Drying of Unripe Banana (*Musa sapientum Linn.*) Using Microwave Combined with Hot Air

Nattapol Poomsa-ad[1], Lamul Wiset[2]

[1]Drying Technology Research Unit, Faculty of Engineering Mahasarakham University Maha Sarakham, Thailand

[2]Postharvest Technology and Agricultural Machinery Research Unit, Faculty of Engineering Mahasarakham University Maha Sarakham, Thailand

E-mail address: nattapol.p@msu.ac.th[1], lamulwiset@hotmail.com[2]

Abstract.

The objective of this research is to study the effect of microwave power on the quality of dried unripe banana including energy consumption. The microwave power was varied from 0-2,000 watts combined with drying temperature of 50 °C. The sliced of unripe banana with the thickness of 3 mm was used. Sample was dried until the a_w was lower than 0.6. Then, color values in term of L* a* b*, whiteness index and viscosity was determined. Result was found that the trend of L*value was decreased when microwave power increased. In addition, the viscosity was the highest when using the microwave power at 1,000 watts. Moreover, the increase in microwave power resulted in the decrease in energy consumption. When considering in quality and energy consumption, the drying at microwave power of 1,000 watts combined with hot air at 50 °C is recommended for unripe banana drying.

Keywords. dehydration, electromagnetic energy, flour.

1. INTRODUCTION

Unripe or green banana (*Musa spp. L.*) is considered as healthy ingredient with a potential source of bioactive compounds and can be used as a functional immunostimulatory food ingredient [1-2]. It contains high resistant starch which is an excellent probiotic growth promotion [3-4]. Volunteers who consumed unripe banana flour for 6 weeks found that significantly reduced hunger and increase satiety with glucose homeostasis in health. This might reduce risks of certain non- communicable diseases owning to its high resistant starch level [5].

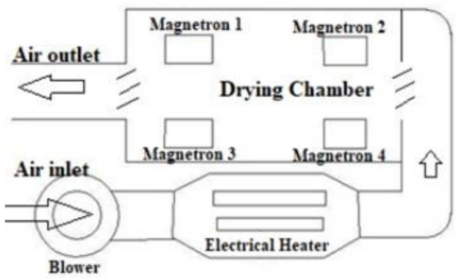
Drying is one of important process of green sliced banana into flour. Nowadays, microwave techniques have been applied to reduce moisture content for fruit and food products. This is due to high drying rate which reduce the drying time as well as energy consumption reduction [6-8]. Apart from considering in energy consumption, quality of product is considered as important variable for consumer and product user in particular texture, appearance, flavor, color and rehydration in some product e.g. mushroom. Products have been dried with microwave assisted hot air drying had acceptable quality [9-12]. Moreover, consumers are interested in bioactive compounds and antioxidant activity. Microwave-hot air drying could maintain these compounds which was better than only hot air drying [13]. Also, there has been reported that phenolic compounds of dried saskatoon berries with microwave vacuum drying was not significantly different with freeze drying [14].

In this work, we are interested in drying unripe banana using microwave assisted hot air. Quality of dried unripe banana and energy consumption of drying are studied to find the suitable microwave power.

2. MATERIAL AND METHOD

2.1. Microwave-hot air dryer

a) The pilot scale microwave assist hot air dryer



b) Schematic of the dryer

Figure 1 Experimental dryer

The pilot scale microwave assist hot air dryer was constructed at Faculty of Engineering, Mahasarakham University, Thailand. A schematic diagram of this dryer is shown in Figure 1. Drying chamber size of this equipment was 80 (L) x 80 (W) x 80 (H) cm and manufactured with stainless steel No. 304. The four of 1000 W magnetrons were used to generate microwave with the frequency of 2,455 MHz. Hot air generator and circulator used 9 kW electric heater and 1.5 kW centrifugal fan with electric motor. Hot air duct was connected to drying chamber with flange and perforated plate was installed for microwave shielding. The circular trays with driving system were mounted to the bottom of the drying chamber. The turning speed was adjusted by using frequency inverter.

