Research Article

Drying Kinetics, Rehydration Behavior and Morphological Properties of Pre-Blanched Thai Basil Leaves

Nhu Bich Ma
Department of Food Technology, International University, Ho Chi Minh City, Vietnam
Vietnam National University, Ho Chi Minh City, Vietnam
Institute of Applied Science and Technology, Van Lang University, Ho Chi Minh City, Vietnam

Thanh Thi Ha Le and Ngoc Lieu Le*
Department of Food Technology, International University, Ho Chi Minh City, Vietnam
Vietnam National University, Ho Chi Minh City, Vietnam

* Corresponding author. E-mail: lnlieu@hcmiu.edu.vn DOI: 10.14416/j.asep.2021.10.010
Received: 17 June 2021; Revised: 21 August 2021; Accepted: 6 September 2021; Published online: 26 October 2021

Abstract

Drying characteristics of Thai basil (*Ocimum basilicum* var. thyrsiflorum) leaves during the hot-air drying process at different air temperatures with and without blanching pre-treatment were in-depth investigated. The increase in drying rate and decrease in drying time were observed at elevated temperatures. Blanching further reduced the drying time by approximately 19–45%, indicating to potentially reduce the energy consumption of drying. The Midilli *et al.* model demonstrated the best fitting to describe the process. The effective moisture diffusivity was computed as 0.21–1.55×10–10 m^2s^{-1}. The lower activation energy of water removal during drying for blanched leaves indicated that blanching had more energy efficiency at lower temperatures. Blanching also improved the rehydration capacity of dried leaves. Microstructural analysis revealed that blanching caused the collapse of the cellular structure and shrinkage and hence reduced the resistance of moisture removal leading to a higher drying rate. The findings in this work prove that blanching can be a potential approach to save consumed energy, reduce drying time, and hence potentially preserve beneficial properties of bioactive compounds in agricultural plants.

Keywords: *Ocimum basilicum*, Drying model, Blanching, Drying rate, Diffusivity, Rehydration, Morphology

1 Introduction

The genus *Ocimum* in the Lamiaceae family comprises at least 150 species worldwide grown in Asia, Africa, and South and Central America [1]. Among them, Thai basil (*Ocimum basilicum* var. thyrsiflorum) is popularly cultivated in South and Southeast Asia as culinary herbs [2]. It is also considered an important medicinal plant used in the food, cosmetic and pharmaceutical industries.

In order to preserve herbs for convenient use and product development, air hot drying is a traditional method to reduce their moisture content, which could protect them against deterioration and prolong their shelf-life [3]. Compared to the traditional open sun drying commonly used in many developing countries, hot air drying, which is operated in a closed system using hot air as the heating medium, could provide a quicker and more uniform process, higher sanitation, easier scale-up, and control without affected by climatic factors.

To scale up the drying technology in industrial production, mathematical models are needed to describe the drying process, which allows engineers to select the most suitable operation condition or design drying equipment accordingly [4]. In recent years, many studies have established the mathematical models for drying of diverse fruits, such as grape [5], banana [6], apricot [7], and kiwi [8]; vegetables, such as potato [9], sweet potato [10], pumpkin [11], and eggplant [12]; and herbs and spices such as mint, thyme [13], coriander [14], rosemary [15], and lemongrass [16]. The controlling parameters of the drying process, such as air temperature, airflow rate, humidity, etc. have been investigated.

In addition, the quality of dried food can be further improved by employing different pre-treatment methods before drying. The selection of pre-treatment techniques depends on the food type, its end-use, and availability [17]. Among them, blanching is one of the most common methods in drying fruits, vegetables, and other plants. It can be undertaken by steam or hot water [18], which can inactivate certain enzymes responsible for undesirable changes, such as darkening and off-flavor formation. It also generates physical changes in tissue structure, which increases the drying rate and shortens the drying time [19]–[24]. Comparison by Maharaj and Sankat [25] indicated that hot water was more efficient than steam for the blanching of leaves in terms of color and nutrient preservation.

To our best knowledge, no work has been done detailing the mathematical models of drying Thai basil using hot air as well as the effect of blanching pre-treatment on the drying kinetics of Thai basil. Therefore, the aims of this study are 1) to examine the effects of hot-water blanching pre-treatment and air temperature on the drying curves of Thai basil leaves, 2) to fit the experimental data of drying with different mathematical models, 3) to calculate effective moisture diffusivity through samples and activation energy of drying process, and 4) to evaluate the rehydration capacity and morphological changes of dried samples.

