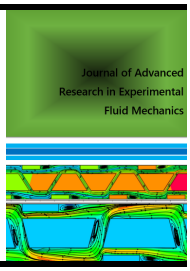
Journal of Advanced Research in Experimental Fluid Mechanics and Heat Transfer

Journal homepage: https://akademiabaru.com/submit/index.php/arefmht/index
ISSN: 2756-8202



Effect of Different Drying Conditions on Vacuum Freezing and Microwave-Combined Drying of Pineapple

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ARTICLE INFO

Keywords:
Vacuum freeze drying, vacuum microwave drying, color parameter, rehydration rate

ABSTRACT

In this study, the vacuum freeze and microwave-combined drying is implemented to measure the effect of the microwave power density, moisture content of different transition points, and temperature control of pineapple. Higher microwave power density speeds up the drying process, but it also increases the risk of overheating the sample. The lower the moisture content of transition point, the better the dry sample quality, but the more energy consumption. Enable temperature control prevents sample from overheating during drying process and have high rehydration rates.

1. Introduction

Vacuum freeze-drying (VFD) is a technology that combines vacuum, freezing and drying, and can be used in the field of food, medicine and chemistry [1-3]. VFD has many advantages, but its main disadvantages are high production cost and long drying time. VFD generally uses heat conduction to transfer heat into material. Because of the excessively large pores left in the drying area in the later stage of drying, the heat conduction efficiency is poor, and removing the remaining moisture takes a long time. As a result, in the later stages of drying, we transitioned to vacuum microwave-drying (VMD), microwaves are used to create a heat source inside the sample, which can save more than a half of the drying time [4]. In this work, pineapple was used as the experimental sample, the effects of different microwave power density, moisture content of different transition points, and temperature control on the drying process of VFD-VMD were discussed.

2. Methodology

In this study, the main factors influencing sample quality on vacuum freezing and microwave-combined drying of pineapple were discussed, including microwave power density, moisture content of transition point, and temperature control. Fig. 1 shows the vacuum microwave drying device.

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Based on performance indicators such as rehydration rate, color and other indicators, the dried samples of the experiment will be subjected to quality analysis. In all experiments, the VFD process refers to the drying process of Wang *et al*. [5].

The first part, after VFD of pineapple to moisture content of 40%, than transfer to VMD process. The influence of different microwave power densities (4, 6, 8W/g), and with or without the temperature control were performed. The second part, the pineapple was VFD to different moisture contents (50, 40, 30, 20 and 10%) and transfer to VMD process with microwave power density of 8 W/g; the effects of different moisture content of transition point were discussed.

In all experiments, the sample is taken out when the residual moisture content of the pineapple reaches 5%, and observe the rehydration rate and color of the sample. Immerse the dry sample in distilled water at 35°C for 5 minutes and measure the weigh it to determine the rehydration rate. Measurement of color use a high-sensitivity color meter to measure and calculate the color of the pineapple before and after drying. The smaller the color difference, the better the quality of the pineapple after drying.

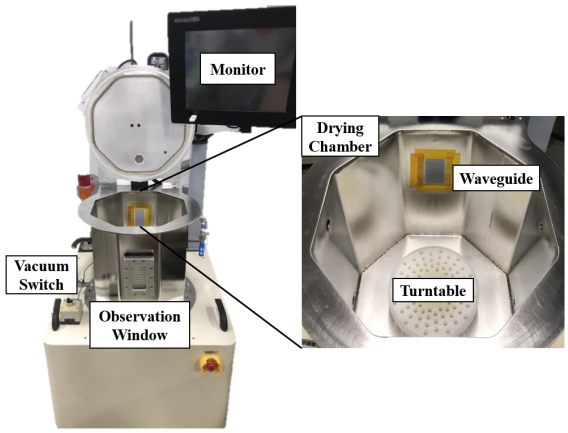

Fig. 1. The device of vacuum microwave drying

3. Result and discussion

3.1 Effect of microwave power density

Figure 2 shows the drying curves of different microwave power densities of 4, 6, and 8 W/g after VFD of pineapple to moisture content of 40%. It can be seen that the microwave power density has a significant effect on the drying rate. The higher of the microwave power density, the drying rate is faster and have the short drying time. However, if the microwave power density is too high, is easy to cause overheating and coking of the material. In order to improve the drying rate and take into account the sample quality of pineapple, the microwave power density should be selected between 4 and 6W/g.

