Influences of drying temperature on drying characteristics and physical properties of *Aloe barbadensis* Mill. leaves using hot air drying

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Abstract

The aims of this research were to investigate the effects of drying air temperatures and thickness of *Aloe barbadensis* leaves on drying characteristics and physical properties of the leaves. Thickness of the leaves were 2.5 and 5 mm. The leaves were subjected to dry in a hot air dryer at 40, 50 and 60°C. Drying data were fitted to zero model. Color parameters and rehydration ratio were determined. The results revealed that zero model was a good model to describe drying behavior due to high coefficients of determination (R^2) which were in the range of 0.9637 – 0.9727. Falling rate period were found in this study. Drying constant (K) were in the range of 0.0087 – 0.0182 min^{-1} and 0.07341 -0.0583 min^{-1} for both dried leaves thickness 2.5 and 5 mm, respectively. Increasing drying air temperature led to reduce drying time. The leaves with thickness of 2.5 mm dried at 40°C provided the highest hue (H*) value and the results also showed that drying at high temperature gave low total color difference from fresh sample (ΔE*) and browning index (BI). Moreover, drying at 60°C with 2.5 mm of thickness provided the shortest drying time and the highest rehydration ratio (21.78 ± 0.52).

Keywords: *Aloe barbadensis* leaves, color parameter, drying characteristics, drying model, rehydration ratio

Introduction

Aloe vera is the perennial tropical plant which is original plant from Africa. The scientific name of this plant is *Aloe barbadensis* Miller. which belongs to the family Liliaceae. There are a number of different varieties of the plant in the world. There are over 360 species. The aloe vera gel contains over 98-99% of water and the benefits of the gel are protectting from evaporation and used as antioxidant agent. The gel is also a source of water, protein, carbohydrate, fiber and vitamins including C and E. The aloe vera gel is widely used in many kinds of foods and some cosmetics products, e.g. juices, yoghurts, biscuits, lotion and shampoo. The plant is used in the industries but there is some problems during processing. The gel contains high moisture content leading to low shelf life and high handing costs [1, 2].

Drying or dehydration is an ancient food processing method which is potential to preserve and reduce the cost of packing, storing and transportation by reducing both mass and volume of the dried or dehydrated product [3]. Dried or dehydrated foods are microbiologically stable. Microbial growth is controlled by the low water activity. Protective packaging and some dehydration methods may be required to retain the product qualities including color, flavor, structure [4]. Hot air drying is convection drying methods that consists of passing heated air through the layer of product. The hot air dryer can be conducted with a tray or cabinet dryer, where perforated trays hold thin layers of materials. Tray dryer consists of an insulated cabinet, equipped with a fan, an air heater that thermostat is used to controlled air temperature which is generally set between 50 and 70°C and a space occupied by trays of food. The advantage of tray dryer is simple and low operation cost.

The objectives of this research were to evaluate the influences of drying temperature including 40, 50 and 60°C and thickness levels of *Aloe barbadensis* leaves for 2.5 and 5 mm on the quality aspects of dried leaves including color parameter and rehydration ratio.

Materials and methods

A. barbadensis leaves were purchased from a private garden in Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand. The leaves were peeled out and washed in 5 ppm

chlorinated water, then subjected to slice in to 2 thickness levels which were 2.5 and 5 mm. The leaves were used for drying experiments.

The *A. barbadensis* leaves (~200 g) were dried in a tray dryer (Armfield Limited, Ringwood Hamshire, England) at 40, 50 or 60°C at constant air velocity (0.5 m/s) [5]. Air velocity was measured by an air velocity meter (model 3K-27V No. 7680-00, Sato Keiryoki, Tokyo, Japan) with an accuracy of 0.01 m/s. A hygrometer (Vaisala HMP-5D, Delta OHM-VIAG, Galilei, Italy) with an accuracy of 0.01% relative humidity (RH) was used to measure the RH of drying air. A data recorder (DT 800 Data Taker, Scoresby, Victoria, Australia) was used to record the weight loss of the leaves at intervals of 5 min. Drying was terminated when the sample weight was constant. Three replicates were performed for each drying condition and average moisture content from those tests was used.

