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ORIGINAL ARTICLE

Solar drying of whole mint plant under natural and forced convection

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ABSTRACT

Two identical prototype solar dryers (direct and indirect) having the same dimensions were used to dry whole mint. Both prototypes were operated under natural and forced convection modes. In the case of the later one the ambient air was entered the dryer with the velocity of 4.2 m s^{-1}. The effect of flow mode and the type of solar dryers on the drying kinetics of whole mint were investigated. Ten empirical models were used to fit the drying curves; nine of them represented well the solar drying behavior of mint. The results indicated that drying of mint under different operating conditions occurred in the falling rate period, where no constant rate period of drying was observed. Also, the obtained data revealed that the drying rate of mint under forced convection was higher than that of mint under natural convection, especially during first hours of drying (first day). The values of the effective diffusivity coefficient for the mint drying ranged between 1.2×10^{-11} and 1.33×10^{-11} m^2 s^{-1}.

Introduction

Open air sun drying is the dominant method that is used to preserve agricultural products, in which agriculture plants are directly exposed to solar radiations in an open environment. However, the contamination with dust, soil, sand particles and insects are some problems associated with this method [1,2]. To overcome previous problems, solar drying method could be used to dry agriculture products instead of traditional sun drying method as the drying process takes place in enclosed structures [3]. Utilization of solar energy as a reliable energy source to dry foods in Egypt has a great potential, as, the annual daily average solar radiation on a horizontal plane in Egypt is 8 kW m^{-2} day^{-1} and the measured annual average daily sunshine duration is approximately 11 h [4].

Mint is a genus of the Labiatae family, which comprises a wide number of species, varieties and hybrids. It helps in colds, flu, fever, poor digestion, motion sickness, food poisoning and for throat and sinus ailments [5–7]. Mint as flavoring agent is coming after vanilla and citrus flavors over the world [8].

Several researches have investigated the drying kinetics of mint leaves and evaluated various mathematical models to describe thin layer drying characteristics [5,6,9,10]. The best drying models to explain thin layer drying behavior of mint leaves under different drying methods were Wang and Singh model [9], logarithmic model [6] and Midilli and Kucuk model [5,10].

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However, the literature is scarce on the drying kinetics of mint as a whole plant. Müller et al. [11] found that, the drying of whole mint in greenhouse solar dryer from initial moisture content of 80% (w.b.) to final moisture content of 10% (w.b.) took 3 days. Lebert et al. [12] examined the effect of drying conditions (air temperature, humidity and air velocity) on drying kinetics of mint, and they concluded that, the drying air temperature was the main factor in controlling the rate of drying. The effect of the drying temperature schemes on the drying kinetics of chopped mint in a rotary dryer was investigated by Tarhan et al. [13]. They found that, the drying durations were decreased from 15 to 18 h for constant temperature profile to 12–15 h when rectangular wave-shaped temperature profiles were used.

As mentioned above, the literature is scarce on the drying kinetics of the solar drying of mint as a whole plant. Besides, most previous studies used small amounts in their investigations. So, this study was carried out to study the drying kinetics of mint as a whole plant using pilot scale solar dryers considering the effect of solar dryer type (direct and indirect) and drying air flow mode. In addition, ten mathematical models were used to fit the drying curves of mint. Finally, the effective diffusivity of drying of mint was calculated.

Material and methods

Drying experiments

Fresh mint was purchased at a local market in Giza, Egypt. Before drying, the foreign materials, as weeds, spoiled and discolored plants were removed. Drying experiments were carried out using direct and indirect prototype solar dryers. The two prototypes are constructed from wood frames and have the same dimensions as shown in Figs. 1 and 2. The direct prototype solar dryer was covered by transparent polyethylene film; while black polyethylene film was used to cover the indirect prototype solar dryer. Each dryer has six perforated galvanized steel trays with the dimension of $1.00 \times 0.90 \times 0.04$ m, and the spacing between them was 0.12 m. Each tray was loaded with 1.2 kg of fresh whole mint, which was spread as a single thin layer. The two prototypes were installed on the roof of the Department of Food Science and Technology building, Faculty of Agriculture, Cairo University, Giza (latitude of 30°00N and longitude of 31°10E).