2.2. Sample preparation

Banana cv. Namwa was purchased from local market in Maha Sarakham province. Banana with green color and unripe stage was only used in this study. It was boiled for 45 secound before peeling and then soaked in 1% sodium metabisulfite solution for 30 minute to prevent browning reaction. Then, it was sliced using slicing machine to obtain the sample with thickness of 3 mm. The sliced unripe bananas of 500 g were placed on tray as shown in Figure 2.

Figure 2 Tray sample and arrangement

2.3. Drying condition

The microwave power was varied to 0, 500, 1,000, 1,500 and 2,000 watts combined with hot air at drying temperature of 50 °C. Unripe banana was dried until the a_w less than 0.6 to prevent the microbial growth. The drying was conducted for 2 duplications for each treatment. After drying, sample was ground to pass a 45-mesh sieve to obtain homogenous before quality analysis.

2.4. *Quality determination*

Moisture content

Unripe banana was chopped to small piece before determining moisture content. It was used oven method at temperature of 103 °C for 24 hr. Moisture was calculated from the water evaporation divided by the fresh weight

Water Activity (a_w)

Dried sample was measured the a_w using an AquaLab water activity meter (Aqua-Link 3.0, Pullman, WA) which was calibrated with distilled water to obtain aw in the range of 1.000 ± 0.003

Color values

The color of sample was measured by a Hunter Lab Colorimeter (type Color Flex, USA). The Hunter L*, a*, b* scale gave measurement of colors in units of approximate visual uniformity throughout the solid. The L* value measures lightness and varies from 100 for a perfect white and 0 for black, a* and b* when positive measure redness and yellowness, respectively. For whiteness index (WI), it was calculated as following

$$WI= 100-[(100-L)^2 + (a^2 + b^2)]^{1/2}$$

Viscosity

Unripe flour was mixed with water at the ratio between flour (dry weight) and water of 20:500. Mixing sample was controlled the temperature of hot plate at 30 °C with magnetic stirrer for 15 minute. The solution was measured the viscosity using Brookfield Viscometer Model LVDV-E with the probe number 61. The highest torque was recorded as the obtained viscosity.

Energy consumption

Energy consumption from 3 phases was determined using digital electric meter (brand Eastron model sdm 230-8i) with 5% less error. The energy consumption was from different sources i.e. blower, heater, motor and microwave power.

3. RESULTS AND DISCUSSIONS

Table 1 presents the drying time, initial moisture content, final moisture content and a_w of unripe banana drying. You can see that the drying time is decreased when the microwave power increased. This due to the microwave power could accelerate the moisture evaporation from inside to environment. This finding is agreed with the previous report that drying time of using microwave combined with hot air was reduced in particular increasing microwave power [6-8]. The a_w in all treatments was lower than 0.6 which is safe for further process and longer storage.

Table 1 Drying time, moisture content and water activity of unripe banana drying

Microwave power (W)	Drying time (h)	Initial Moisture content (% w.b.)	Final moisture content (% w.b.)	Water Activity a_w
0	6	68.81+0.33	7.99+0.47	0.27+0.02
500	4.5	67.61+0.98	7.49+0.11	0.25+0.03
1000	3	69.19+3.13	6.86+1.40	0.25+0.07
1500	2	67.84+1.08	6.92+0.76	0.22+0.05
2000	1.5	68.36+1.03	7.98+0.40	0.30+0.07

After drying, the product was ground to become homogenous before measuring the color. The color values are shown in Table 2. The significant result is L* value. The L* value represents the brightness, the product from the study is brighter than the product purchased from the market. This might be the drying method was different which caused the different color. However, the increase in microwave power results in the decrease in brightness and increase in redness (a*). This might be the browning reaction occurred when increased microwave power. In overall appearance, the whiteness index is used to assess the color quality. It is found that all treatments show significant higher than commercial product. This could be implied that the drying by microwave combined with hot air drying is good in color assessment. However, by visual evaluation, the picture of product is shown in Figure 3. It is illustrated that all products are similar appearance.