Drying data were presented as the moisture ratio (MR):

$$MR = \frac{X_t - X_e}{X_0 - X_e} \quad (1)$$

where X_t is the moisture content at a specific time (g water/g dry basis); X_0 is the initial moisture content (g water/g dry basis); X_e is the equilibrium moisture content.

Zero drying model was used to fit with the data. The model is shown as follow:

$$X = X_0 \exp(-Kt) \quad (2)$$

K is a drying constant in the fitting process. The former describes a characteristic time over which the MR decays, while the latter shows how the process deviates from a purely exponential decay. In case of zero model, X_e was closed to zero so, MR = (X_t/X_o) [5].

The model parameters were obtained from fitting of drying data with drying model which processed by non-linear regression technique using SPSS 19.0 for Windows (SPSS, Inc., Chicago, IL). In addition, coefficient of determination (R^2) and standard error of estimation (SEE) were used to determine the goodness of the fit.

$$SEE = \sqrt{\frac{\sum_{i=1}^{N}\left(x_{pre,i} - \bar{x}_{\exp,i}\right)^2}{d.f}} \quad (3)$$

where (n – 1) gives the number of degrees of freedom of the fitted equation.

Hunter Lab (Ultra Scan Xe U3115, Color Global Co., Virginia, USA) was used to measure the color of *A. barbadesis* leaves in both before and after drying. The color parameters including L*, a*, and b* values were measured. L* represents the lightness or darkness of the object. Hunter a* represents redness (+) or greenness (-). Hunter b* represents yellowness (+) or blueness (-). H* (hue angle) was also determined to evaluate yellow-green color of the leaves (equation (4)):

$$\text{Hue angle} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (4)$$

The total color difference from fresh sample (ΔE*) was the parameter that used to consider total color difference evaluation, between a dried sample and the fresh leaves in equation (5):

$$\Delta E^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2} \quad (5)$$

Fresh *A. barbadensis* leaves were used to be a reference and a larger ΔE* denotes greater color difference from the reference material.

Browning index (BI) is important color parameter to measure the degree of browning in dried sample [6]. BI represents the purity of brown color and is given by

$$BI = \left[\frac{100(x - 0.31)}{0.17}\right] \quad (6)$$

where

$$x = \frac{(a + 1.75L)}{(5.645L + a - 3.012b)} \quad (7)$$

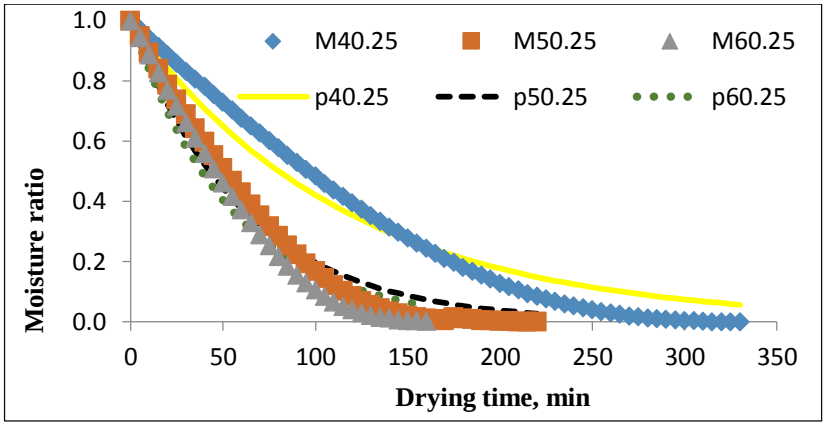
The ability to reabsorb water of the dried *A. barbadensis* leaves was determined using the rehydration ratio. One gram of dried leaves was soaked in 500 mL of distilled water at 30°C. Every 5 minutes, the dried sample was removed from the distilled water, drained and weighted the dried leaves until the weight of the leaves was constant. The rehydration ratio of dried leaves was calculated by equation (8) [7].

