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Influence of Drying Temperature on the Changes of Colour in Green Banana Flour Following Infrared Radiation Heating

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Abstract

*The visual appearance of flour is one factor that influences consumer choice in several ways, the purpose of this study was to examine the impact of three different drying temperatures (55, 60, and 65°C) on the colour characteristics of green banana flour and the associated process variables. The study involved conducting experiments utilizing a far-infrared power of 3000 watts. The drying process resulted in a reduction of the moisture content to a range of 10 to 12% dry basis. The CIE L*a*b* system was employed to define the colour parameters. These parameters were used to calculate the hue angle (°h), browning index, chroma, and total colour change (△E*). The L* value exhibited a reduction, whilst the a* and b* values demonstrated an increase in response to the rise in temperature. The drying temperature of 65°C resulted in the least noticeable change in colour, followed by 60°C and 55°C. The corresponding drying times were 210, 300, and 330 minutes, respectively. Drying at 65 °C provided the least lightness, resulting in a browner product colour than the other drying temperatures and the highest browning index due to the partial Maillard reaction that may have occurred due to high amounts of starch and protein, including the high temperatures.*

Keywords

Far-infrared, Drying, Banana flours, Colour

INTRODUCTION

Bananas *(Musa spp.)* are a significant fruit grown in the tropics and subtropics that is abundant with vitamins, minerals, polyphenols, carbs, and other nutrients [1]. Unripe bananas possess a considerable amount of resistant starch, dietary fiber, and polyphenols, rendering them a very suitable material for the development of flour that can effectively contribute to the lowering of the glycemic index. The positive effects of unripe or green banana flour on human health have garnered significant interest [2]. The method of preserving bananas is by making green banana flour. The production of banana material involves the utilization of drying-based processing procedures, which serve as a means to preserve the nutritional content and extend the lifespan of the product [3]. The process of making green banana flour involves a variety of components, such as the banana ripening stage and the drying process. The drying conditions employed, particularly the application of heat, play a crucial role in determining the qualitative attributes of the end product, including its color, texture, and microbiological stability throughout the storage period. Traditional drying procedures, such as natural or convective drying, can have drawbacks such as prolonged processing times throughout the period of dropping rates, exposure to high temperatures, excessive energy use, nutritional decomposition, and a decrease in sensory attributes. As a result of ineffective drying, food may deteriorate and experience structural changes [4]. The organoleptic and nutritional characteristics of high-grade dried goods are comparable to those of fresh goods. As a result, they serve as efficient quality control tools that are also safe, economical, and kind to the environment. Colour is an important component of food product appearance because it affects consumer acceptance or functions as an ingredient in food products.

Green banana flour has been carried out by different methods, such as convective air-drying [5], foam-mat drying [6], drying in a spouted bed [7], air-drying oven [8], spray-dried [9], air-oven and freeze drying [3]. Thus far, no research efforts have been conducted to investigate the impact of infrared drying temperatures on the properties of green banana flour. Nowadays, several agricultural items have been effectively dehydrated using far-infrared technology. In the context of infrared radiation drying, the product undergoes direct absorption of energy in the form of electromagnetic waves, leading to energy conservation without any dissipation into the surrounding environment. As a result, drying uniformizes temperature distribution, maintaining acceptable product quality while removing more moisture and using less infrared power [10, 11]. In order to produce dried products with these properties, infrared drying methods are required.

Therefore, this study used a far-infrared dryer to investigate how drying temperature affects the coloration of green banana flour, as well as other process factors such as moisture ratio and drying time. The drying studies were conducted using three different air temperatures: 55, 60, and 65°C. The results could suggest the future development and improvement of banana flour in order to satisfy consumers and expand the potential applications of green banana flour.

MATERIAL AND METHODS

Kluai Namwa were bought from a local market in Talat HaYak, Mahasarakham, Thailand. The banana was utilized during its second stage of ripeness, characterized by a green color with a slight presence of yellow. The fruit specimens were subjected to a drying process at a temperature of 105 °C for a duration of 5 hours in order to determine the initial moisture content of the fruits [12]. The green bananas' fruits underwent a cleaning procedure, followed by the removal of their peels, and subsequently were sliced into pieces with a thickness measuring 3 mm. In order to mitigate the occurrence of enzymatic browning, the slices underwent a 5-minute immersion in a citric acid solution with a concentration of 0.5% (w/v), followed by drainage. Then, the slices were arranged over the filtrate in order to facilitate the evaporation of water from their surfaces. Following, the slices were evenly distributed onto steel grids within a far infrared drier until they reached a final moisture content of 10–12%. Afterward, the bananas were milled and sieved through an 80-mesh sieve. The green banana flour was carefully packed in polyethylene bags and maintained at ambient temperature until further examination. The production process of dried green banana flour is depicted in Figure 1.