2 Materials and Methods

2.1 *Material preparation*

Thai basil was purchased from a local farm in Ho Chi Minh City, Vietnam. The whole basil was washed with tap water and drained off. The blanching pre-treatment was then conducted by putting the basil in boiling water for 10 s. Boiling water was chosen because of its simplicity and efficiency. The blanching duration was selected by pre-screening that could provide the highest antioxidant capacities (unpublished data). The excess water was removed by tissues. The leaves were then separated from stems, arranged on trays and put in a cabinet dryer. Before the drying process, the initial moisture content of Thai basil leaves was determined according to the Association of Official Analytical Chemists (AOAC) method (AOAC 2000).

2.2 *Drying experiments*

Drying experiments were performed in a laboratory-scale cabinet air-ventilated and forced-convection dryer (SOF-W155, Korea) with a constant air velocity of 1.2 m/s. The air temperature was kept at 50, 60, 70, and 80 °C. The dryer was operated for 30 min to obtain the set air temperature before loading the samples. Basil leaves of 100 g for each experiment were uniformly distributed on trays and put in the dryer. Moisture loss was recorded until a constant weight was obtained. Triplicate experiments were done.

2.3 *Mathematical modeling of drying curves*

The moisture ratio (MR) of basil leaves was calculated by Equation (1) below:

$$MR = \frac{M - M_e}{M_o - M_e} \tag{1}$$

where M is the moisture content of basil leaves during drying; M_o is the initial value; M_e is the equilibrium moisture content (g water/g dry matter). M_e is typically small as compared to M and M_o and hence M_e can be neglected [9], [26].

The drying data were then fit with five mathematic models of thin-layer drying (as in Table 1) to explore the best one to describe the drying process of Thai basil leaves. They are the commonly used models to describe the drying process of leaves [27]. The software LabFit was applied for non-linear regression analyses of experimental data. The coefficient of determination, R^2 could be used to determine the best equation [28], [29] as Equation (2) below. In addition to R^2, other statistical parameters, namely, reduced chi-square (χ^2), mean bias error (MBE), and root mean square error (RMSE) were also determined for the goodness of fitting as the Equations (3)–(5) below. The best fit would be concluded based on the highest R^2 and minimum χ^2, MBE and RMSE [28], [30], [31].

$$R^2 = \frac{\Sigma_{i=1}^{N}(M_{R_i} - M_{R_{pre,i}}) \times (M_{R_i} - M_{R_{exp,i}})}{\sqrt{\left[\Sigma_{i=1}^{N}(M_{R_i} - M_{R_{pre,i}})^2\right] \times \left[\Sigma_{i=1}^{N}(M_{R_i} - M_{R_{\exp,i}})^2\right]}} \tag{2}$$

$$\chi^2 = \frac{\Sigma_{i=1}^{N}(M_{R_{\exp,i}} - M_{R_{pre,i}})^2}{N-n} \quad (3)$$

$$MBE = \frac{1}{N}\Sigma_{i=1}^{N}(M_{R_{\exp,i}} - M_{R_{pre,i}}) \quad (4)$$

$$RMSE = \left[\frac{1}{N}\Sigma_{i=1}^{N} M_{R_{\exp,i}} - M_{R_{pre,i}}\right]^{1/2} \quad (5)$$

where $M_{R_{pre,i}}$ and $M_{R_{exp,i}}$ are the predicted and experimental moisture ratios, respectively. N is the number of observations and n is the number of constants in the drying models.

Table 1: Selected drying models to describe the drying process of Thai basil leaves

Model Name	Model
Lewis	MR = exp(–*kt*)
Midilli *et al.*	MR = *a*exp(–*kt*^{n}) + *bt*
Hederson and Pabis	MR = *a*exp(–*kt*)
Logarithm	MR = *a*exp(–*kt*) + *c*
Wang and Singh	MR = 1 + *at* + *bt*^{2}

2.4 *Effective moisture diffusivity and activation energy*

The effective moisture diffusivity was calculated by using the Fick's diffusion equation [32] when the leaves were considered to have a slab geometry [4] as the Equation (6) below:

$$MR = \frac{8}{\pi^2} exp\left(\frac{-\pi^2 D_{eff} t}{4L^2}\right) \quad (6)$$

where D_{eff} is the effective diffusivity (m^2/s), t is the time (s) and L is the thickness of the slab (m) with the assumption that the evaporation occurred from one side of the slab. The thickness was measured by a micrometer (Mitutoyo 547-400S, Japan) on multiple points of 10 leaves and the average values were calculated.