$$\text{Rehydration ratio} = \frac{\text{Weight of rehydrated sample}}{\text{Weight of dried sample}} \qquad (8)$$

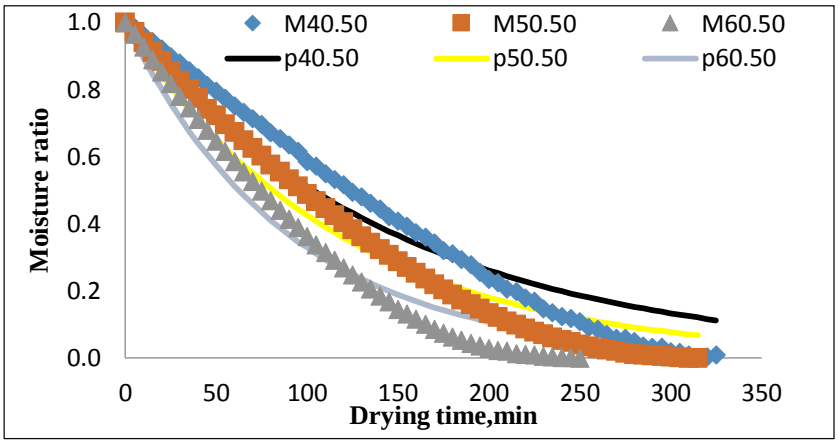
A completely randomized design (CRD) 2x3 factorial experiment was used to study the main factor of thickness (2.5 and 5 mm) and drying air temperature (40, 50 and 60°C). Triplicate were used to determine each drying treatment. SPSS 19.0 for Windows (SPSS, Inc., Chicago, IL) was used to calculate analysis of variance (ANOVA). Duncan's new multiple range test was used to compare the significance of treatment means at a 95% confidence interval.

Results and discussion

The drying data from the drying experiment were fit by zero model. Constant values of dried *A. barbadensis* leaves are presented in Table 1. It was found that drying constant (K, min^{-1}) were in the ranges from 0.0087 to 0.0182 min^{-1} and 0.0067 to 0.0111 min^{-1} for 2.5 and 5 mm thickness, respectively. The result also showed that increasing drying air temperature led to increase drying constant in both 2.5 and 5 mm thickness. The results showed that constant drying period did not occur in this study and drying took place only in the falling rate period because drying rates were entirely decreased during the drying processes. Moreover, drying time reduces with increasing drying air temperature in both 2.5 and 5 mm thickness (Fig. 1). The results were agreed with kaffir lime leaf drying [8], leaf drying [9] and moringa leaf drying [10]. Increasing drying air temperature substantially increased the drying rate. The results indicated that mass transfer within the sample was more rapid during higher drying air temperature because more heat was generated within the sample creating a large vapor pressure difference between the center and the surface of the product.



(A)



(B)

Figure 1. Moisture ratio of *A. barbadensis* leaves for 2.5 mm (A) and 5 mm (B) leaves thickness from zero model compared with the observed experimental data. M40.25, M50.25 and M60.25 and M40.50, M50.50 and M60.50 were drying data which were measured at temperature 40, 50 and 60°C for 2.5 and 5 mm, respectively. P40.25, P50.25 and P60.25 and P40.50, P50.50 and P60.50 were drying data which were predicted at temperature 40, 50 and 60°C for 2.5 and 5 mm, respectively.