The experimental data were manually recorded every 2 h from 10 a.m. to 6 p.m. over two days, except forced convection drying runs which were started at 12 noon in the first drying day. Natural convection runs were conducted during 10–11/07/2012, while forced convection runs were conducted during 5–6/08/2012. Both prototypes (the direct and indirect solar dyers) were operated under natural and forced convection. In the forced convection mode, a fan (0.50 m diameter and 0.75 kW) was mounted in the exit channel of each prototype, where the air velocity at the entrance channel of both solar dryers was 4.2 m s^{-1} as measured. The dryers were shut down during the night, and experimentation was resumed the next day at 10 a.m.

Measurements and calculations

Drying air temperatures in the middle of the dryer, 6-cm above each tray was measured using a calibrated thermocouple

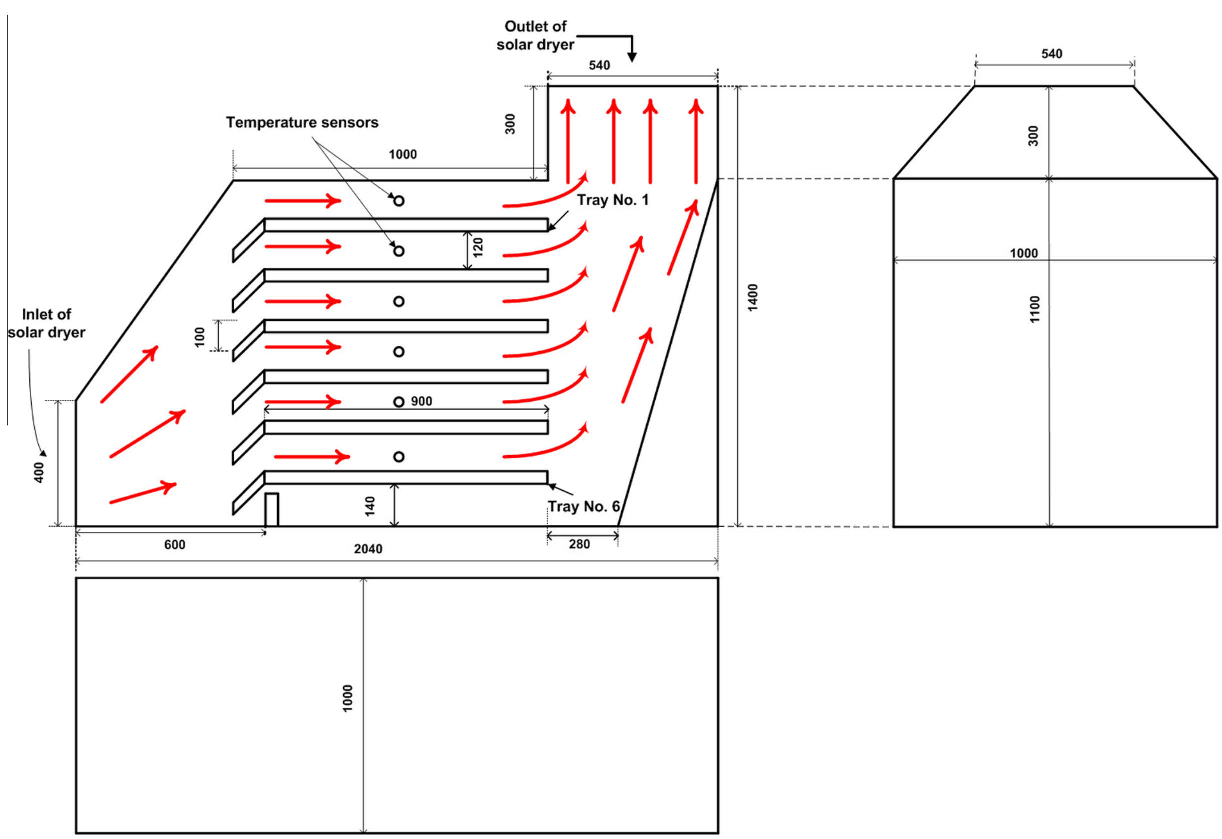

Fig. 1 A diagram of the solar dryer (dimensions in mm – the bold arrows refer to air streamlines).