Equation (6) can be re-written as Equation (7) below:

$$ln(MR) = k_o t + ln\frac{8}{\pi^2} \quad (7)$$

where k_o is the slope determined by plotting the graph of $ln(MR)$ over time using Equation (8) to calculate the effective diffusivity of moisture at different temperatures.

$$k_o = -\left(\frac{\pi^2 D_{eff}}{4L^2}\right) \quad (8)$$

Arrhenius equation can be used to describe the temperature affinity of the effective diffusivity as the Equation (9) below [33]:

$$D_{eff} = D_o exp\left(\frac{-E_a}{RT}\right) \quad (9)$$

where D_o is the pre-exponential factor (m^2/s), R is the universal gas constant (kJ/mol K), E_a is the activation energy (kJ/mol), and T is the absolute temperature (K). The E_a value can be calculated from the slope of the plot of lnD_{eff} versus the reciprocal of T.

2.5 *Rehydration behavior and morphological observation*

Rehydration characteristics of dried leaves were examined at 25, 50, and 80 °C in water. Briefly, dried leaves (5 g) were placed into 150 mL water, stirred for 6 h. The samples were removed every 30 min, drained, and weighed. Triplicate experiments were done. The Peleg's model [34] was employed to describe the rehydration behavior as the Equation (10) below:

$$X = X_o + \frac{t}{K_1 + K_2 t} \quad (10)$$

where X and X_o are the moisture content at the time t and the initial moisture content, respectively; K_1 and K_2 are the Peleg rate constant and capacity constant, respectively.

Their cross-sectional morphologies were imaged using a scanning electron microscope (SEM, JSM-635F, JEOL, Tokyo, Japan). Before imaging, the samples were coated with gold for 60 s.

3 Results and Discussion

3.1 *Drying curves*

Moisture ratio over drying time plots of the drying process of Thai basil leaves conducted at 50–80 °C with and without blanching pre-treatment are represented in Figure 1. The hot air temperature had an evident effect on drying time. The curves of moisture ratio shifted to the left when the temperature increased, indicating shortened drying durations. The increase in air

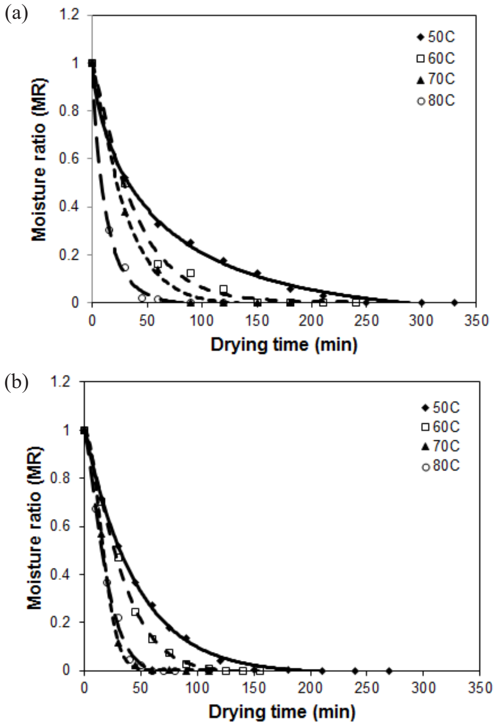

Figure 1: Effect of drying temperature on drying curve of basil leaves (a) without and (b) with blanching pre-treatment; dot: experimental data, line: predicted data.

temperature led to higher drying rates with the highest extent obtained for the experiment at 80 °C. The results are consistent with previous studies on the drying of various products [4], [8], [35]. This phenomenon was explained by the enhanced vapor pressure of moisture at higher surrounding air temperatures. Without blanching, the drying durations required to reduce the moisture content of Thai basil leaves to a final value of 7% (wet basis) (equivalent to the approximate MR value of 0.0075), which were calculated from the Midilli et al's models, are 272, 174, 115, and 72 min at 50, 60, 70, and 80 °C, respectively (Table 2). The final moisture content of 7% was selected in the desired range of 3–10% (wet basis) reported by Babu *et al.* [27] for dried leaves. Consequently, the influence of air temperature was interpreted in drying rate and drying duration.