Color values in dried fruits and vegetables was used to indicate pigment nutrients retention. If the color of the final product is considered as quality indicator, the color parameters can be used to optimize the drying process and minimize the degradation of important compounds [11].The total color difference from the fresh samples (ΔE*) have been used to explain the color change during drying process. Larger values of ΔE* denote a larger color change from the reference material [12]. Browning index (BI), defined as brown color purity, is one of the most common indicators of browning in sugar containing food products [13].Color parameter of dried *A. barbadensis* leaves using different drying conditions were reported in Table 2. It

was found that color parameter in terms of ΔE* and BI decreased with increasing drying air temperature. The results were agreed with Aral and Bese [11] who revealed that increasing drying time led to increases the degradation of color due to longer time exposed to heat.

Table 1. Constants of zero model of dried *A. barbadensis* leaves

Thickness (mm)	Constant	Temperature (°C)		
		40	50	60
2.5	K (min^{-1})	0.0087	0.0163	0.0182
	R^2	0.9637	0.9727	0.9661
	SEE	0.0594	0.0522	0.0588
5	K (min^{-1})	0.0067	0.0085	0.0111
	R^2	0.9668	0.9637	0.9648
	SEE	0.0734	0.0592	0.0583

The rehydration ratio of dried *A. barbadensis* leaves affected by drying air temperature and thickness was summarized in Table 2. Rehydration ration were in the rages from 8.96 to 21.78 and 7.01 to 11.83 for the thickness of 2.5 and 5 mm, respectively. The result showed that thickness of 2.5 mm provided higher rehydration ratio than 5 mm and highest rehydration ratio was found in the treatment of 2.5 mm thickness and dried at 60°C. Aral and Bese [11] investigated the effect of drying air temperature on rehydration ration of dried products. The result showed that drying using drying air temperature at 70°C provided more porous and uniform structure than the sample has been dried at 50°C, and this porosity allows the higher water penetration. It indicated that drying at higher drying air temperatures provided higher rehydration capacity that drying at low drying air temperature [14]. Drying at low drying air temperature took long drying time which was the cause of cell collapse and tissue damage.

Conclusions

The effects of thickness and drying air temperature which were performed in tray dryer on quality parameters in term color parameters and rehydration ratio of dried *A. barbadensis* were evaluated. The the falling rate periods were found in this research. Drying constant were in the rages from 0.0087 to 0.0182 min^{-1} and 0.0067 to 0.0111 min^{-1} for 2.5 and 5 mm thickness,

respectively. Increasing drying air temperature led to increase drying constant in both thickness of 2.5 and 5 mm. High drying air temperature provided better color quality and rehydration ratio than low drying air temperature due to short drying time of drying at high temperature. Drying of 2.5 mm at 60°C was found to be the highest rehydration ration which was 21.78 ± 0.52. Thickness for 2.5 mm and dried at 60°C was proposed to dry *A. barbadensis* due to high qualities of dried products.

Table 2. Color parameters and rehydration ratio of dried *A. barbadensis* leaves

Thickness (mm)	Temperature (°C)	H*	ΔE*	BI	Rehydration ratio
2.5	40	104.23 ± 3.32^{c}	16.32 ± 0.25^{c}	196.52 ± 1.83^{d}	8.96 ± 0.28^{b}
	50	99.24 ± 1.11^{bc}	11.92 ± 0.62^{b}	192.54 ± 1.71^{bc}	19.43 ± 0.52^{d}
	60	96.26 ± 0.74^{b}	12.48 ± 1.09^{b}	191.60 ± 1.37^{ab}	21.78 ± 0.52^{e}
5	40	86.29 ± 4.63^{a}	12.67 ± 0.28^{b}	195.44 ± 0.52^{cd}	7.01 ± 0.77^{a}
	50	96.26 ± 0.38^{b}	11.83 ± 0.15^{ab}	189.86 ± 0.47^{ab}	10.93 ± 0.84^{bc}
	60	98.04 ± 0.14^{b}	10.52 ± 0.11^{a}	189.16 ± 0.35^{a}	11.83 ± 0.76^{bc}

Mean values in the same column with different superscripts are significantly different at $p \leq 0.05$ by Duncan's New Multiple Range Test.

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