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Original Research Article

Comparative study of color retention of dried stevia leaves (*Stevia rebaudiana* Bertoni) by single-stage drying and multi-stage drying

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ABSTRACT

The color of dried stevia leaves is an important component quality and primary consideration of consumers when making purchasing decision. This study aimed to investigate an effect of single-stage drying temperature and multi-stage drying temperature on drying rate and color quality of dried stevia leaves. The drying conditions of single-stage drying temperature are at 50, 60, 70, 80 and 90°C and multi-stage temperature for 80°C follows by 50°C and 90°C follows by 50°C. The drying rate of single-stage temperature required to reduce moisture content of stevia leaves from 5.23±0.41 to 0.075±0.003 $g_{water}/g_{dry\ matter}$ was 0.0018-0.0179 $g_{water}/g_{dry\ matter}$*min. Whereas the drying rate of multi-stage drying temperature was 0.0032 to 0.0076 $g_{water}/g_{dry\ matter}$ *min. It was found that multi-stage drying temperature provided the higher drying rate and color retention than that of single-stage drying temperature. The results of these tests suggest that multi-stage drying temperature provided better color quality of dried stevia leaves in terms of color. It was found that the suitable conditions for multi-stage drying temperature were 80°C for 30 min and 50°C for 730 min. The color qualities of dried stevia leaves for multi-stage drying temperature in CIELAB system namely *L**, *a**, *b** and *TCD* were 54.15±1.83, -10.41±1.99, 18.97±1.47 and 5.01±0.84, respectively. In addition, the Chroma values (C^*) and Hue angle (h^o) were 39.19±3.11 and 108.84±4.39.

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INTRODUCTION

Stevia is a sweetener and sugar substitute made from the leaves of the plant species *Stevia rebaudiana*. Stevia's taste has a slower onset and longer duration than that of sugar, and some of its extracts may have a bitter or licorice-like aftertaste at high concentrations (http://en.wikipedia.org). Drying is an important method in which water is reduced for food preservation in order to inhibit enzyme activity and growth of microorganisms that cause food deteriorations (Orikasa *et al*., 2014 and Borompichaichartkul, 2013). However, during the drying process, changes in food products such as shrinkage, darkening of color, or loss of volatile compounds and nutritional value can devalue the dried products. Hybrid drying is an alternative approach that can be used to solve problems that occur during conventional drying by employing multi-stage (Borompichaichartkul, 2013).

Color is an important attribute which significantly affects the consumer's perception as well as determines the nutritional quality of dried agriculture product (Saxena *et al*., 2012). Color is not only the primary consideration of consumers, but is also an important characteristic accounting about 40% for the criteria for acceptance of a product (Arabhosseini *et al*. 2011; Kolawole *et al*., 2007).

Convective drying using single-stage drying temperature is a common method for drying agricultural products. Disadvantages of single-stage drying temperature include its low drying rate and requirement for relatively long time and high temperatures (to be completed), which cause color degradation (Wojdylo *et al*., 2014). Consequently, a multi-stage drying temperature is considered to be an alternative method for production improvement of convective drying. In addition, nutrients and phytochemical constituent of dried agricultural materials using multi-stage drying temperature could not be maintained as well as single-stage drying temperature (Phomkong, 2010). However, there is not available information on the production improvement of convective drying using multi-stage temperature. Therefore, this research investigates the effect of different drying temperature condition, such as single-stage temperature at 50, 60, 70, 80 and 90°C and multi-stage temperature for 80°C follows by 50°C and 90°C follows by 50°C on drying rate and color changes using CIELAB (L^*, a^*, b^*, total color change (TCD)) and MUNSELL color system (hue angle, h^o; chroma, C^*).

MATERIALS AND METHODS

Preparation of sample

A quantity of 10 kg stevia leaves were purchased from Sa-Ngo Royal Project Foundation, Chiang Rai Province, Thailand, and were stored in refrigerator at approximately 10°C prior to the experiment.