Blanching reduces the initial moisture content of Thai basil leaves from 10.11 kg water/kg dry matter to 8.09 kg water/kg dry matter. During drying, blanching further shifted the curves of moisture ratio to the left, where the significant influence was observed at 50 °C while the impact at 80 °C was minor. Without blanching, the drying rate at 80 °C was much higher than those at 70, 60, and 50 °C. However, blanching reduced these differences. At the same moisture contents, drying rates of blanched leaves were higher than those of fresh leaves. The observed drying behavior was partially attributed to the impact of blanching on cell structures, such as cell membrane disruption, middle lamella damage, and the cleavage of hemicellulosic polysaccharides in the cell wall [36]. Table 2 presents that blanching shortened drying duration approximately 36, 36, 45, and 19% at 50, 60, 70, and 80 °C, respectively. According to Kusuma and co-workers [37], [38], electric consumption is directly proportional to duration when the power consumption is constant (at the same temperature in this case). Therefore, blanching could potentially reduce the energy consumption of the drying process.

Table 2: Drying durations of Thai basil leaves to reach the moisture content of 7% (wet basis) computed from the Midilli *et al.*'s models

Temperature (°C)	Drying Duration (min)	
	No Blanching	Blanching
50	272	175
60	174	111
70	115	63
80	72	58

3.2 *Mathematical models of the drying process*

The moisture content data of fresh and blanched leaves over drying time at different drying air temperatures were expressed in the term of moisture ratio and the curve fitting was subsequently conducted by using the models of Lewis, Handerson and Pabis, and Midilli *et al.*, Logarithm, Wang and Singh models as listed in Table 1. The constants of models and statistical parameters are shown in Tables 3 and 4, respectively for the drying processes without and with blanching pre-treatment. The coefficient of determination (R^2), reduced chi-square (χ^2), mean bias error (MBE) and root mean square error (RMSE) were calculated. The best fit model was determined based on the highest R^2 value and the lowest χ^2, MBE, and RMSE values. All proposed models could fit well the data with all R^2 values of greater than 0.97 except Wang and Singh's model, where the R^2 value varied from 0.86 to 0.99. Among them, the Midilli *et al.* model provided the best fitting with the $R^2 > 0.995$, $\chi^2 < 0.0014$, MBE in the range of $10^{-3} - 10^{-2}$, and RMSE < 0.03. The predicted data from the Midilli et al's model for the moisture ratio versus drying time are hence expressed in Figure 1 under the continuous lines.

3.3 *Effective moisture diffusivity and activation energy*

Fick's second law as described in Equation (6) was applied to model the diffusion process by assuming the slab geometry of Thai basil leaves and their negligible shrinkage during the drying, uniform initial moisture distribution with constant diffusivity. The computed effective moisture diffusivity (D_{eff}) for Thai basil leaves with and without blanching pre-treatment dried at different air temperatures is summarized in Table 5. The D_{eff} value increased with the increase in air temperature. This phenomenon was attributed to the accelerated movement of water molecules inside the food when higher temperatures were applied, leading to higher moisture diffusivity [36]. Interestingly, even though blanching increased the drying rate at equal moisture contents, it led to lower Deff values. In fact, the increase in drying rate was attributed to the fact that blanching reduced the thickness of the leaves from 108 µm to 78 µm. The decreases in thickness and ineffective moisture diffusivity was due to the blanching-induced disruption of cell membranes and cell walls leading to the collapse of cell structure. The Deff values varied from 0.21×10^{-10} to 1.55×10^{-10} m^2s^{-1}, which were in the general range of 10^{-11} to10^{-9} m^2s^{-1} for agricultural products.

