

## Longan drying using microwave-hot air and microwave-vacuum

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### **Abstract:**

Dried longan Thai economic product with an export revenue of 4,026.3 million baht in 2013, is traditionally produced by a hot air drying method, which takes more drying times and deteriorates qualities of the dried product. To improve the qualities of dried longan, alternative drying techniques, i.e. microwave combined with hot air (MHD) and microwave under vacuum pressure (MVD) were proposed in this study. Longans (Dor variety) were dried from the initial moisture content of 360-400% (d.b.) to the intermediate moisture content of 70% (d.b.) with MHD and MVD, and then further dried by only hot air to the final moisture content of 20% (d.b.) Temperature of hot air with velocity of 0.3 m/s and recycled air of 80% was set at 65 °C and vacuum pressure was set at 10 kPa. The effect of microwave power at 100, 125 and 150 W on longan drying kinetics and qualities of dried longan in terms of color as well as drying energy were studied. Comparison to hot air drying, it was found that the MHD and MVD reduced drying time and specific energy consumption as well as produced dried longan with less redness and yellowness but more lightness.

**Keywords:** combined drying; hot air; longan; microwave; vacuum

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## **1. Introduction**

Longan (*Dimocarpus longan* Lour.) is one of exported fruits of Thailand. Among these, dried longan gave an export value of 4,026.3 million baht in 2013 (Office of Agricultural Economics, 2014). Nowadays peeled and unpeeled longan is dried with the hot-air drying that requires long drying time and high energy consumption. Moreover, this method deteriorates qualities of a dried product. The development of dried fruits and vegetables using the microwave techniques have been succeeded in reducing drying time because the water molecules inside dried materials can directly absorb the microwave energy resulted in rapid heating of the material from the inside out (Hu et al., 2006). The combined drying with microwave techniques such as microwave combined with hot air, microwave under vacuum pressure, microwave combined with far-infrared, etc. have been intensively studied.

The microwave combined with hot air has successively been used in several fruits such as longan, apple, kiwi, grape, etc. This is because this technique can reduce drying time and energy consumption and also improve the quality of dried fruits such as color, shrinkage and rehydration as compared to hot air drying (Maskan, 2001). Other drying techniques that improve the quality of dried products is microwave-vacuum drying. Low pressure combined with microwave heating in this technique can lower boiling point temperature of moisture inside a drying product, create high pressure difference between inside and outside of the product and enhance mass transfer rate and shorten drying time as a result.

The objective of this study is, therefore, to investigate combined microwave-hot air, combined microwave-vacuum and hot air drying of longan and to compare the drying kinetics and the quality of dried longan in terms of color as well as drying energy of each drying method.

## **2. Material and methods**

### **2.1 Materials**

Fresh longans (Dor variety) with a diameter of  $25 \pm 1$  mm were purchased from a local market. The peel and seed of the sample were removed with fruit carving knife and then rinsed with tap water.

Afterwards, the samples were wiped with blotting paper. The 360 grams of prepared longan were used in each drying experiment. The remaining prepared longan was determined the initial moisture content by using the hot air oven with hot air temperature of 103°C for 3 h. This method was calibrated with AOAC official method 934.06. The percentage error from two methods is approximately 1.5%.

## 2.2 Experimental set-up

The combined microwave-hot air and hot air dryer consists of a modified domestic microwave oven, blower, heater, globe valve and load cell. The modified oven (LG, MS2427BM, Thailand) has a maximum microwave power output of 800 W. Drying air temperature was heated by 1-kW heater and controlled by PID controller (WLKC, 400, Taiwan) having an accuracy of  $\pm 1^\circ\text{C}$ . The hot air temperature was set at 65°C. The 0.4-kW Blower (LDL, RT2005, Taiwan) was used to blow hot air through the microwave oven with the velocity of 0.3 m/s. The inverter (YASKAWA, CIMR-J7AA40P7, Taiwan) was used to control the air velocity. The microwave-vacuum dryer consists of modified domestic microwave oven, vacuum pump, buffer tank, ball valve and pressure gauge. This dryer used the same model of microwave oven as the microwave-hot air dryer. The 1.5-kW water ring vacuum pump (EMMECOM, AL50M50, Italy) sucked air in the chamber passing the buffer tank to stabilise the chamber pressure. The absolute pressure was set at 10 kPa.

