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Thin-layer drying behaviour of mint leaves

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Abstract

The thin-layer drying behaviour of mint leaves for a temperature range of 35–60 °C was determined in a cabinet dryer. The increase in air temperature significantly reduced the drying time of the mint leaves. Drying data of this material were analysed to obtain diffusivity values from the falling rate-drying period. In this period, moisture transfer from mint leaves was described by applying the Fick's diffusion model. Effective diffusivity varied from 3.067×10^{-9} to 1.941×10^{-8} m^2/s and increased with the air temperature. An Arrhenius relation with an activation energy value of 62.96 kJ/mol expressed effect of temperature on the diffusivity. Four thin-layer drying models available in the literature were fitted to the experimental data. Among all the drying models, the logarithmic model was found to satisfactorily describe the kinetics of air-drying of mint leaves.

Keywords: Modelling; Mint leaves; Drying; Diffusivity; Activation energy

1. Introduction

Mint (*Mentha spicata* L.), in botany, common name for members of the Labiatae, a large family of chiefly annual or perennial herbs. Several species are shrubby or climbing forms or, rarely, small trees. Members of the family are found throughout the world, but the chief centre of distribution is the Mediterranean region, where these plants form a dominant part of the vegetation.

Mint has been used as a medicinal and aromatic plant since ancient times. Its leaves are used for flavouring, tea infusions and spicing. It combines well with many vegetables such as new potatoes, tomatoes, carrots and peas. A few chopped leaves give refreshment to green salads and salad dressings. Dried mint is sprinkled over humus and other pulse and grain dishes (Encyclopedia of spices, 2003). In addition, mint oil is an important, most popular and widely used essential oil (Dwivedi, Khan, Srivastava, Syamasunnder, & Srivastava, 2004). In order to preserve this seasonal plant, and make it available to consumers during the whole year, it undergoes specific technological treatments, such as drying (Park, Vohnikova, & Brod, 2002). Drying provides a very useful preservation. Generally, a part of the mint may be tied in small bundles and hung up, or the leaves and flowering tops spread on a screen and dried in the shade. Dried mint should be kept in a tightly sealed glass jar away from light (Encyclopedia of spices, 2003).

Drying is one of the oldest methods of food preservation, and it represents a very important aspect of food processing. The main aim of drying products is to allow longer periods of storage, minimise packaging requirements and reduce shipping weights (Okos, Narsimhan, Singh, & Weitnauer, 1992). Sun drying is the most common method used to preserve agricultural products in the World and also Turkey. However, it has some problems related to the contamination with dust, soil, sand particles and insects, and being weather dependent. Also, the required drying time can be quite long. Therefore, the drying process should be undertaken in closed equipments to improve the quality of the final product (Ertekin & Yaldiz, 2004).

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Nomenclature

a, c	experimental constants	M_0	initial moisture content, kg water/kg dry matter
D_{eff}	effective diffusivity, m^2/s	M_t	moisture content at t, kg water/kg dry matter
D_0	constant in Arrhenius equation, m^2/s	M_{t+dt}	moisture content at $t + dt$, kg water/kg dry matter
E_a	activation energy, kJ/mol	N	number of observations
k	drying rate constant, 1/min	n	exponent and positive integer
k_0	slope	R	gas constant, kJ/mol K
L	slab thickness, m	R^2	coefficient of determination
MR	moisture ratio (dimensionless)	T	temperature, °C
M	moisture content at any time, kg water/kg dry matter	t	drying time, min
M_e	equilibrium moisture content, kg water/kg dry matter	z	number of constants

Recently, there have been many studies of the drying behaviour of various vegetables (Akpinar, Midilli, & Bicer, 2003; Doymaz & Pala, 2002; Doymaz, 2004; Ertekin & Yaldiz, 2004; Kaymak-Ertekin, 2002; Madamba, Driscoll, & Buckle, 1996; Senadeera, Bhandari, Young, & Wijesinghe, 2003; Simal, Mulet, Tarrazo, & Roselló, 1996; Yaldiz & Ertekin, 2001). However, studies on the drying characteristics (air temperature, air velocity, ... etc.) of mint leaves are scarce in the literature. Muller et al. (1989) used a greenhouse-type solar dryer for mint drying. They reported that the drying process from an initial moisture content of 80% (w.b.) to a final moisture content of 11% (w.b.) took 3–4 days. Lebert, Tharrault, Rocha, and Marty-Audouin (1992) examined the effect of drying conditions (air temperature, humidity and air velocity) on drying kinetics of mint. Park et al. (2002) investigated the effect of mint leaves 0.5–1.0 m/s of air-flow rate and various temperatures (30, 40 and 50 °C) on the drying kinetics.

The aim of this research was (1) to observe the effect of air drying temperature on the drying time, (2) to fit the experimental data to four thin-layer drying models and estimate the constants, (3) to calculate the effective diffusivity and activation energy, for drying of mint leaves.

2. Material and methods

The drying of mint leaves (*Mentha spicata* L.) was investigated in cabinet dryer that is described previously by Doymaz, Gorel, and Akgun (2004) and installed in the Chemical Engineering Department of Yildiz Technical University, Istanbul, Turkey. To establish the influence of air temperature on drying curves, experiments at 35, 45, 55 and 60 °C were carried out, relative humidity of 8–40%, respectively. The relative humidity of air was determined using wet and dry bulb temperatures obtained from the psychometric chart. During the drying experiments, air-flow rates of 4.1 m/s were measured with Testo 440 Vane Probe Anemometer, and flowed horizontal to the bed. The initial moisture content of mint leaves was determined using a standard method (AOAC, 1990), by vacuum drying at 70 °C for 24 h over a magnesium sulphate desiccant. This was repeated three times to obtain a reasonable average.

Fresh mint leaves were purchased at a local market in Istanbul, Turkey. Samples were stored in a refrigerator at 4 °C prior to the drying experiments. Prior to placing the sample in square tray, the drying system was run for at least 30 min to obtain steady conditions. Then, sample was placed on the drying tray in a thin single layer. The sample weight was kept constant at 30 g (±0.5 g) for all runs. The moisture loss was recorded at 15 min intervals during drying by a specially developed weighing unit. This weighing unit consisted of a balance (capacity of 0–20000 g and accuracy of ±0.001 g), hanger rod, digital indicator and load cell (Revere Transducers Europe, Holland). Drying of mint leaves were finalised when the moisture content decreased to 10 ± 0.5% (w.b.) from an initial value of 84.7 ± 0.5% (w.b.). The product was cooled in room temperature for 10 min after drying, and kept in air glass jars. Drying tests were replicated three times at each inlet air temperature, and averages are reported.

2.1. Mathematical modelling of drying curves

Drying curves were fitted with four thin-layer drying models, namely, the Lewis, the Henderson and Pabis, the Page and the logarithmic models (Table 1). The moisture ratio and drying rate of mint leaves during drying experiments were calculated using the following equations:

$$\text{Moisture ratio (MR)} = \frac{M - M_e}{M_0 - M_e} \tag{1}$$