

DRYING KINETICS AND QUALITY OF DRIED LONGAN USING MICROWAVE-VACUUM TECHNIQUE

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ABSTRACT

Dried longan, Thai economic product with an export revenue of 4,026.3 million bahts in 2013, is traditionally produced by a hot air drying (HA), which takes more drying times and deteriorates qualities of the dried product. To improve the qualities of dried longan, alternative drying technique, i.e. microwave under vacuum pressure (MVD) was 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 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 65oC and vacuum pressure was set at 10 kPa. The effect of microwave power at 125 and 150 W on longan drying kinetics and qualities of dried longan in terms of color, texture, microstructure and shrinkage were studied. It was found that the MVD reduced drying time as compared to hot air drying. In terms of qualities of dried longan, the MVD can decrease redness and yellowness but increase lightness. Moreover, this technique can also reduce shrinkage, hardness, and toughness of dried longan because of large pore size resulted from microwave power.

Keywords: Combined drying; Hot air drying; Longan; Microwave drying; Vacuum

INTRODUCTION

Longan (*Dimocarpus longan* Lour.) is one of exported fruits of Thailand. In form of dried longan gave an export values of 4,026.3 million bahts in 2013. [1] 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 dried products. [2, 3]

The development of dried fruits and vegetables using the microwave techniques have been succeeded in reduced drying time because the water molecules inside dried materials can directly absorb the microwave energy resulted in rapid heating of the materials from the inside out.[4] The com-bined drying with microwave techniques such as microwave combined with hot air [3,5-7], microwave under vacuum pressure [8-11], microwave combined with Far-infrared [12], etc. have been intensively studied.

The combined microwave techniques have successively been used in several fruits such as longan, apple, kiwi, grape and etc. [3, 5-7]. This is because this technique can reduce

drying time and energy consumption and also improve the quality of dried fruits [5, 13] One drying technique that improve the qualities 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 which enhances mass transfer rate and shorten drying time as a result. The high-pressure difference also creates uniform porous structure in the dried product. [10, 14] Drying under low pressure can preserve the natural color of the product due to less oxygen inside the drying chamber and provide better qualities in terms of shrinkage and rehydration compared to hot air drying. [14, 15]

The objective of this study was, therefore, to investigate 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, texture, shrinkage, and microstructure of each drying method.

MATERIALS AND METHODS

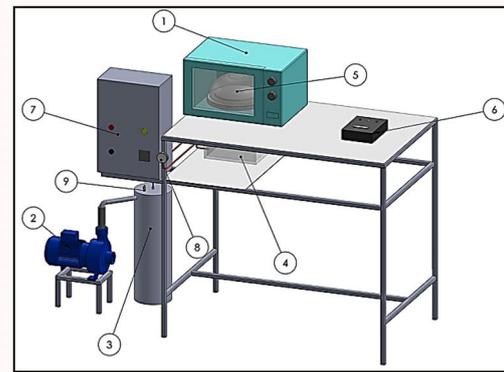
Materials

Fresh Longans (Dor variety) with a diameter of 25 ± 1 mm were purchased from a local market. They were peeled and seeds were removed with a *fruit carving knife* and then rinsed with tap water. Afterwards, the samples were wiped with blotting paper. The 360 grams of the prepared longan were used in each drying experiment. The initial moisture content of the samples was measured by the hot air oven method with hot air temperature of 103°C for 3 h. [16] This method was calibrated with AOAC official method 934.06. [17] The percentage error between the two methods is approximately 1.5%.

Experimental set-up

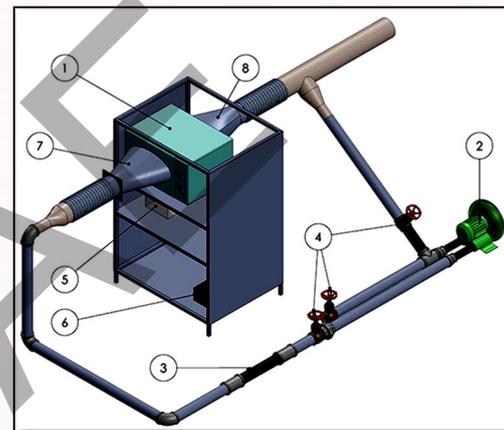
The microwave-vacuum dryer (Fig.1) consisted of modified domestic microwave oven, vacuum pump, buffer tank, ball valve and pressure gauge. The modified oven (LG, MS2427BM, Thailand) had a maximum microwave power output of 800 W and microwave frequency of 2,450 MHz. The 1.5-kW water ring vacuum pump (EMME-COM, AL50M50, Italy) sucked air in the chamber passing the buffer tank to stabilise the chamber pressure. The absolute pressure was set at 10 kPa.

