TOLABA‡ and C. SUAREZ‡

† Dto de Tecnología, Univ. Nac. de Luján (CONICET), 6700 Luján, Argentina
rojagu@mail.unlu.edu.ar.
‡ Dto de Industrias, Fac. de Ciencias Exactas y Naturales, Univ. de Buenos Aires. (1428) Buenos Aires
suarez@di.fcen.uba.ar

Abstract — Many processes in food technology involve water migration from or into the processed product. Modeling of food water migration knowledge could result speeding up the processes, improving the quality of final products, and reducing energy costs. A mathematical formulation for mass transfer during drying and hydration of a porous solid sphere with volume change was developed in terms of the diffusion equation. The present model also provides an analytical expression for the ariation of water diffusivity with moisture content based on a simple relationship between the activation energy for diffusion and sorption energy. The nonlinear diffusion equation was solved numerically, moisture profiles, the kinetics curves for drying and hydration and the moisture concentration dependence of diffusivity coefficient were calculated. Marked differences were observed in the moisture profiles for drying and hydration. The kinetic curves of both processes are strongly dependent on the range of moisture tested. Moisture diffusivity falls drastically at low moisture contents.

Keywords — shrinking, hydration, swelling, drying, moisture diffusivity.

I. INTRODUCTION

Although drying and rewetting cause shrink and swelling of the processed samples respectively, the usual mathematical treatment of the experimental results involves the assumption that the drying process is controlled by internal diffusion in a homogeneous and isotropic solid which does not change its size. Based on these assumptions, the diffusive process is usually described in terms of Fick’s second law of diffusion for which analytical solutions for the three conventional geometries (infinite slab, cylinder and sphere) are available in the literature (Crank, 1979).

One of the first investigations focused to solve the diffusion problem in swelling or shrinking bodies is due to Crank (1979). That author proposed the use of a reference frame fixed to one of the components of the system that remains unchanged, to solve the Fick’s diffusion equation. Such procedure was used by Gekas and Lamberg (1991) to determine the diffusion coefficient in systems with volume change. The differential equation that describes diffusion in an infinite slab, with unidirectional shrinkage, was derived by Viollaz and Suarez (1985) and integrated by means of Von Karman’s method. To account for the effect of shrinkage on food dehydration, a usual procedure is to solve Fick’s second law for diffusion by numerical procedure, assuming that the instantaneous thickness of the solid is proportional to the amount of evaporated water (Simal et al., 1996). An alternative procedure which supposes that the phenomenon of shrinkage is equivalent to a convective flow was employed by Hawlander et al. (1999) to simulate the drying of a solid slab, assuming linear and quadratic variations with moisture content for the shrinkage velocity. More recently, Bialobrzewski (2006) proposed the use of Lagrange-Eulerian method to solve mass transfer equation when the shrinkage phenomenon is present.

The exact evaluation of water diffusivity, and particularly its dependence on moisture concentration, is usually a quite difficult task. Solutions for different functionalities of diffusivity with moisture concentration were reported by Crank (1979). Particularly, for the drying of food materials, Schoeber and Thijssen (1977) developed a method to determine the concentration-dependent diffusion coefficient for systems in that the water diffusivity diminishes when decreasing the moisture concentration.

The purpose of the present work was the following:

1. To derive an analytical expression for moisture migration in a solid that undergoes change of volume during drying or hydration processes.

2. To solve the resulting diffusion equation by numerical procedure, taking into consideration the variability of the diffusion coefficient with moisture content. The present model will be used to simulate moisture migration in a solid sphere that undergoes swelling or shrinkage during the respective process of hydration or drying.

II. METHODS

A. Model Development

Is an experimental fact that food materials usually undergo swelling on water uptake. Swelling occurs as a result of the creation of a transient capillary structure (Stamm and Millet, 1941). Water migration in a porous solid that suffer dimensional changes is regarded as a diffusive process in a binary system formed by a solid B whose mass remains constant and a diffusant A, migrating in liquid phase. Fick’s equation is applied to de-