Drying Kinetics and Total Phenolic Content of Dried Mentha arvensis Linn Leaves

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Abstract—The objective of this study is to investigate the effects of sun drying and infrared drying on drying characteristics and total phenolic contents (TPC) of MA leaves. Infrared drying temperature was ranged from 50°C to 80°C, average temperature of natural sun drying and enhanced sun drying was 34 ± 1.2°C and 45.67 ± 0.5°C respectively. To represent the experimental data, five different empirical models (Lewis, Page, Henderson & Pabis, Two-term Exponential and Midilli et al.) were used. The best model was selected based on highest R², lowest RMSE and x². TPC of dried leaves was determined and it was found that enhanced sun drying gave the highest TPC.

Keywords—Mentha arvensis Linn, thin layer modelling, natural sun drying, infrared drying, total phenolic content

1. Introduction

Mentha arvensis is a type of herb commonly known as “Japanipudina” [1]. This plant is originally from Japan [1]. M. arvensis contains menthol (66%), (-)-menthyl acetate (15%) and (-)-menthone (8%) and it also has some phenolic content [2].

Literature review of sun drying and infrared drying on M. arvensis leaves were done. These two drying methods were chosen because there was very limited information on drying of MA leaves using these methods. TPC of MA leaves was analysed. Phenolic is a natural antioxidant which very important to human health. The findings will be useful for future scientific interest of processing similar herbs.

The objective of this research is to compare sun drying and infrared drying in term of the drying characteristics and the total phenolic content found in dried M. arvensis in this two drying methods.

2. Materials and Methods

M. arvensis leaves were purchased from SS15, Subang Jaya, Selangor, Malaysia.

2.1. Design of Sun Drying Tray

Sun drying tray was built using plywood. The dimension for the tray was 600 mm x 400 mm x 245 mm (L x W x H). Bottom of the tray was covered with aluminium sheet; top of the tray was covered with a wire net; inside of the tray has a portable stainless steel sheet.

Fig. 1 Sun Drying Tray

2.2. Experimental Procedure

For sun drying, 10 g of freshly washed leaves was put in the designed sun drying tray and exposed to the sunlight. The weight of leaves was measured at 15 minutes time interval until the equilibrium moisture content. Dried leaves were then put into an oven at 105°C for 24 hours.

For infrared drying, 1.0 g of fresh washed leaves was put in a moisture analyser (XM 50; accuracy of ±0.001g; Swiss made). The temperature used was 50°C to 80°C. The weight of leaves was recorded at 1 min time interval until the equilibrium moisture content. Then, dried leaves were left to dry at 105°C (AOAC method 1990).

For determination of TPC, the dried leaves were extracted using diethyl ether. The dried leaves extract was mixed with 1N Folin-Ciocalteu reagent. After 5 min, 4 ml of 7.5% sodium carbonate (Na2CO3) and 3 ml of distilled water were added and allowed to react for 2 hours at room temperature. Then, absorbance of the mixture was measured using a UV spectrophotometer (model: HASA RB-10; country: Dynamica, Switzerland) at 765 nm. A standard curve of gallic acid solution of 15000 ppm to 20000 ppm was prepared.

3. Drying Characteristics

3.1. Drying Kinetics and Drying Rate

Drying kinetic process is the process of recording change of the average moisture content against time or the drying rate against moisture content (MC) [3]. MC [4], MR [5], and drying rate (DR) [6] were calculated using Eq. 1, Eq. 2 and Eq. 3 respectively.

\[ MC (dry basis) = \frac{M_t - M_b}{M_o - M_b} \] (1)

\[ MR = \frac{M_t - M_b}{M_o - M_b} \] (2)

\[ DR = \frac{M_t - M_b}{dt} \] (3)

3.2 Mathematical Modelling

Table 1 showed the thin layer modelling used to fit the data from the experiment. The best model was determined for each variables parameters. R², RMSE and x² were used to determine the goodness of the data fitted into the thin layer modelling equations and calculated using Eq. 4, Eq. 5 and Eq. 6 respectively.