## 2.3 Methods

In case of the microwave-hot air and microwave-vacuum drying, longans (Dor variety) were dried from the initial moisture content to the intermediate moisture content of 70% (d.b.) and then further dried by only hot air to the final moisture content of 20% (d.b.) Temperature of hot air with velocity of 0.3 m/s and recycled air of 80% was set at 65°C and vacuum pressure was set at 10 kPa. In case of hot air drying, longans were dried to the same final moisture content. The combined microwave dryers were operated at three microwave output power of 100, 125 and 150 W which were controlled by intermittent on/off operation of magnetron. The on/off operation of each microwave power was 3.750/26.250, 4.688/25.312 and 5.625/24.375 s, respectively. From the preliminary experiment of microwave-vacuum drying at microwave output of 100 W cannot dry longan to the final moisture content. The temperature of longan was measured by a fiber optic thermometer (OMEGA, FOB 104, Canada) which has precision of  $\pm 0.8^\circ\text{C}$ . The weight of longan was measured by a load cell which has precision of 0.1 gram.

## 2.4 Drying energy efficiency

Drying energy efficiency of dried longan process was indicated in terms of electric and thermal specific energy consumption (SEC). The electric SEC calculated from energy inputs of microwave, vacuum pump and blower, and the thermal SEC calculated from energy input of heater. All energy inputs were measured by watt-hour meters. Each SEC can be determined from Eq. (1) where SEC is specific energy consumption (MJ/kg),  $E$  is energy input to blower or heater or microwave or vacuum pump (kWh) and  $m$  is total mass of evaporated water (kg).

$$\text{SEC} = \frac{E \times 3.6}{m_{\text{water}}} \quad (1)$$

## 2.5 Color measurement

The color of dried longans were measured in terms of  $L^*$ ,  $a^*$  and  $b^*$  using colorimeter (HunterLab, 45/0, USA) where  $L^*$  is lightness/darkness,  $a^*$  is redness/greenness and  $b^*$  is yellowness/blueness. Ten samples were used for measuring color value and each sample was measured three times at different position.

### 3. Results and Discussion

#### 3.1 Drying kinetics of longan

Drying time and temperature are the most important parameters which affect energy consumption and quality of longan. The drying kinetics of longan undergoing MHD, MVD and HA are indicated in Fig. 1. In case of combined microwave drying, the moisture ratio of longan decreased with the increase of microwave power. This is because more microwave energy absorbed by high moisture inside longan at the initial state made the longan temperature increase rapidly. This high temperature accelerated evaporation rate of the moisture inside, as a result increased mass transfer and drying rates. Similar results were found in longan and grape undergoing MHD (Varith et al., 2007; Kassem et al., 2011) and durian undergoing MVD (Bai-Ngew et al., 2011). The higher drying rate of MHD than MVD may be because the convective heat transfer at the surface of drying longan in MHD had more effect to mass transfer rate than the pressure difference in MVD.

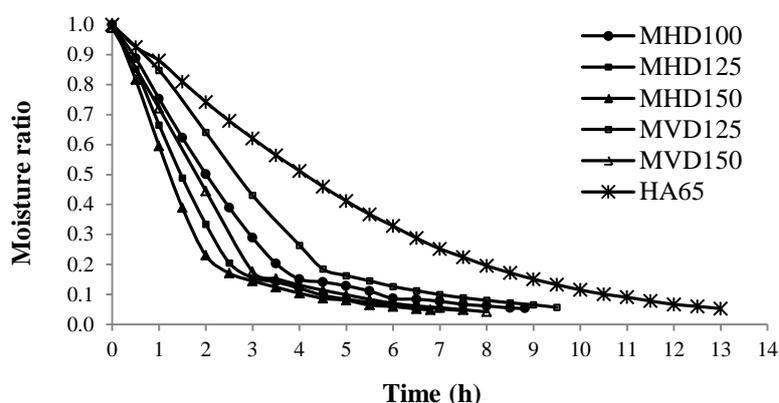


Fig. 1 Moisture ratio of longans dried by MHD, MVD and HA.