Figure 1. The production process of dried green banana flour.

In the Laboratory of Physics program in the Faculty of Science and Technology at Rajabhat Mahasarakham University, an infrared drying system has recently been installed by Hi-den Heattech Co., Ltd. The drying equipment primarily consists of an infrared heating system and a control system. The dimensions of the dryer are 90x60x60 cm, with a stand that is 50 cm in height. Additionally, the dryer is equipped with three infrared heaters that operate at 220 V and have a power output of 1000 W. The heating system comprises a silicon carbide plate that functions by emitting far infrared rays in order to facilitate the heating of the material. The temperature sensor records the signal generated by a thermocouple. In this investigation, the drying temperatures employed were 55, 60, and 65 °C, with K type. The samples were quickly weighed at 30-minute intervals using an electronic digital scale to determine moisture content (MC) until a moisture level of less than 12% dry basis was reached. The estimation of moisture content during the preparation of banana slices was conducted using equation (1) [13]:

$$MC = \frac{W - W_d}{W_d} \tag{1}$$

In this context, MC denotes the moisture content of the samples expressed as a percentage on a dry basis. W refers to the mass of the samples, and W_d indicates the mass of the samples after they have been dried. W and W_d were measured in kilograms.

Moisture ratio (MR) was determined based on experimental drying curves utilizing the following equation (2) [6]:

$$MR = \frac{M_e - M_t}{M_e - M_0} \tag{2}$$

Where MR represents the moisture ratio, M_e represents the equilibrium moisture content (kg/kg, %db) of the samples. M_t is the moisture content of the samples at the designated drying time t (kg/kg, % db), while M_0 is the initial moisture content of the samples (kg/kg, %db).

The colour properties of fresh slice banana (as control) and the green banana flour samples (L*, a*, and b*) were measured at room temperature (26 °C) in triplicate for each of the 9 points on the samples with a Chroma Meter Colorimeter (Hunter Lab, Model MiniScan Ez, Japan). The CIE L*a*b* system is utilized to establish colour parameters, wherein brightness is denoted by L* and ranges from 0 (representing darkness) to 100 (representing whiteness). The colours red and green are associated with positive and negative values of a*, respectively. Yellow and blue are represented by positive and negative b* values, respectively. For each colour, three mean colour values were obtained based on three replicate measurements and three replicates. The total colour difference between fresh and desiccated samples, as measured by ΔE*. As derived from equation (3) [14], it was determined as follows:

$$\Delta E^* = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \tag{3}$$

Chroma levels close to zero were considered to describe muted colour, while it was formerly believed that high chroma levels indicated a more vibrant color. The hue angle (°h) represents the relative amounts of redness and yellowness, with the colour red/magenta being assigned a value of 0°/360°. The colour red is associated with an angle of 0° and 360°, yellow with an angle of 90°, green with an angle of 180°, and blue with an angle of 270°. The calculation of chroma and hue angle was performed using the formula shown follows: [6].

$$Chroma = \sqrt{a^* + b^*} \tag{4}$$

$$Hue\,angle = \tan^{-1}\left(\frac{b^*}{a^*}\right) when\ a \rangle 0\ and\ b \rangle 0 \quad (5)$$

where L_0^*, a_0^* and b_0^* represent the color of a fresh banana piece. The treated sample values are L*, a*, and b*. The water activity (a_w) was measured in triplicate at 25 °C using the Vapor Sorption Analyzer (DECAGON, model Aqualab-VSA, USA). The assessment of the browning index, which measures the degree of brown coloration, is widely acknowledged as a significant determinant of browning. The calculation of the browning index was performed with the subsequent formula, incorporating the L*, a*, and b* variables [3].

$$Browing\ Index(B.I) = \frac{[100(x-0.31)]}{0.17} \quad (6)$$

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

The statistical analysis of variance (ANOVA) was conducted using SPSS software (Ver. 20.0) to assess the impact of varying drying temperatures on quality metrics and color analysis. The study was performed at a confidence level of 95%. The data was presented in the form of the mean and standard deviation of three distinct determinations.