Drying procedures

A sample of 50 g of stevia leaves was spread into a single layer on the 20x20 cm^2 stainless steel tray, and dried in tray dryer (Figure 1). The sample was dried with different drying temperature condition as single-stage drying temperature (50, 60, 70, 80 and 90°C) and multi-stage drying temperature (80°C follows by 50°C and 90°C follows by 50°C). The tray dryer consisted of the drying chamber constructed by stainless steel sheets as a rectangular tunnel. The tray dryer was equipped with an electrical heater with a PID temperature controller. The heating system consisted of a 3.3 kW electric heater placed inside a duct which was used to heat the air to the desired drying temperature. The drying air velocity was also fixed to be 0.32 m/s which were measured by an anemometer (Lutron, AM-4201, Taiwan). Weight loss during drying process was recorded using a computer software data logger through a balance that connected to a PC. The loss in weight was calculated in term of percent moisture as follow Eq. (1)

$$Moisture\ content\ (g_{water}/g_{dry\ matter}) = \frac{Initial\ weight - Final\ weight}{Solid\ weight} \quad (1)$$

The sample was dried with two different drying condition as single-stage drying temperature (50, 60, 70, 80 and 90°C) and multi-stage drying temperature (80°C follows by 50°C and 90°C follows by 50°C) to determine drying characteristics.

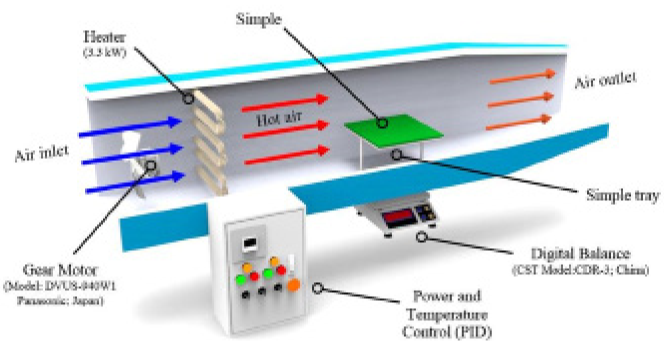


Figure 1 Experimental setup of laboratory tray dryer

Color Measurement

The color of fresh and dried stevia leaves was determined using spectrophotometer (HunterLab Model MiniScan XE PLUS). The measurements were recorded in two color system, referring to color space CIELAB and MUNSELL. The CIELAB color system was expressed as L^* (whiteness/darkness), a^*(redness/greenness), b^*(yellowness/blueness) and total color difference (*TCD*) was calculated by equation 2.

$$TCD = \sqrt{(L_0 - L^*)^2 + (a_0 - a^*)^2 + (b_0 - b^*)^2} \quad (2)$$

MUNSELL- color system had two color parameters as hue angle (h^o) and chroma (C^*) was calculated by equation 3 and 4.

$$\text{Hue angle } (h^o) = \tan^{-1}(b^*/a^*) \quad (3)$$

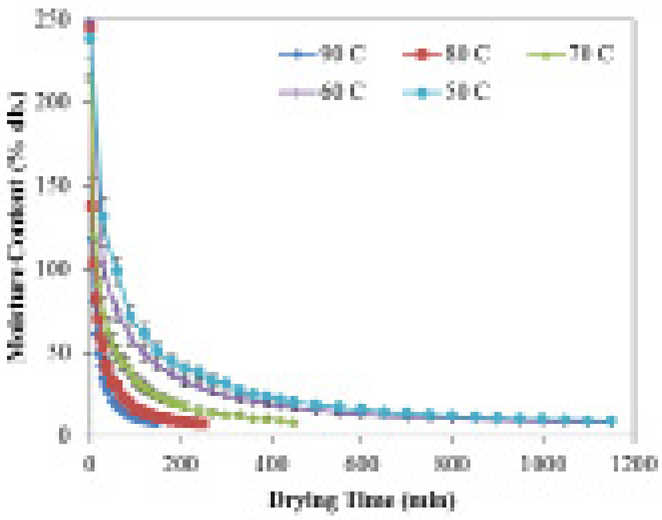
$$\text{Chroma } (C^*) = \sqrt{(a^*)^2 + (b^*)^2} \quad (4)$$