#### 3.2 Color

The color dried longans were measured in term of  $L^*$ ,  $a^*$  and  $b^*$  indicated in Table 1. It was found that the MHD and MVD gave dried longan with low redness ( $a^*$ ) and yellowness ( $b^*$ ) but more lightness ( $L^*$ ) than the hot air drying. This is due to long exposure to heat of longan in the hot air drying. MVD at higher microwave power produced lighter dried longan than MVD at low microwave power, MHD and hot air drying respectively. This result may be caused by short drying time at high microwave power and less oxygen level in MVD drying. However, an hour and a half difference of drying time in MVD drying between high and low microwave power together with low drying product temperature was not enough to make redness and yellowness of both cases significantly different. In contrary, dried longan from MHD at high microwave power had more redness and yellowness but similar lightness than that at low microwave power. Higher temperature of dried longan at MHD with high microwave power was the reason for this result. Combined effect of product temperature and drying time in MVD and MHD at the same microwave power caused the redness and yellowness of dried longan from both techniques not significantly different.

Table 1 Color of dried longan

Drying method	$L^*$	$a^*$	$b^*$
MHD100	38.99±1.22 <sup>b</sup>	3.02±0.84 <sup>a</sup>	20.14±1.54 <sup>a</sup>
MHD125	39.08±1.95 <sup>b</sup>	3.51±1.43 <sup>ab</sup>	20.71±2.20 <sup>ab</sup>
MHD150	38.49±2.10 <sup>b</sup>	4.46±1.47 <sup>c</sup>	21.74±1.79 <sup>cd</sup>
MVD125	40.70±2.65 <sup>c</sup>	3.27±1.04 <sup>ab</sup>	20.58±2.07 <sup>ab</sup>
MVD150	42.81±2.16 <sup>d</sup>	3.85±1.25 <sup>bc</sup>	21.50±1.70 <sup>bc</sup>
HA65	36.47±2.12 <sup>a</sup>	6.73±1.21 <sup>d</sup>	22.57±1.94 <sup>d</sup>

The different superscripts in same column of table indicate significantly different ( $p < 0.05$ ).

### 3.3 Specific energy consumption

Specific energy consumption (SEC) which was indicated in table 2 could explain energy efficiency of longan drying processes. It was found that the higher microwave power can decrease the electrical and thermal SEC due to short drying time at high microwave power. The MHD and MVD were less thermal SEC as compare to the hot air drying. However, The MVD was highest electrical SEC because the MVD had more electric devices. Moreover, the MHD and MVD had lower total SEC as compare to the hot air drying. These results agreed with other studies, i.e. longan and grape undergoing the MHD (Varith et al., 2007; Kassem et al., 2011).

**Table 2** Specific energy consumption of different drying method

Drying method	Drying time (h)	Evaporated water (kg)	SEC (MJ/kg water evaporate)		
			Electrical Energy	Thermal Energy	Total Energy
MHD100	8.80	0.2743	21.46	50.66	72.12
MHD125	7.50	0.2777	18.86	40.06	58.92
MHD150	6.80	0.2789	17.33	34.33	51.67
MVD125	9.50	0.2649	28.76	27.18	55.94
MVD150	8.00	0.2660	24.45	25.17	49.62
HA65	13.00	0.2756	22.30	65.83	88.13

### 4. Conclusion

Combined microwave drying with hot air drying (MHD) and under vacuum pressure (MVD) showed higher drying rate and lower specific energy consumption as compared to the hot air drying. High microwave power consumed less energy than the low one and the MVD consumed less energy than the MHD. Microwave also made the color of dried product lower redness and yellowness but more lightness than that undergoing the hot air drying. High microwave power increased redness and yellowness in MHD and increased lightness in MVD. The redness and yellowness of dried longan from MVD and MHD at the same microwave power were not significantly different.

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