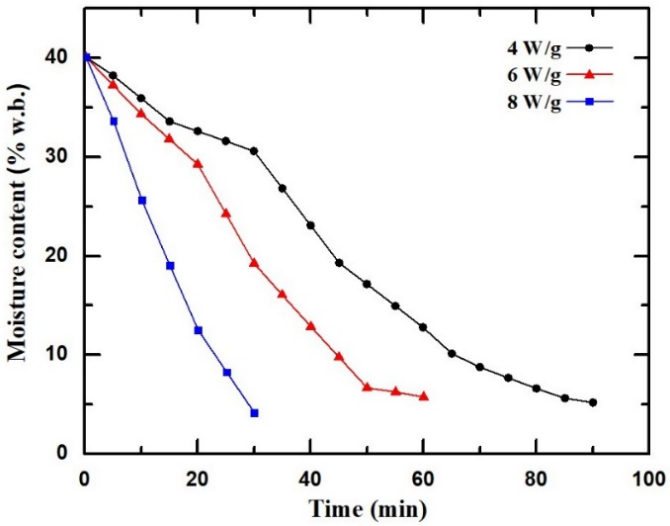

Fig. 2. Drying curves of pineapple with different microwave power densities

3.2 Effect of different moisture content of transition point

Fig. 3 shows the effect of different moisture transition point on the rehydration rate of pineapple. In VFD-VMD process. It was found that when the moisture content at the transition point decreased, the rehydration rate increased, and the rehydration rate is significantly increased after the transition point was lower than 40%. It may be because at high water content, there are still a lot of ice crystals in the material, resulting in a poor follow-up microwave effect. Table 1 shows the effect of different moisture transition points on the color of pineapple. It can be seen that the low moisture content of the transition point, the color of the sample is close to fresh pineapple (the smaller ΔE^*).

Table 1
Color parameters of different moisture content transition points of pineapple

M.C.	**Color parameters**			
-	L^*	a^*	b^*	ΔE^*
FD	69.33	5.02	33.01	6.46
10%	65.07	2.22	32.07	6.51
20%	73.86	4.81	35.28	10.65
30%	64.03	4.89	29.05	12.9
40%	75.82	3.91	22.43	15.37
50%	81.35	5.02	39.5	18.09
Fresh	63.43	5.92	37.17	-

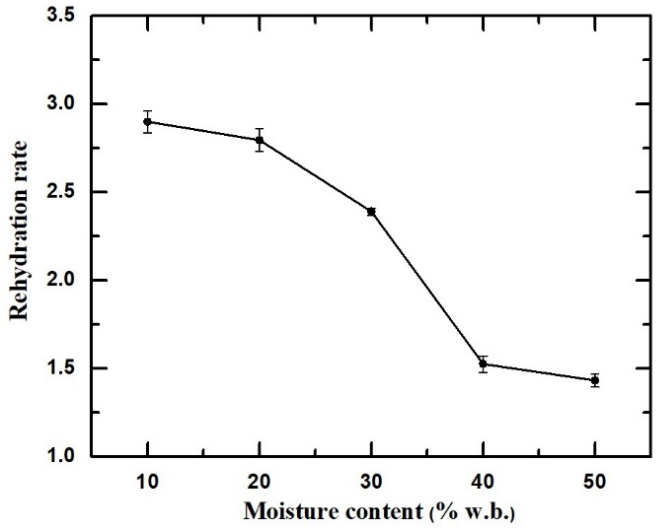

Fig. 3. Rehydration rate of different moisture content transition points of pineapple

3.3 Effect of temperature control

Table 2 shows the effect of the color parameter of pineapples with and without temperature control. The dried pineapples without temperature control at a fixed power density have higher a^* and b^* values, which means the surface of the product is duller; this is due to the large temperature deviation and overheating. While the dried pineapples with temperature control have lower a^* and b^* values, which means that the product surface is brighter.

Table 3 shows the effect with and without temperature control on the rehydration rate of pineapples. The drying group after temperature control was heated evenly, so that all parts of the sample were fully dried, and the rehydration rate was also higher.

Table 2
Influence of color parameters with and without temperature control

No.	**Color parameters**			
-	L^*	a^*	b^*	ΔE^*
No temperature control	63.43	5.92	37.17	-
Temperature control (60°C)	81.35	5.02	39.5	18.09
Fresh	76.62	3.69	34.03	13.74

Table 3
Influence of c rehydration rate with and without temperature control

No.	**Before Rehydration**	**After Rehydration**	**RR**
No temperature control	8.423	11.935	1.471
Temperature control (60°C)	6.169	11.178	1.821

4. Conclusions

In the vacuum freezing and microwave-combined drying experiment of pineapple, the influence of microwave power density, moisture content of different transition points, and temperature control are mentioned. The result is as follows: 1. Microwave power density increase, drying time decrease, every 2W/g increase reduces drying time by about 30 minutes. However, the higher the power density, the more easily overheating and coking occur. 2. The lower moisture content at the transition point that the drying material has high rehydration rate and color close to fresh sample. However, it takes longer drying times and higher energy consumption to reach the transition point of low moisture content. Therefore, under the condition of ensuring the rehydration rate and appearance of the product, the moisture content of the transition point should be selected around 30%. 3. Temperature control improves rehydration rate and prevents overheating, and the color of the sample is more similar to fresh.

Acknowledgements
This study is supported by Ministry of Science and Technology (grant number MOST 110-2221-E-027-056 -MY2) and Research Center of Energy Conservation for New Generation of Residential, Commercial, and Industrial Sectors from Ministry of Education (MOE) in Taiwan.

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