RESULTS AND DISCUSSION

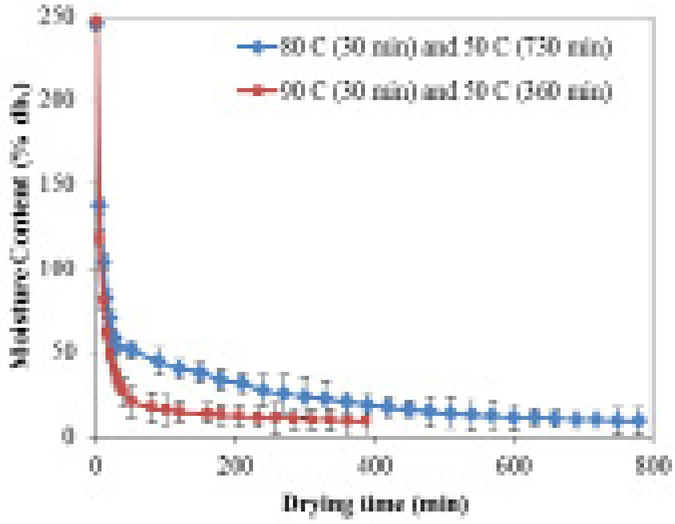
Drying Characteristics

The characteristics of drying curve for dried stevia leaves using single-stage temperature and multi-stage temperature are shown in Figure 2(*a*) and 2(*b*). The final moisture at 0.075±0.003 $g_{water}/g_{dry\ matter}$ of dried stevia leaves was proved to retain good natural sweeteners (Abou-Arab *et al*., 2010). The time required to dry stevia leaves from the initial moisture contents of 5.23±0.41 $g_{water}/g_{dry\ matter}$ until the final moisture content of 0.075±0.003 $g_{water}/g_{dry\ matter}$ was achieved in 1150, 1050, 450, 250, 150 min. The drying rates were 0.0019, 0.0021, 0.0048, 0.0103, 0.0179 $g_{water}/g_{dry\ matter}$ min at 50, 60, 70, 80 and 90°C of single-stage temperature, respectively. The decrease in drying rate with an increase in drying air temperature has been reported for many agricultural product such as persimmon slices (Doymaz, 2012), jackfruit (Saxena *et al*., 2012) and tarragon leaves (Arabhosseini *et al*., 2011).

Hybrid drying technology has developed to improve quality of dry products and increase drying rate. Multi-stage drying temperature is the same step-wised changing of drying temperature dryer types (Borompichaichartkul, 2013). The multi-stage drying temperature was applied at high temperature at the first stage of drying period, followed by lower temperature at following stage (Phomkong, 2010). The results in Figure 2 (*b*) showed the drying curve of dried stevia leaves using multi-stage temperature of 80°C follows by 50°C and 90°C follows by 50°C, respectively. The results showed that drying rate using multi-stage temperature at first stage at 80°C follows by 50°C was 0.0032 $g_{water}/g_{dry\ matter}$ min. Then the drying rate of using multi-stage temperature at first stage at 90°C about 30 min and second stage at 50°C about 360 min was 0.0076 $g_{water}/g_{dry\ matter}$ *min. Additionally, it was found that there was a possibility to reduce the drying rate to reach the desired moisture content using multi-stage temperature. Similar results have been reported by Wiriya *et al*. (2009) Davison and Brown (2004) and Chua (2001).



(a)



(b)

Figure 2 Changes in the stevia leaves moisture content during different drying condition (a) Single-stage drying temperature and (b) Multi-stage drying temperature

Evaluation of Color Parameters

Multi-Stage Drying using higher drying temperature was applied to remove free water from stevia leaves during constant rate period. This period gave minimum effect of thermal reaction on color degradation. Then, drying temperature was lower during falling rate period. Preliminary experiment discovered that the suitable condition to maintain color of dried stevia leaves was higher drying temperature at 80°C during constant rate period for 30 min, and changing of drying temperature at 50°C during falling rate period for 730 min. Nevertheless, higher drying temperature at 90°C during constant rate leaded to too high thermal color degradation on stevia leaves which induced the darkening of color. Therefore, this condition was not proper for multi-stage drying process. Similar result was found by Cuervo *et al*. (2012).

Figure 3 The photographs of fresh and dried stevia leaves using single-stage drying temperature and multi-stage drying temperature