The hot air dryer was shown in Fig. 2. This dryer consisted of blower, heater, globe valve and load cell. The front and back of drying chamber was connected to hot air duct. 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 drying chamber with the velocity of 0.3 m/s. The inverter YASKAWA, CIMR-J7AA40P7, Taiwan was used to control the air velocity. The globe valve was used to adjust the percentage of recycled air which set at 80%.



1-Microwave oven 2-Vacuum pump 3-Buffer tank 4-Load cell 5-vacuum chamber 6- Microwave controller 7-Vacuum controller 8-pressure gauge 9-ball valve

Fig.1 A schematic diagram of microwave-vacuum dryer



1-Drying chamber 2-Blower 3-Heater 4-Globe valve 5-loadcell 6-Weighing Indicator 7-Inlet air temperature 8-Outlet air temperature

Fig.2 A schematic diagram of microwave-hot air dryer

Methods

In case of 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 dryer was operated at two microwave outputs of 125 and 150 W which were controlled by intermittent on/off operation of magnetron. The on/off times of 125 and 150 W were 4.688/-25.312 and 5.625/24.375 seconds, respectively. The temperature of hot air was measured by k-type thermocouples connected to a data logger

(SUPCON, R3000, China), and the temperature of longan was measured by a fiber optic thermometer (OMEGA, FOB 104, Canada) which had precision of $\pm 0.80^{\circ}\text{C}$. The weight of longan was measured by a load cell (TEDEA HUNTLEIGH, 1022, China) connected to a weighing indicator (A&D, AD-4329, Korea) which had precision of 0.1 gram.

Color measurement

The color dried longans were measured in term of L^* , a^* and b^* using colorimeter (HunterLab Reston, ColorFlex, VA, USA) which was calibrated with a standard plate ($L^*=93.19$, $a^*=-1.12$, $b^*=1.33$) where L^* is lightness/darkness, a^* is redness/greenness and b^* is yellowness/blueness. Ten samples from each experiment were used for measuring color value and each sample was measured three times at different position. The mean color values from the experiments were compared by an analysis of variance (ANOVA) and Duncan's multiple-rang test using SPSS® software (Version 13) and were considered significantly different at a confidence level of 95% ($p < 0.05$).

Texture

Texture analyzer (Stable Micro System, TA.XT.Plus, UK) was used to determine the hardness and toughness of dried longans. The dried samples were cut vertically in half, placed on the hollow plate and compressed by a 2 mm cylindrical probe that moved at a test speed of 30 mm/s. The maximum compression force was indicated as hardness, while the toughness was determined by the area under the graph between forced and deformation until the maximum force.

Shrinkage

The volume of fresh and dried longan was determined by the volumetric displacement method using n-heptane that had a density of 0.684 g/cm^3 . A sample of each method was measured quickly to avoid water uptake into a sample. The shrinkage was indicated as percentage of shrinkage that was calculated using

$$\% \text{Shrinkage} = (V_0 - V / V_0) \times 100 \quad \dots (1)$$

Where V_0 is the volume of fresh longan before drying and V is the volume of dried longan after drying.

Microstructure

The scanning electron microscope (SEM) (JEOL, JSM-5600LV, Japan) was used to analyze the microstructure of dried longan after drying. A cut sample of about $5 \times 3 \times 2 \text{ mm}$ was coated with gold and fixed on the SEM stub. Afterwards, a cross-section of the dried longan was viewed at an accelerating voltage of 10 kV and a magnification of 15 times.

RESULTS AND DISCUSSION

Drying kinetics of longan

Drying time and temperature were the most important parameters which affect quality of longan. The drying kinetics of longan undergoing MVD and HA were indicated in Fig 3. In case of MVD, 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. (See Fig. 4) This high temperature accelerated evaporation rate of the moisture inside, as a result increased mass transfer and drying rates. In addition, the lower pressure in case of MVD can increase the driving force for mass transfer and decrease the boiling point temperature, thus the moisture was evaporated rapidly. Similar results were found in durian and mushroom undergoing MVD. [8, 10]

