NON DIMENSIONAL ANALYSIS OF CASSAVA TRANSIENT DRYING IN PACKING BEDS

H. SANTAMARIA, N. DURANGO, A. BULA† and M. SANJUAN

Mechanical Engineering Department, Universidad del Norte, Barranquilla, Colombia.
†abula@uninorte.edu.co

Abstract— Transient mass transfer process is analyzed for cassava drying (Manihot Esculenta Crantz) in a pack bed. Experiments were performed in a thermally insulated radial dryer, considering cylindrical pieces of non peeled cassava with three different thicknesses: 4, 6, and 8 mm. The void fractions considered were 0.22, 0.49, 0.64 and 0.66, while the temperature values were 50ºC and 70ºC. The humidity removed from the cassava was measured from 10 pieces randomly selected at the beginning of the process. These pieces were weighed every 15 minutes during a three hours period. From the data gathered a non linear regression model was attained as a function of non dimensional numbers, which is valid for the following ranges: $700 \leq Sc \leq 1900$, $10000 \leq Sc \leq 31000$, $0 < Fo < 4$. The fitted regression coefficient is $R^2_{adj} = 0.87$, and the average error when comparing with experimental data is 24%.

Keywords— Drying, Mass Transfer, Transient, Cassava, Food.

I. INTRODUCTION

Experiments conducted for food dehydration are considered important since they allow an adequate process design that ensures the appropriate drying of the products (Shukla, 2001). Cassava has been considered for the experiments because FAO (2004) (Food and Agriculture Organization of the United Nations) has concluded that this food stock is a vital element to fight famine in emerging and developing economies.

For the drying process, researchers have developed mathematical models for different drying materials, either organic or inorganic, under different conditions. Furthermore, particular solutions have been presented to these models considering numerical methods. These numerical solutions allow solving for different parameters such as mass diffusivity (Bon et al., 1998); heat and mass transfer inside the materials to be dried (Wu et al., 2003; Chourasia and Goswami, 2007). Additionally, the simulated drying process has also been used for materials such as sugar (Rastikian and Capart, 1998), bagasse (Vijayaraj and Saravanan, 2008), fruits (Lagunez-Rivera et al., 2007), and cassava (Durango et al., 2001a).

Some authors have worked in the drying process considering an experimental approach, fitting curves for different organic materials such as mate leaves (Zanoelo et al., 2006), penicillium (Friese et al., 2004), cassava (Durango et al., 2005), using natural variables such as temperature, air velocity and size. The regression models attained have good agreement with the data gathered presenting correlation coefficients around 90%. Moreover, parametric analysis for transient drying of crops has been assessed considering the non dimensional numbers governing the phenomena (Chen, 2005; Rahman et al., 2007).

The physical changes that the drying material undergoes during the process has been under study, considering specifically how the shrinkage affects the variables involved in the drying process, such as mass diffusivity (Hernández et al., 2000; 2004). The construction of the drying equipment and the influence in the materials has also been studied (Lee et al., 1992; Shukla, 2001; Durango et al., 2001b; Freire et al., 2005).

This paper studies the transient mass transfer process presented during the drying of cassava using non dimensional parameters, which will allow a better design of industrial dryers.

II. MATHEMATICAL MODEL

The drying process is generated by the non-equilibrium condition between the water vapor pressures at the drying media and at the surface of the material to be dried. Many mechanisms describing the process have been proposed in order to describe the water migration inside biological products during the drying process, such as: diffusion, capillary flow, interior pressure variation and combinations of these. The preponderance of each one of these mechanisms depends on the material, moisture content, link between the water and the solid constituent of the material, the temperature and the size of the porous. Most of these variables are complex to measure and some of them change as the drying process advances (Treybal, 1987; Johnson, 1999). Industrial drying processes are carried out most of the time in packing beds. These packing beds are made out of pieces of the material to be dried, and they are distributed in a random compact way. This configuration is used in order to enhance heat and mass transfer at the surface exposed (Incropera and De Witt, 1996). This formation allows a large area to volume ratio, leaving spaces for the fluid to go through the packing bed. The drying process in a packing bed is considered a boundary phenomena described by the following equation in cylindrical coordinates:

$$m_{\rho,\theta} = -D_{\rho,\theta} \frac{\partial C_{\rho,\theta}}{\partial r}$$

(1)