Figure 3 presents the visual color of fresh and dried stevia leaves undergoing single-stage temperature (50, 60, 70, 80 and 90°C) and multi-stage temperature (80°C follows by 50°C and 90°C follows by 50°C) convective drying. The color parameters *L**, *a**, *b**, *h°*, *C** of fresh stevia leaves were 39.82±1.45, -13.54±1.09, 19.77±1.49, 112.58±2.65 and 21.38±3.41 respectively. All green color pigment value (*a**) and *h°* of all dried samples decreased significantly in comparison to fresh stevia leaves. Chlorophyll is a green pigment found in cyanobacteria and the chloroplasts of stevia leaves (http://en.wikipedia.org). The greenness of dried stevia leaves was correlated with a loss of chlorophyll during drying process (Naowanit *et al*., 2013). and the most suitable condition for maintaining the color of stevia leaves because it concerns the human visual perception on the colors of dried agricultural-product. On the other hand, drying by single-stage temperature gave no-significant difference of color quality. The worst drying condition would be drying at high temperature; 90°C because it destroyed color pigment and created browning reaction. The enhancement in knowledge of multi-stage drying temperature could be used as a method for the improvement in color during drying stevia leaves.Similar results for the enhancement of multi-stage drying for color retention of agricultural product were found in the drying of chilli (Wiriya *et al*., 2009) and ginseng root (Davison and Brown, 2004).

Table 1 CIE-color parameters of fresh and dried stevia leaves as affected by different single-stage drying temperature and multi-stage drying temperature

Drying Temperature Conditions	L*-values	a*-values	b*-values
Single-stage drying temperature			
Fresh	39.82±1.45*a*	-13.54±1.09*a*	19.77±1.49*a*
50°C	46.35±2.56*b*	-4.27±1.12*c*	23.26±2.12*b*
60°C	46.03±1.14*b*	-5.16±0.82*dc*	20.26±2.54*ba*
70°C	45.91±2.38*b*	-6.81±0.94*dc*	25.26±1.12*c*
80°C	46.81±3.59*b*	-6.08±0.54*d*	24.64±3.84*cb*
90°C	28.30±7.32*d*	-2.06±1.15*ed*	39.91±4.23*d*
Multi-stage drying temperature			
80°C follows by 50°C	**54.15±1.88*a***	**-10.41±0.94*b***	**18.97±1.47*a***
90°C follows by 50°C	31.35±1.18*d*	4.55±2.25*d*	16.97±2.37*a*

Table 2 MUNSELL-color parameters of fresh and dried stevia leaves as affected by different single-stage drying temperature and multi-stage drying temperature

Drying Temperature Conditions	ΔE	Hue angle	Chroma values
Single-stage drying temperature			
Fresh		112.58±3.65*a*	21.38±3.41*a*
50°C	8.35±2.12*b*	100.23±2.34*c*	23.73±1.92*a*
60°C	8.96±2.73*b*	102.91±4.31*c*	23.99±2.62*a*
70°C	9.10±2.38*b*	104.94±3.16*cb*	26.18±2.48*a*
80°C	9.43±1.83*b*	103.48±0.95*c*	25.42±2.98*a*
90°C	15.92±3.2*c*	93.16±2.54*d*	40.00±3.62*b*
Multi-stage drying temperature			
80°C follows by 50°C	**5.01±1.14*a***	**108.84±2.39***b*	**39.19±3.11*b***
90°C follows by 50°C	9.72±0.97*b*	68.36±6.05*e*	17.02±2.12*c*

Table 1 and 2 were presented CIE-color parameters and MUNSELL-color parameters of fresh and dried stevia leaves as affected by different single-stage drying temperature and multi-stage drying temperature. The total color change (*TCD*) in the dried stevia leaves was determined using color value (*L**, *a**, *b**) to evaluate the color change during drying. The *TCD* can be very important for the dried product, which expresses the human eye's ability to discriminate colors of dried sample (Wojdyl., *et al*., 2013; Hii and Lim Law, 2010). The experiment showed that multi-stage drying temperature of stevia leaves at 80°C followed by 50°C gave better color quality than other drying conditions because it provided similar green color pigment value (*a**) and *h°* as fresh stevia leave, and had the least TCD. Results obtained in this study suggested that multi-stage drying temperature at 80°C for 30 min and 50°C for 730 min are the best drying condition

CONCLUSION

Convective drying of stevia leaves using multi-stage temperature provided various advantages such as high drying efficiency, reduction of drying rate and retention of color quality. The multi-stage drying temperature, first stage at 80°C about 30 min and second stage at 50°C about 730 min gave the best color quality. The color qualities of dried stevia leaves in CIELAB system namely *L**, *a**, *b** and *TCD* were 54.15±1.83, -10.41±1.99, 18.97±1.47 and 5.01±0.84, respectively. In addition, the Chroma values and Hue angle were 39.19±3.11 and 108.84±4.39.

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