

## SUPERHEATED STEAM DRYING OF PARSLEY: A FIXED BED MODEL FOR PREDICTING DRYING PERFORMANCE

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**Abstract -- Superheated steam drying technique has been known for a long time, but its application to food drying has received little attention. In this work, superheated steam was applied to dry fresh parsley (*Petroselinum Crippsum*). A mathematical model to simulate this drying process was developed by using mass and energy conservation equations for solid and steam phases. The resulting partial differential equation system was solved by means of a finite difference method. Software Matlab 5.3 for Windows was used for programming the algorithm. The development of the drying kinetics equation, required in the model, was based on thin layer experimental results. The simulation model was used to analyze the influence of different variables (bed height, operating pressure, steam velocity and steam temperature) on solid moisture content, as well as on solid and steam temperature profiles along the bed. Experimental determinations in a fixed bed arrangement were done at different operating pressures (0.07-0.17 kgf/cm<sup>2</sup>), steam temperatures (70-100°C), steam velocities (5-12 m/sec.) and bed heights (thin layer, 2 cm and 10 cm). Solid temperature at the top of the bed and average solid moisture content were measured as drying proceeded. An acceptable agreement between experimental and theoretical average solid moisture contents was obtained.**

**Keywords-- Parsley Drying, Superheated Steam, Fixed Bed.**

### I. INTRODUCTION

The principle of drying with superheated steam has been known for a long time and its industrial utilization increased significantly in the last years. Superheated steam drying presents potential benefits, although it is necessary to analyze the convenience of its application for a particular product. Besides the energy saving and environmental benefits, the oxygen-free atmosphere appears to improve product quality by retarding some deterioration reactions. Under-atmospheric pressures are often required with foodstuffs, which are sensitive to high temperatures due to denaturalization reactions. Several research works have been presented in the

literature about the application of superheated steam drying for different solid materials and drier types, but references to drying of foodstuffs are relatively scarce (Akao, 1983; Nomura and Hydo, 1985; Denventer and Heijmans, 2000; Elustondo, 2001).

Solid drying in a packed bed circulated by a gaseous thermal agent is a complex, non-steady state process in which fundamental transfer phenomena appear simultaneously. Different fixed bed models have been developed for air drying, but there are a few references about fixed bed drying using superheated steam (Khan *et al.*, 1991; Wimmersted and Hager, 1996; Elustondo, 2001).

A fundamental information required in dryer modeling is the drying kinetics. Several works related to steam drying kinetics have been reported, most of them for porous inorganic materials (Perre *et al.*, 1993; Shibata and Ide, 1991; Wimmersted *et al.*, 1997; Cenkowski *et al.*, 1996; Daurelle *et al.*, 1998; Topin *et al.*, 1999; Hager *et al.*, 2000; Elustondo, 2001).

The main objectives of the present work were to obtain an adequate drying kinetics expression for superheated steam drying of parsley from thin layer drying experimental data, and to develop a fixed bed model for superheated steam drying of vegetables that allows to analyze the influence of different process variables.

### II. EXPERIMENTAL

Fresh parsley (85-87% w.b. moisture content), bought at a local market, was dehydrated in a pilot plant steam dryer (Elustondo, 2001). The experimental device consists of an insulated drying chamber connected to a vacuum pump. The solid is placed in a perforated bottom basket. The steam is heated by an electrical resistance and conveyed through the solid bed by a fan. The equipment is provided with an automated steam temperature control, a velocity controller connected to the fan motor, a pressure gauge, and a thermocouple for solid temperature measurement.

Experiments were performed under different operating pressures,  $P$  (0.07-0.17kgf/cm<sup>2</sup>), steam temperatures,  $T_v$  (70-100°C), steam velocities,  $v$  (5-12 m/sec.), and bed heights,  $L$  (thin layer, 2 cm and 10 cm). The experimental determinations provided the total