The activation energy (E_a) is an effective indicator to evaluate the total energy consumption of the drying process and hence the energy efficiency [39]. As presented in Table 6, the activation energy of water removal during drying was computed as 46.17 and 27.71 kJ/mol for fresh and blanched leaves, respectively. Higher

Table 3: Statistical quality analyses of fit mathematical models to thin-layer drying data of basil leaves without blanching pre-treatment (time in min)

Temp (°C)	Constants and Coefficients					Model Parameters			
	k	*n*	*a*	*b*	*c*	χ^2	*RMSE*	*MBE*	R^2
Lewis's model: $MR = \exp(-kt)$									
50	0.0171					0.0013	0.0345	–0.0013	0.9878
60	0.0257					0.0007	0.0243	0.0016	0.9943
70	0.0339					0.0004	0.0194	0.0063	0.9975
80	0.0750					0.0004	0.0193	–0.0008	0.9968
Henderson and Pabis's model: $MR = a\exp(-kt)$									
50	0.0165		0.9650			0.0013	0.0327	–0.0033	0.9876
60	0.0258		1.0069			0.0008	0.0242	0.0021	0.9943
70	0.0340		1.0041			0.0231	0.1521	–0.0740	0.9974
80	0.0748		0.9965			0.0004	0.0193	–0.0012	0.9968
Logarithm model: $MR = a\exp(-kt) + c$									
50	0.0172		0.9582		0.0115	0.0010	0.0321	1.09×10^{-08}	0.9878
60	0.0254		1.0114		–0.0056	0.0006	0.0240	4.76×10^{-09}	0.9943
70	0.0323		1.0192		–0.0169	0.0003	0.0161	-7.52×10^{-09}	0.9978
80	0.0754		0.9941		0.0027	0.0004	0.0192	-9.71×10^{-13}	0.9968
Midilli *et al.* model: $MR = a\exp(-kt^n) + bt$									
50	0.0559	0.7162	0.9992	-1.39×10^{-04}		0.0014	0.0297	0.0219	0.9976
60	0.0174	1.1001	1.0021	7.04×10^{-06}		0.0009	0.0228	–0.0015	0.9949
70	0.0193	1.1471	0.9995	-3.69×10^{-05}		0.0005	0.0146	0.0039	0.9983
80	0.1160	0.8532	0.9996	-5.96×10^{-05}		0.0006	0.0166	0.0036	0.9977
Wang and Singh's model: $MR = 1 + at + bt^2$									
50			–0.0091	1.93×10^{-05}		0.0139	0.1068	0.0286	0.9208
60			–0.0130	3.89×10^{-05}		0.0132	0.1012	0.0215	0.9256
70			–0.0174	6.86×10^{-05}		0.0108	0.0877	0.0176	0.9489
80			–0.0296	1.85×10^{-04}		0.0321	0.1514	0.0382	0.8602

Table 4: Statistical quality analyses of fit mathematical models to thin-layer drying data of basil leaves with blanching pre-treatment (time in min)

Temp (°C)	Constants and Coefficients					Model Parameters			
	k	*n*	*a*	*b*	*c*	χ^2	*RMSE*	*MBE*	R^2
Lewis's model: $MR = \exp(-kt)$									
50	0.0225					0.0002	0.0133	0.0045	0.9987
60	0.0297					0.0011	0.0349	0.0077	0.9927
70	0.0541					0.0024	0.0349	0.0101	0.9745
80	0.0526					0.0015	0.0482	0.0114	0.9881
Henderson and Pabis's model: $MR = a\exp(-kt)$									
50	0.0227		1.0055			0.0002	0.0132	0.0049	0.9986
60	0.0307		1.0363			0.0011	0.0327	0.0109	0.9917
70	0.0553		1.0308			0.0035	0.0588	0.0139	0.9739
80	0.0541		1.0370			0.0019	0.0434	0.0143	0.9867
Logarithm model: $MR = a\exp(-kt) + c$									
50	0.0217		1.0160		–0.0152	0.0001	0.0100	1.30×10^{-09}	0.9989
60	0.0276		1.0659		–0.0397	0.0007	0.0257	1.98×10^{-09}	0.9937
70	0.0506		1.0620		–0.0345	0.0030	0.0547	4.17×10^{-09}	0.9754
80	0.0462		1.0865		–0.0618	0.0011	0.0327	-6.73×10^{-09}	0.9907
Midilli *et al.* model: $MR = a\exp(-kt^n) + bt$									
50	0.0192	1.0375	0.9962	-4.30×10^{-05}		0.0002	0.0120	0.0054	0.9989
60	0.0100	1.2906	0.9964	-3.28×10^{-05}		0.0002	0.0100	0.0027	0.9991
70	0.0030	1.9269	1.0003	2.65×10^{-05}		0.0001	0.0053	–0.0021	0.9998
80	0.0174	1.3413	0.9979	-1.47×10^{-05}		0.0007	0.0192	0.0062	0.9972
Wang and Singh's model: $MR = 1 + at + bt^2$									
50			–0.0124	3.42×10^{-05}		0.0116	0.0990	0.0288	0.9413
60			–0.0187	8.20×10^{-05}		0.0030	0.0499	0.0088	0.9806
70			–0.0291	1.91×10^{-04}		0.0118	0.0941	0.0140	0.9359
80			–0.0343	2.80×10^{-04}		0.0016	0.0353	0.0046	0.9902