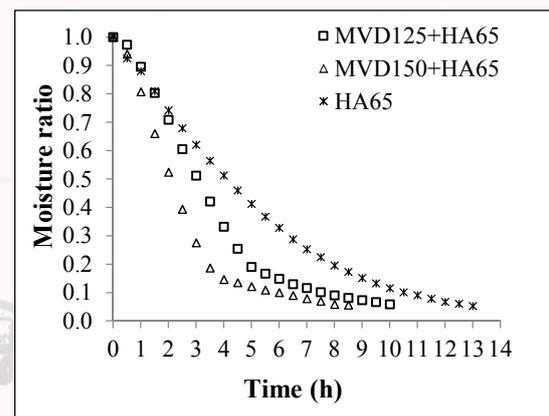


Fig.3 Moisture ratio of longans dried by MVD and HA

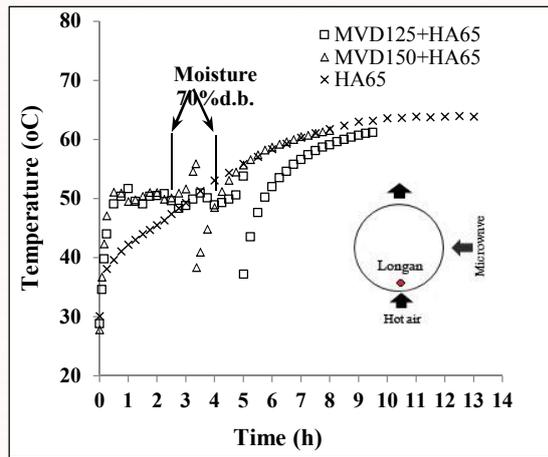


Fig. 4 Longan temperature changes during drying with MHD, MVD and HA

Color

The color dried longans were measured in term of L*, a* and b* indicated in table 1. It was found that the 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. In addition, this result may be caused by low boiling point temperature and less oxygen in MVD drying. Moreover, an hour and a half difference of drying time in MVD drying between high and low microwave power was not enough to make redness, yellowness and lightness of both cases significantly different.

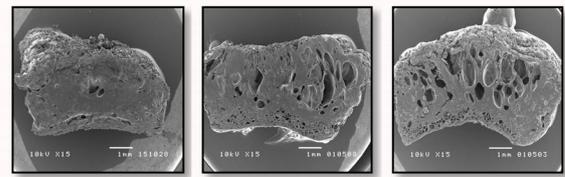
Table 1 Color of dried longan

Drying method	L*	a*	b*
MVD125+HA65	40.33±1.47b	3.26±0.95a	21.27±2.04a
MVD150+HA65	41.14±2.49b	3.40±1.11a	22.32±2.30ab
HA65	36.47±2.12a	6.73±1.21b	22.57±1.94b

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

Microstructure

The effect of the drying methods on the microstructure of dried longan under SEM at a magnification of 15 times was shown in Fig. 5. The figures show that the dried longan undergoing the MVD had more a porous structure than the hot air drying. This is because the low pressure and rapid increase in longan temperature in MVD at the initial state accelerated moisture evaporation rate inside the longan. This phenomenon develops high vapor pressure inside the drying product, which creates the porous structure. [8, 18]



HA65 MVD125+HA65 MVD150+HA65
 Fig. 5 Scanning electron microscope of cross section of dried longan at magnification of 15 times.

Texture

The hardness and toughness were used to evaluate the quality of dried longan, as shown in Table 3. It can be seen that the MVD gave a dried longan with low hardness and toughness as compared to hot air drying. This is due to the fact that the dried longan undergoing MVD had a more porous structure and a large pore size indicated in the microstructure results. On the contrary, a compact structure of dried longan with low porosity in case of HA resulted in the more hardness and toughness. [19] Moreover, difference of microwave power was not enough to make hardness and toughness of both cases significantly different.

Table 2 Hardness and toughness of dried longan.

Drying method	Hardness (N)	Toughness (N.mm)
MVD 125+HA65	7.98±0.82a	20.19±3.40a
MVD 150+HA65	7.63±0.70a	19.01±2.61a
HA65	9.76±1.56b	24.89±5.43b

a and b in the same column with different superscripts mean that the data were significantly different (p<0.05)

Shrinkage

The percentage shrinkage of dry longan undergoing MVD and HA is shown in Table 3. It was found that the MVD gave dried longan with low shrinkage as compared to HA. This is due to the fact that the dried longan undergoing MVD had a porous structure (as shown in Fig. 5). Increasing the microwave power in case of MVD, the percentage shrinkage of dried longan was not significantly different.

Table 3 Percentage shrinkage of dried longan.

Drying Method	Shrinkage (%)
MVD 125+HA65	75.79±2.38a
MVD 150+HA65	73.86±2.78a
HA65	80.60±0.96b

a and b in the same column with different superscripts mean that the data were significantly different (p<0.05)

CONCLUSIONS

Combined microwave drying with vacuum pressure (MVD) showed higher drying rate as

compared to the hot air drying. This method also made the color of dried product lower redness and yellowness but more lightness as compared to the hot air drying. Moreover, this technique can also reduce shrinkage, hardness, and toughness of dried longan because of large pore size developed by microwave power. The quality of dried longan from MVD at the different microwave power were not significantly different.

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