Prediction models for colour changes in red fleshed dragon fruit (*Hylocereus polyrhizus*) during hot air drying

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ABSTRACT

The main objective of this study was to investigate the effect of different temperatures of hot air drying on the quality attributes of red fleshed dragon fruit including colour parameters and colour sensory quality. The drying experiments were carried out at five air temperatures of 40, 50, 60, 70 and 80\degree C. The colour parameters, \( L \) (whiteness/darkness), \( a \) (redness/greenness) and \( b \) (yellowness/blueness) for colour change of the materials were quantified by the Hunter Lab system. These values were also used for calculating total change (\( \Delta E \)), hue angle, chroma and browning index. A consumer preference test was conducted with 60 consumers to assess the colour quality of five dried red fleshed dragon fruit samples. Least square regression was used to determine the relationship between colour sensory scores of consumer’s taste and quantification of three Hunter parameters wherein the variable “\( L \)” and “\( b \)” could be distributed to decrease while variable “\( a \)” contributory increased the colour quality of dried red fleshed dragon fruit products. The zero-order model appeared best suited to explain the colour change kinetics during hot drying red dragon fruit slices at 60\degree C.

Key words: Red dragon fruit colour, drying predictive model.

INTRODUCTION

Red dragon fruit (*Hylocereus polyrhizus*) is one of the most important fruit crops in Vietnam. Red dragon fruit or pitahaya is a cactus species belonging to the genus *Hylocereus* under the *Cactaceae* family (Caryophyllales order) (Wybraniec and Mizrahi, 2002). Drying method in fruit is a solution for fruit preservation and inhibits the growth of bacteria, yeasts, and mold through the removal of water, and for developing new types of products in case of over quantities of red dragon fruit during the season or difficult exporting. Most farmers, however, do not have any knowledge of red fleshed dragon fruit drying which could add more value to the produce having much market alteration to users or consumers (Teow et al., 2007).

Drying is one of the oldest methods of processing and preserving red dragon fruit for later use. Red dragon fruit can be dried under the sun, in an oven, or in a food dehydrator by using the right combination of warm temperature, low humidity and air flow. The common drying method applied for red dragon fruit in Vietnam is sun drying which has so many disadvantages, especially related to food safety. Therefore, more rapid, safe and controllable drying methods are required. The forced convection hot air drying is an effective and rapid method used to produce a uniform, hygienic and attractive colour product. Therefore, a forced convective cabinet dryer has been developed to address such problem (Law et al., 2014).

However, the colour of red fleshed dragon fruit product could be affected by hot temperature during drying. Besides, the chemical composition and the colour also significantly affect the sensory quality of products. Hence, it
is crucial to determine and control the colour and chemical composition of the processed red fleshed dragon fruit. The changes of colour can be related with the degradation of nutritional compounds during processing that have important nutritional properties (Tran and Quang, 2019). Standardized instrumental colour measurements corresponding to visual assessments of food colour are critical objective parameters that can be used as quality index (raw and processed foods) for the determination of conformity of food quality to specification and for analysis of quality changes as a result of food processing, storage and other factors. Several colour scales have been used to describe colour, those most being used in food industry are the Hunter colour L, a, b CIE system and the Munsell colour solid (Choudhury et al., 2014). Maintaining the natural colour in processed and stored foods is a major challenge in food processing. Most studies were concerned with changes in colour due to time and temperature treatments during food processing such as drying and heating.

The drying behaviour of different materials was studied by several authors and a variety of kinetic models have been established such as for pumpkin, sweet potato, carrot, apricot, etc. (Toğrul and Pehliyan, 2003; Doymaz, 2004). However, no significant research on the kinetics model for colour of red fleshed dragon fruit during hot drying as well as relation between colour and sensory evaluation has been reported so far. Therefore, the objectives of the present study is to study the effect of hot drying temperature on colour change kinetics and to find the relationship between colour and sensory quality to predict the quality of red fleshed dragon fruit colour changes with time by drying techniques.