RESULTS AND DISCUSSION

Banana slice drying behavior

The influence of varying drying temperatures on the shift of colour in green banana flour, when applied to far infrared radiation heating, is visually exhibited in Figure 2. They were slightly different in terms of appearance. Figure 3(a) represents the variations in moisture content that occurred as related to the amount of time spent drying at three different temperatures: 55, 60, and 65 °C. The initial moisture content of 298.78 ±1.05% (d.b.) was used to carry out the drying procedure. Increasing temperatures resulted in a decrease in the total time of drying. The drying times were 330, 300, and 210 minutes at 55, 60, and 65 ˚ C, respectively. Our findings are very similar to those for infrared strawberry drying [15]. As the temperature increased during the drying process, the moisture content reduced significantly. Initially, the banana slices quickly lost moisture because there was still a lot of moisture on the surface of the banana. As the drying temperature increased, the dry base moisture ratio decreased, and the reduction rate was greater at higher drying temperatures, as shown in Figure 3(b). These findings provide additional evidence that raising the temperature from 55 °C to 60 °C leads to a reduction in drying time of approximately 9.1%. The drying time observed a reduction of around 30.0% when the temperature was increased from 55 °C to 65 °C and a 36.4% reduction in the overall drying time. As a result, the moisture content dropped more quickly, and the drying rate increased as the drying infrared temperature rose.

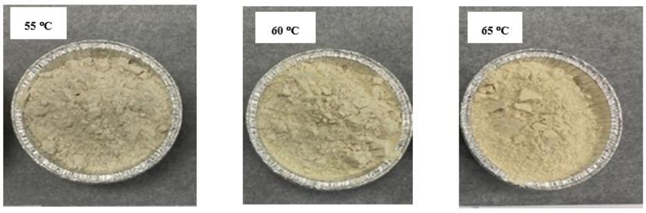

Figure 2. Appearance of green banana flour with different drying temperature.

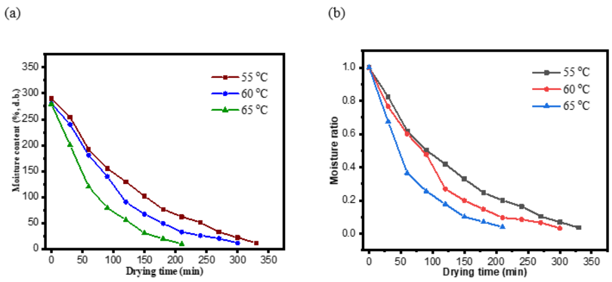

Figure 3. The influence of drying temperature on (a) moisture content and (b) moisture ratio.

Drying Temperature on colour and water activity of green banana flour

Table 1 demonstrates the results of colour evaluates done at different temperatures on fresh and dried green banana slices. The lightness (L*) of all the samples slightly decreased from 82.94±0.69 to 82.44±0.44, while Jirukkakul and Rakshit [16] found L values of Kluai Namwa flour at 90.12 by hot oven, depending on the ripening stages of banana and the method of production. However, the a* and b* values increased from 0.24±0.09 to 0.50±0.28 and 10.24±0.85 to 11.57±0.93, respectively. It was discovered that drying temperature and drying time influence the brightness L* of banana slices. Since colour is measured along the light-dark axis, decreasing values indicate a darker sample, consistent with the browning index shown in Table 2. This result corresponds with Eliseth de Souza Viana [17] and Amir Amini Khoozani [18] findings on green banana four prepared by the convection oven, which showed that increasing the temperature darkened the sample colour. Furthermore, high levels of starch and protein and a high temperature could have caused a partial Maillard reaction [19]. The total colour change parameter had the lowest value of 6.24±0.86 at 65 °C (210 mins) and the highest value of 7.50±0.84 at 55 °C (330 mins). Hence, the total colour change of banana flour was affected by drying temperature and dying time in significant quantities. If considering this factor, it could be concluded that 65 °C is the optimum drying temperature for green banana flour. The intensity of chroma shown in Table 2 increased with the increasing drying temperature, resulting in a darker colour, but there was no statistically significant change observed in the chroma value between the drying temperatures of 55 and 60 °C, whereas this parameter was significantly increased with the drying temperature of 65 °C.