Table 2 The color values and whiteness index of dried unripe banana

Microwave power (W)	L*	a*	b^{*ns}	Whiteness index
Commercial product	84.42 ± 0.37^{d}	2.05 ± 0.01^{a}	10.41 ± 0.06	80.98 ± 0.27^{c}
0	$90.41+0.34^{a}$	$0.11+0.07^{c}$	10.80+0.95	$85.55+0.94^{a}$
500	$90.51+0.12^{a}$	$0.16+0.27^{c}$	10.92+0.70	$85.53+0.61^{a}$
1,000	$88.72+1.79^{bc}$	$0.63+0.51^{b}$	11.89+1.73	$83.59+2.50^{b}$
1,500	$89.74+0.50^{ab}$	$0.13+0.08^{c}$	10.91+0.97	$85.02+1.05^{ab}$
2,000	$88.45+0.63^{c}$	$0.51+0.52^{bc}$	11.30+0.33	$83.85+0.70^{ab}$

ns=non significance different
Means with the different letter within a column are significantly different ($p \leq 0.05$) by DMRT

a) 0 W

b) 500 W

c) 1000 W

d) 1500 W

e) 2000 W

Figure 3 Dried product from different microwave power combined with hot air at 50 ^{o}C

Viscosity is one of an important factor of power to be considered for further use in ingredient mixing with other components to make the product. If the viscosity is still high, it means that the property of flour is still good for using as ingredients. It is implied that the longer drying time and higher heat cause the disruption of internal structure of product. The drying at 1,000 watts had the best viscosity in this study with the drying time only 3 hr. Also, the viscosity is higher than the product from the market.

Table 3 The viscosity of solution prepared from dried unripe banana

Microwave power (W)	Viscosity (cP)
Commercial product	21.31$\pm$0.94^{b}
0	15.29$\pm$1.77^{de}
500	18.90$\pm$3.58^{bc}
1,000	24.59$\pm$2.05^{a}
1,500	17.51$\pm$3.43^{cd}
2,000	14.10$\pm$0.54^{e}

Means with the different letter within a column are significantly different ($p \leq 0.05$) by DMRT

You can see that the total energy consumption is considered from different sources i.e. blower, motor, heater and microwave. The highest energy consumption is from heater. This is the reason why drying without microwave has the highest energy consumption. Therefore, the increase in microwave power results in the less energy consumption. Therefore, to produce the dried product, the producers have to consider in the quality as well as the energy consumption. In this study, when consider in quality and energy use, the drying at 1,000 watts combined with hot air is appropriate

This finding is an alternative process for potential producer. With this method we could control product with good quality. However, the only 500 g sample was used in this research. Therefore, scale up process is necessary for mass production. Considering in energy consumption, we can replace heater by using LPG to reduce the processing cost

Table 4 Energy consumption of drying with different conditions

Microwave power (W)	Drying time (h)	E_{blower} (kWh)	E_{motor} (kWh)	E_{heater} (kWh)	$E_{microwave}$ (kWh)	E_{total} (kWh)
0	6	1.41	0.84	15.33	0.00	17.58
500	4.5	1.05	0.63	11.49	2.25	15.43
1,000	3	0.70	0.42	7.66	3.00	11.79
1,500	2	0.47	0.28	5.11	3.00	8.86
2,000	1.5	0.35	0.21	3.83	3.00	7.39

4. CONCLUSION

The unripe banana was dried under different microwave powers assisted with hot air at drying temperature of 50 °C. It could be concluded as following.

- The drying time was decreased from 6 hr without microwave power to 4.5, 3, 2 and 1.5 hr when used microwave power at 500, 1,000, 1,500 and 2,000 watts, respectively.
- The trend of L* value was decreased when the microwave power increased. While as a* value was increased.
- The drying at 1,000 watts had the highest viscosity.
- The increase in microwave power resulted in the decrease in energy consumption.
- When considering in quality and energy consumption, the drying at microwave power of 1,000 watts combined with hot air 50 °C is recommended for unripe banana drying.

5. ACKNOWLEDGMENT

The authors would like to thank Faculty of Engineering, Mahasarakham University for financial support. Also thanks to Mr. Thanakorn Yothanon for doing experiment

6. REFERENCES

[1] K. Horie, M. S. Hossain, S. Morita, Y. Kim, A. Yamatsu, Y. Watanabe, and M. Kim, “The potency of a novel fermented unripe banana powder as a functional immunostimulatory food ingredient,” J. Funct. Foods, vol. 70, 103980, July 2020.