MATERIALS AND METHODS

Materials

The red fleshed dragon fruit samples were collected from Vinh Phuc Province. The fruits were stored at 5 ± 0.5°C in refrigerator. To determine the initial moisture content, 50 g samples were oven-dried at 80°C for 24h. The initial moisture content of red fleshed dragon fruit was calculated as 85% as an average of the results obtained.

Drying treatment was performed in a laboratory convection dryer. The airflow was measured by a portable, 0-15 m/s range digital anemometer and adjusted by means of a variable speed blower. Prior to drying, red fleshed dragon fruit (RDF) were taken out of storage, washed and sliced in thickness of 2 mm. About 150g of RDF slices were uniformly spread in a tray and kept inside the dryer. The hot air drying was applied until the weight of the sample reduced to a level corresponding to 8±1% moisture content. The experiment was operated at temperatures of 40°C, 50°C, 60°C, 70°C and 80°C with fixed air velocity at 1.3 m/s. The drying experiments were replicated three times for each temperature and the average values were computed.

Color measurements

The colour was measured before drying and at pre-specified time interval during drying period by Hunter-Lab ColorFlex, A60-1010-615 model colorimeter. This system uses three values (L, a and b) to describe the precise location of a colour inside a three-dimensional visible colour space. The colorimeter was calibrated against standard white and green plates before each actual colour measurement. For each sample, at least five measurements were performed at different positions and the measured values (mean values) were used. The measurements were displayed in L, a and b values which represent light-dark spectrum with a range from 0 (black) to 100 (white), the green – red spectrum with a range from -60 (green) to + 60 (red) and the blue-yellow spectrum with a range from -60 (blue) to +60 (yellow) dimensions, respectively (Choudhury, 2014).

Total colour difference was calculated using the following equation, where subscript “0” refers to color reading of fresh red fleshed dragon fruit which was used as the reference and a larger ΔE indicates greater colour change from the reference material.

\[
\text{Chroma} = (a^2 + b^2)^{0.5}
\]

\[
\text{Hue Angle} = \tan^{-1}(b/a)
\]

\[
BI = \frac{100(x - 0.31)}{0.17}
\]

Where

\[
x = \frac{(a + 1.75L)}{(5.645L + a - 3.012b)}
\]

Consumer test

A consumer preference test was conducted with 60 consumers to assess the colour quality of five dried red dragon samples. Vietnamese consumers, age between 18 and 45, were recruited from the Hanoi, Vietnam. Consumers indicated their degree of liking of the products on the 7-point horizontal lines with “dislike extremely” on the left end and “like extremely” on the right end of line.
Statistical analysis

Statistical comparisons of the mean values for each experiment were performed by one-way analysis of variance (ANOVA), significance was declared at p ≤ 0.05. Experimental data for the different parameters were fitted to prediction models (zero and first-order model) and processed by using SPSS version 22 software. PLS regression was performed by XLSTAT (version, 2014).

RESULTS AND DISCUSSION

Colour and sensory evaluation of dried orange fleshed sweet potato

The result of consumer preference test on 60 consumers to evaluate dried red fleshed dragon fruit showed that the product dried at 60°C was the most preferable (mean 6.27), followed by the sample dried at 60°C (mean 5.94), 40°C (mean 4.72), 50°C (3.58) and least preferable at 80°C (3.36) (Figure 1). The significant differences observed in the colour evaluation provides a reasonable basis for the evaluation of possible relationship between three values (L, a and b) and colour characteristics and/or colour evaluations.

Based on the Hunter colour parameters analyzed by Hunter-Lab ColorFlex and preference scores of five dried red fleshed dragon fruit products, the PLSR analysis indicated the positive and negative correlations between Hunter colour parameter and specific sensory attributes. The validation coefficients of three colour values which were developed from regression models are shown in Table 1. Both the weight vectors of b values was positively correlated with sensory attributes (colour quality), while the others were negatively or positively correlated.