Table 5: k_o and R^2 values of the linear equations for the determination of moisture diffusivity of basil leaves during the drying process

Pre-treatment	Temp (°C)	R^2	k_o	D_{eff} × 1010 (m^2s^{-1})
No blanching	50	0.98	–0.0155	0.32
	60	0.97	–0.0237	0.49
	70	0.95	–0.0275	0.56
	80	0.96	–0.0756	1.55
Blanching	50	0.95	–0.0368	0.21
	60	0.98	–0.0428	0.24
	70	0.96	–0.0854	0.49
	80	0.95	–0.0795	0.45

activation energy for non-blanched leaves indicated that moisture diffusion was more susceptible to temperature change. In other words, blanching has more energy efficiency at lower temperatures. The E_a value of drying blanched Thai basil leaves in this work was similar to that for coriander leaves [40] and lower than those for basil [41], mint [4], dill, and parsley [42] and black tea [43]. The activation energy of the food drying process was correlated with their composition, tissue structure, effective surface area, variety, and maturity as well as the pretreament methods. All these factors determine the different E_a values of Thai basil leaves and other plant leaves [39].

Table 6: Comparison of activation energy of drying process for different plant materials in literature

Material	Activation Energy (kJ/mol)	References
Thai basil leaves (no blanching)	46.17	This study
Thai basil leaves (blanching)	27.71	This study
Basil leaves	33.21	[41]
Coriander leaves	26.5	[40]
Mint	62.56	[4]
Black tea	406.02	[43]
Dill leaves	35.05	[42]
Parsley leaves	43.92	[42]

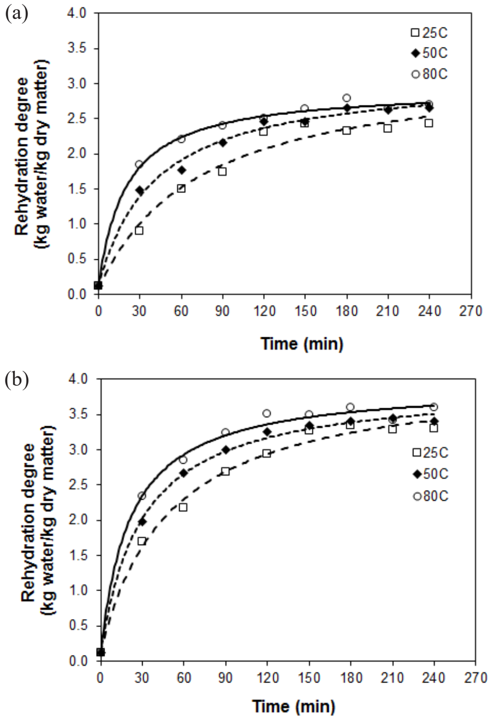

Figure 2: Rehydration behavior of Thai basil leaves dried at 50 °C (a) without and (b) with blanching pre-treatment, immersed in water at different temperatures.

3.4 *Rehydration behavior*

Rehydration characteristics of dried foodstuffs are important because they generally undergo rehydration prior to or during usage. Rehydration is a complicated phenomenon that is influenced by its processing condition and food characteristics. Figure 2 illustrates the rehydration behavior of the basil leaves dried at 50 °C influenced by the aid of blanching prior to drying and water temperature. The water absorption was quick at the initial stage of approximately 90 minutes and the process slowed down afterward. The fast initial water uptake was ascribed to the filling into capillaries and cavities near the product surface. When these easily accessible spaces were virtually full, a decline in soaking rate was expected. A similar observation was also reported for other dried leaves such as betel [44], wormwood [45], and amaranth [46]. The Peleg's model was employed to fit the experimental data of rehydration [46] and its constants (K_1 and K_2) and coefficient of determination (R^2) are presented in Table 7.