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Model</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lewis</td>
<td>MR = exp(−kt)</td>
<td>[4]</td>
</tr>
<tr>
<td>Page</td>
<td>MR = exp(−kt²)</td>
<td>[7]</td>
</tr>
<tr>
<td>Henderson &amp; Pabis</td>
<td>MR = a exp(−kt)</td>
<td>[8]</td>
</tr>
<tr>
<td>Two-term exponent</td>
<td>MR = a exp(−kt) + (1 − a) exp(−kat)</td>
<td>[9]</td>
</tr>
<tr>
<td>Midilli et al.</td>
<td>MR = a exp(−kt) + bt</td>
<td>[10]</td>
</tr>
</tbody>
</table>

\[ R² = \frac{\sum_{i=1}^{n} (MR_{exp} - MR_{pre})^2}{\sum_{i=1}^{n} (MR_{exp})^2} \] (4)

\[ RMSE = \sqrt{\frac{\sum_{i=1}^{n} (MR_{exp} - MR_{pre})^2}{n}} \] (5)

\[ x² = \frac{\sum_{i=1}^{n} (MR_{exp} - MR_{pre})^2}{N - 2} \] (6)

3.3 Effective Moisture Diffusivity
Eq. 7 was proposed using Fick’s second law to calculate effective moisture diffusivity [11].

\[
MR = \frac{M - M_e}{M_e - M_0} = \frac{8}{\pi^2} \exp \left(-\frac{\pi^2 D_{eff} t}{4d^2} \right)
\]  

(7)

4. Results and Discussion

As shown in Fig. 2, there was only falling rate period for sun drying. This result was the same as the result obtained by earlier researcher [12]. For infrared drying, there was preheating period, where the leaves were being heated up to heating temperature and falling rate period, where the drying process of leaves took place. Drying rate was increased with temperature. This was because as the temperature increased, more heat was provided to the leaves, leading to increased moisture removal, hence drying rate increased. These results were in good agreement with earlier research on saffron stigmas [13].

For sun drying, the drying rate decreased with moisture content. For infrared drying, the drying rate decreased with moisture content after the samples were heated up to the desired temperature. Drying time decreased with the increase of temperature. Page was the best descriptive model for IR at 50°C, 70°C, 80°C and enhanced sun drying; Midilli et al. and Page both were the best models for IR at 60°C; Handerson & Pabis model for natural sun drying. Effective moisture diffusivity was in the range of 9.90 x 10^{-12} to 1.17 x 10^{-11} m²/s. Range of TPC found in mint leaves was between 14.77 mg GAE/g to 16.72 mg GAE/g.

My deepest thank goes to my family and friends for their constant support and encouragement. My gratitude for my supervisors’ guidance throughout this research.

References


Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>M₀</td>
<td>Initial moisture content</td>
</tr>
<tr>
<td>Mₑ</td>
<td>Equilibrium moisture content</td>
</tr>
<tr>
<td>Dₑ</td>
<td>Effective moisture diffusivity</td>
</tr>
<tr>
<td>M</td>
<td>Moisture content</td>
</tr>
<tr>
<td>dₜ</td>
<td>Half-thickness of leaves</td>
</tr>
<tr>
<td>Mₑ(t)</td>
<td>Moisture content at time t</td>
</tr>
<tr>
<td>Mₑ(t+dt)</td>
<td>Experimental moisture ratio at time t+dt</td>
</tr>
<tr>
<td>Mₑ(t)</td>
<td>Half-thickness of leaves at time t+dt</td>
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<tr>
<td>Mₑ(t+dt)</td>
<td>Predicted moisture ratio</td>
</tr>
<tr>
<td>dt</td>
<td>Time interval</td>
</tr>
<tr>
<td>R</td>
<td>Correlation coefficient</td>
</tr>
<tr>
<td>N</td>
<td>Number of observations</td>
</tr>
<tr>
<td>k, n, a, b</td>
<td>Empirical constants in the drying models</td>
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</tbody>
</table>

Fig. 4 Comparison of TPC in Different Drying Methods

5. Conclusions