When considering the calibration sets, a good correlation between three values (L, a and b) and colour quality ranking could be achieved as observed from a high coefficient of determination (R² = 0.921). The error rate of predictability of calibration model could be expressed from a term of root mean square error of estimation (RMSE), which was found at 0.296. The close correlation of the reliable calibration model suggested that the complexity of sensory perception could be related directly to the three values (L, a and b) by means of multivariate analysis. The low RMSE values of this model suggested that three values (L, a and b) obtained from instrumental methods provide sufficient correlation information to the colour quality ranking. Figure 2 shows that the “a” value has significant positive related to dried at 60°C.

Furthermore, compounds with high relevance for explaining dependent Y-variables were also identified from variable importance in the projection values (VIP). Large VIP values, > 0.8, are the most relevant for explaining the colour quality rankings of red fleshed dragon fruit and the compounds with VIP values greater than 0.8 are presented in Table 2. It was found that key values contributing to creating the colour quality predictive model composed of various Hunter colour parameters.

Table 1: Correlation matrix of the variables (correlation matrix of W).

<table>
<thead>
<tr>
<th>Variable</th>
<th>w*1</th>
<th>w*2</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>-0.5168</td>
<td>0.5203</td>
</tr>
<tr>
<td>a</td>
<td>0.6402</td>
<td>0.8732</td>
</tr>
<tr>
<td>b</td>
<td>-0.5768</td>
<td>0.1878</td>
</tr>
</tbody>
</table>

Figure 1: Preference scores and products.
All VIP values were higher than 0.8, therefore a simplified model of favourable products was obtained (Equation 1).

\[ Y = 0.6954a - 0.3780b - 0.2623L \]  
(Equation 1)

Equation of the model of favourable products showed that all three colour values be significantly affect colour quality ranking of dried red fleshed dragon fruit.

**Prediction Models for Colour Changes**

To investigate the effect of hot air on colour change kinetics of red fleshed dragon fruit slices during drying, air temperature of 60°C was used for drying of constant amount of 1.0 kg fresh red fleshed dragon fruit. The values of \( L \), \( a \), and \( b \) obtained from the experimental data during hot air drying and model data are presented in Table 3. The \( L \) value decreased with drying time. The change in brightness of dried samples decreased from 48.01±1.21 to 30.30±0.90 during hot air drying of orange fleshed sweet potato samples at 60°C.

The "\( a \)" values varied from 56.51±0.75 to 32.22±0.49 as the drying time increased. Therefore, the colour of red fleshed dragon fruit sample tended to lose its greenness.
when drying time increased. The b value decreased to the end of drying time from 38.55±1.21 to 6.56±0.103 as the time increased. The change of colour may be due to decomposition of pigment compounds, non-enzymatic Maillard reaction (Rizzi, 2005).

Chroma, hue angle and browning index (BI) were calculated using equations (1)-(3) and the results are shown in Table 3. The values of chroma, hue angle and BI decreased as a function of drying time. The hue angle value corresponds to whether the object is red, orange, yellow, green, blue, or violet. The initial hue angle of red fleshed dragon fruit slices was about 56°C, which represents a colour in red purple region of the colour solid dimensions. Upon heating, the hue angle decreased, shifting towards the more slightly red purple region.

For the mathematical prediction of colour change of red fleshed dragon fruit, zero-order and first-order models were used. It was observed that L, a and b values were fitted to the zero-order prediction model. The estimated prediction parameters of these models and the statistical values of coefficients of determination adjusted R² as well as significant values are represented in Table 4.

**CONCLUSION**

On the basis of the Hunter colour parameters, L, a, and b, a model (coefficient of determination (R²) of 0.921, and root mean square error of estimation of 0.296) was constructed to predict the colour quality of dried red fleshed dragon fruit. The colour change of red fleshed dragon fruit slices using the L, a and b system totally explained the real behavior of red fleshed dragon fruit samples undergoing hot air drying. The final values of L, a, b and total colour change (ΔE) were influenced by hot air drying. The zero-order and first-order models were used to explain the colour change kinetics and it was observed that L, b and a were fitted to zero-order model. The L, a and b decreased when the air temperature was increased. From the results obtained in this study, the L, a and b values profiling by instrument methods in the combination with sensory and multivariate data analysis should be a useful reference for colour quality prediction of red fleshed dragon fruit slices.

**REFERENCES**


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