Table 1. The influence of drying temperature on the colour characteristics and moisture content of dried green banana flour.

Drying temperature (°C(	Colour			Total colour change (ΔE*)	Moisture Content (%, d.b.)
	Lightness (L*)	Redness (a*)	Yellowness b*)		
Fresh banana slices	83.40±0.39^{a}	0.32±0.15^{a}	17.70±0.52^{a}	-	298.78±1.05^{a}
55	82.94±0.69^{ab}	0.24±0.09^{a}	10.24±0.85^{b}	7.50±0.84^{a}	11.36±0.09^{b}
60	82.60±0.32^{b}	0.43±0.27^{a}	10.50±0.28^{b}	7.25±0.34^{a}	11.30±0.15^{b}
65	82.44±0.44^{b}	0.50±0.59^{a}	11.57±0.93^{ab}	6.24±0.86^{b}	10.73±0.67^{b}

The values presented in this are expressed as means ± standard deviation. There is no statistically significant difference observed in the lowercase letters ($p < 0.05$).

Table 2. The influence of varying drying temperatures on hue angle, chroma, water activity and browning index.

Drying temperature (°C)	Hue angle)°h(	Chroma	Water Activity (a_w)	Browning index
Fresh banana slices	88.97±0.06^{a}	17.70±0.52^{a}	0.97±0.01^{a}	29.46±0.65^{a}
55	88.63±0.55^{a}	10.25±0.85^{c}	0.27±0.06^{bc}	18.97±1.15^{c}
60	87.64±1.47^{a}	10.51±0.29^{c}	0.33±0.13^{b}	19.54±0.59^{c}
65	87.48±2.61^{a}	11.60±0.96^{b}	0.21±0.02^{c}	21.12±1.83^{b}

The values represent the mean and standard deviation. The difference in lowercase letters is not statistically significant ($p < 0.05$).

The trend of hue angle values decreased marginally from approximately 88.97±0.86 to 87.48±2.61 during drying (see Table 2). This demonstrated that the colour of banana flour changed from slightly yellow before drying to dark brown after drying. Drying at 65 °C gives the product a browner colour than drying at other temperatures, as indicated by the lowest L* and highest browning index. In comparison to various drying temperatures, not statistically significant were the hue angle values ($p<0.05$). The browning index, as shown in Table 2, demonstrates an increase when the drying temperature goes up from 18.97±1.15 to 21.12±1.83. However, it exhibits a decline as the drying duration is extended. The green banana flour exhibited the highest browning index when treated to a drying temperature of 65 °C, which correlated with a* and b* values being increased. That indicates the green flour banana's darker colour. The rise in the browning index value can be ascribed to the degradation of carotenoids and the occurrence of non-enzymatic browning, specifically the Maillard reaction [20]. The water activity of green banana flour at all drying temperatures was not significantly different. Green banana flour had a water activity ranging from 0.21± 0.02 to 0.33±0.13. The reported value of less than 0.6 indicated that all samples were considered suitable for food preservation [21]. Furthermore, the drying technique employed in this investigation was observed to be efficacious in prolonging the shelf life of banana flour.

CONCLUSION

This investigation showed whether drying temperatures of 55, 60, and 65 °C influenced the colour of green banana flour as well as the associated process variables. The experimentation was carried out using a far-infrared power of 3000 watts. Increases in drying temperature led to a significant reduction in drying time and a decline in the moisture ratio. The samples exhibited a slight decrease in lightness as the drying temperature increased, but this parameter was not a significant difference among colour at all drying temperatures. While the redness and yellowness values increased and were not substantially different at higher drying temperatures, the drying temperature possessed less of an influence on the total colour change of green banana flour at 65 °C. The browning index increased as drying temperature increased; the observed result may be ascribed to the processes of carotenoid degradation and non-enzymatic browning. Nevertheless, the water activity of all samples of green banana flour in this study was found to be below 0.6, which is considered adequate for food preservation and extending the shelf life of banana flour.

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