[2] L. Chang, M. Yang, N. Zhao, F. Xie, P. Zheng, J. Simbo, and S. K. Du, “Structural, physicochemical, antioxidant and in vitro digestibility properties of banana flours from different banana varieties (Musa spp.),” Food Biosci, vol. 47, 101624, June 2022.

[3] L. Chang, M. Yang, N. Zhao, F. Xie, P. Zheng, J. Simbo, and S. K. Du, “Structural, physicochemical, antioxidant and in vitro digestibility properties of banana flours from different banana varieties (Musa spp.),” Food Biosci, vol. 47, 101624, June 2022.

[4] P. Jaiturong, N. Laosirisathian, B. Sirithunyalug, S. Eitssayeam, S. Sirilun, W. Chaiyana, and J. Sirithunyalug, “Physicochemical and prebiotic properties of resistant starch from Musa sapientum Linn., ABB group, cv. Kluai Namwa Luang,” Heliyon, vol. 6(12), e05789, December 2020.

[5] F. A. H. Sarda, E. B. Giuntini, M. L. P. Gomez, M. C. Y. Lui, J. A. Negrini, C. C. Tadini, and E. W. Menezes, “Impact of resistant starch from unripe banana flour on hunger, satiety, and glucose homeostasis in healthy volunteers,” J. Funct. Foods, vol. 24, pp. 63-74, June 2016.

[6] Q. Guo, D. Sun, J. Cheng, and Z. Han, “Microwave processing techniques and their recent applications in the food industry.” Trends Food Sci Technol, vol. 67, pp. 236-247, September 2017.

[7] J. Dehghannya, S. Hosseinlar, and M.K. Heshmati, “Multi-stage continuous and intermittent microwave drying of quince fruit couple with osmotic dehydration and low temperature hot air drying,” Innov Food Sci Emerg Technol, vol. 45, pp. 132-151, February 2018.

[8] Y. Wang, X. Li, X. Chen, B. Li, X. Mao, J. Miao, C. Zhao, L. Huang, and W. Gao, “Effects of hot air and microwave-assisted drying on drying kinetics, physicocheica properties, and energy consumption of chrysanthemum,” Chem. Eng. Process, Vol. 129, pp. 84-94. July 2018.

[9] A. Nawirska-Olszanska, B. Stepien, and A. Biesiada, “Effectiveness of the fountain-Microwavedrying method in some selected pumpkin cultivars,” LWT - Food Sci Techno, vol. 77,pp. 276-281, April 2017.

[10] G. Cuccurullo, L. Giordano, A. Metallo, and L. Cinquanta, “Drying rate control in microwave assisted processing of sliced apples,” Biosyst. Eng, vol. 170, pp. 24-30, June 2018.

[11] Q. Wang, S. Li, X. Han, Y. Ni, D. Zhao, and J. Hao, “Quality evaluation and drying kinetics of shitake mushrooms dried by hot air, infrared and intermittent microwave-assisted drying method,” LWT - Food Sci Techno, vol. 107, pp. 236-242, June 2019.

[12] Y. Jia, I. Khalifa, L. Hu, W. Zhu, J. Li, K. Li, and C. Li, “Influence of three different drying techniques on persimmon chips’ characteristics: A comparison study among hot-air, combined hot-air-microwave, and vacuum-freeze drying techniques,” Food Bioprod. Process, vol. 118, pp. 67-76. November 2019.

[13] E. Horuz, H. Bozkurt, H. Karatas, and M. Maskan, “Effects of hybrid (microwave-convectional) and convectional drying on drying kinetics, total phenolics antioxidant capacity vitamin C, color and rehydration capacity of sour cherries,” Food Chem., vol. 230, pp. 295-305. September 2017.

[14] S. Lachowicz, A. Michalska, K. Lech, J. Majerska, J. Oszmianski, and A. Figiel,“Comparison of the effect of four drying methods on phenols in saskatoo berry,”LWT –Food Sci Techno, vol. 111, pp. 727-736, August 2019.