The constant K_1 generally indicates the mass transfer rate and the lower its value, the higher the initial water uptake [47]. Meanwhile, the constant K_2 is inversely correlated to the rehydration capacity of products [48]. Table 7 shows that the increase in water temperature significantly decreased the K_1 value and blanching further reduced it, indicating the positive effects of increased temperature and blanching on the rate of water uptake. On the other hand, the increment in water temperature had minor or no significant effects on K_2 value while the aid of blanching led to its significant reduction, indicating higher equilibrium moisture contents. A controversial relationship between water temperature and Peleg's constants has been reported. Dadali *et al.* [49] and Demirhan and Ozbek [50] observed an inversely proportional relationship while the temperature independence of K_1 and K_2 was recorded by Okpala and Ekechi [51] and Abu-Ghannam and McKenna [52]. Similarly, no constant correlation between blanching and Peleg's constants has been reported [48], [51].

Table 7: K_1, K_2, and R^2 values of the Peleg's models of rehydration behavior for the basil leaves dried at 50 °C

Pre-treatment	Temp (°C)	R^2	K_1	K_2
No blanching	25	0.97	22.78	0.313
	50	0.99	13.85	0.334
	80	0.99	7.14	0.355
Blanching	25	0.99	12.42	0.252
	50	0.99	7.82	0.262
	80	0.98	5.64	0.262

3.5 *Morphological changes*

Morphological changes of Thai basil leaves during drying, which significantly influenced the physicochemical properties and quality of their dried products, are illustrated in Figure 3. The fresh leaves had a laminar structure with opened cellular (porous) cells. Similar structures were observed for other leaves, such as *Thunbergia laurifolia* Linn [53] or *Mentha cordifolia* Opiz ex Fresen [54]. These structures became vague in blanched leaves since the significant shrinkage occurred leading to the collapse of cellular structures and the significant decrease in thickness. The thickness decrease was the main reason to reduce resistance and increase drying rate in the case of blanched leaves as discussed in previous sections. Hot air drying further

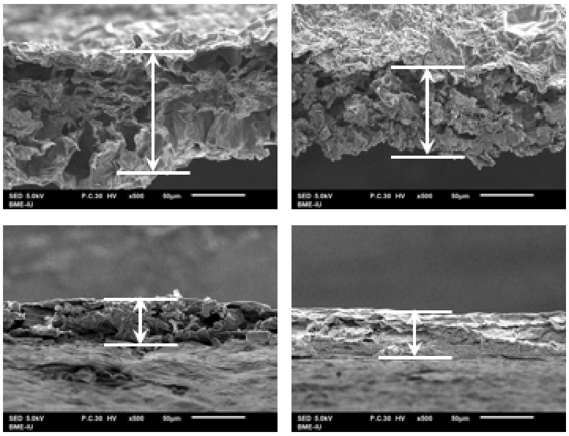

Figure 3: Cross-sectional morphologies of the Thai basil leaves before (upper) and after (lower) hot air drying without (left) and with (right) blanching pre-treatment.

caused an evident microstructural deformation producing a packed structure with an approximately equal thickness for both blanched and unblanched samples. This change was the result of moisture removal from the cell fluid during drying, which led to turgor loss [55].

4 Conclusions

In this study, the effects of blanching pre-treatment and air temperature on drying characteristics of Thai basil leaves were investigated in-depth. Higher air temperatures increased the drying rate and hence shortened the drying duration. Among the studied drying models, Midilli *et al.* model provided the best fitting. Effective moisture diffusivity of Thai basil leaves was in the range of agricultural products. On the other hand, blanching reduced drying duration due to its effects on the cellular structure of leaves and hence could save energy consumption of the drying process. The activation energy of drying blanched Thai basil leaves was mostly lower than those of others in the literature, suggesting more energy efficiency at low temperatures. Blanching was also proved to enhance the rehydration characteristics of Thai basil leaves.

Acknowledgments

The study was supported by The Youth Incubator for Science and Technology Program, managed by Youth Development Science and Technology Center - Ho Chi Minh Communist Youth Union and Department of Science and Technology of Ho Chi Minh City, the contract number is “19/2019/HĐ-KHCNT-VU”.

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