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# Drying of rice paddy using a microwave-vacuum dryer

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## Abstract

Drying of paddy is one of the important processes for the rice millers to produce good quality rice. A conventional drying process is done using hot air which results in time consuming and energy loss. In the present work, Pathumthani paddy was dried using a microwave-vacuum dryer. The drying experiments were carried out by varying two parameters affecting the drying performance including the microwave power and the pulsation period. The microwave incident powers varied from 170 to 500 watts while the pulsation periods varied from 30 to 120 seconds. Moisture contents in the rice paddy were observed for different drying conditions. The properties of milled rice before and after cooking were determined including percents of head rice, brokens, elongation, and gelatinization temperature. The results showed that the removal rate of moisture in paddy decreased as the microwave power increased. The higher microwave power resulted in an increased percent of brokens.

Keywords: paddy, microwave-vacuum drying, head rice, brokens, elongation

## 1. Introduction

Rice is one of important crops of the world. Thailand is one of the biggest worldwide rice exporters with about 7 million tons of milled rice in 2006 (FAO2006). After harvesting, the moisture content of rice paddy is as high as 19%-26 % (wet basis) and even higher during the rainy season. Rice paddy is usually dried to reduce moisture content to 14% or lower for a safe storage before a milling process. However, if the moisture content in paddy is too low, the grains are so fragile when being milled. This can lead to higher fraction of broken kernels. Keeping the rice paddy at acceptable moisture content can prolong storage time and prevent mould growth.

Farmers usually expose rice paddy to the sun rise to reduce the moisture content within the grains. This process totally depends on the weather conditions and can not be done during the rainy season. Most rice millers use a conventional process of hot-air drying which consumes time and energy. The conventional hot-air drying has many disadvantages including the tremendous energy consumption and low drying efficiency. It also diminishes the quality of dried products. To overcome these problems, fluidised and spouted bed dryers were developed to dry rice paddy with higher temperature and shorter residence time to prevent heat damage (Wiset et al. 2001). However, fluidized bed dryer is efficient when the moisture content in the grains is above 18%.

Besides fluidised and spouted bed drying, microwave-vacuum drying additionally offers an appreciable approach to overcome drawbacks of the conventional drying. It combines the advantages of vacuum drying and microwave application. Creating a vacuum in the dryer results in a lower boiling point. This allows water to vaporize at low temperature. Lower drying temperature leads to prevention of a heat damage and nutritional losses. Low-temperature vaporization also leads to lower rate of oxidation resulting in an improvement of colors and flavours of dried products. An application of microwave for drying can cause the heat generation within products. The heat generation inside products can increase the rate of water removal (Yongsawasdigul and Gunasekaran, 1996). When vacuum drying and microwave application are combined, major advantages of both techniques are presented including a prevention of product damage due to an excessive heating, time and energy saving. Gunasekaran (1990) proposed the pulsation microwave energy to maximize drying efficiency. This technique was used for many applications such as fruit and grain dryings.

Though previous studies had been conducted to improve the drying efficiency and the effects of milling on the properties of paddy (Marshall 1992; Mohapatra and Bal, 2006; Thakur and Gupta 2006, Shu et al. 2006), the applications of microwave-vacuum drying for moisture removal in paddy have yet been studied. Therefore, this introductory study was conducted to investigate the following objectives:

(1) To study the feasibility of microwave-vacuum drying to reduce the moisture content of paddy to an accepted value.
(2) To evaluate the effect of pulsation periods and microwave powers on the moisture removal for paddy.
(3) To investigate the effects of microwave-vacuum drying on some characteristics including percents of head rice, brokens, elongation, volume expansion, and water absorption.

## 2. Materials and methods

Pathumthani fragrant rice was chosen for this study. Paddy was procured and harvested from Angthong Province, Thailand. After harvested, paddy was sun dried to about 18% (wet basis) moisture content before being kept in the laboratory storage at 20 ºC.

A laboratory-scale microwave vacuum dryer (Daewoo Model KOR-8667) was set up with a vacuum pump (Edwards High Vacuum International Model RV8). Four levels of microwave powers include 170, 245, 400, and 560 W. The measurement of the power output was conducted by the standard procedure described by Schiffmann (1987) and Cui et al. (2004). The vacuum pressure was fixed at 40 kPa. For a pulsed mode, the magnetron was alternately turned on and off corresponding to specified pulsation periods. Moisture contents were measured by Kett Grain Moisture Tester M401. The experiments were done in duplicate and the average data were used for the analysis.

Paddy was dehulled with Satake bench dehusker and milled with a Satake bench mill. Milled rice was separated by an indent cylinder-type grader. Brokens refers broken rice kernels with lengths are at least 2.5 parts of a whole kernel but less than those of whole kernels. The head rice yield and the amount of brokens were obtained by calculation.

Cooking qualities including elongation, volume expansion, and water absorption ratios were determined according to equations (1)-(3), respectively. Experimental details of procedures can be found elsewhere (Cheepsathit and Pattala, 2005).

$$\text{Elongation ratio} = \frac{\text{average length of cooked rice}}{\text{average length of milled rice}} \tag{1}$$

$$\text{Volume expansion ratio} = \frac{\text{average height of cooked rice}}{\text{average height of milled rice}} \tag{2}$$

$$\text{Water absorption ratio} = \frac{\text{average weight of cooked rice}}{\text{average weight of milled rice}} \tag{3}$$

Gelatinization temperature measurements were conducted using alkaline disintegration method (Little et al., 1958). Ten milled rice grains were placed in petri dish and then treated with 1.7% NaOH solution. The samples were kept at 30ºC for 23 hours. The alkali spreading value (ASV) was then measured on a 2-7 scale.

## 3. Results and Discussion

In this work, the application of pulsed mode of microwave-vacuum drying was used to observe drying behavior of paddy. The effects of microwave powers and pulsation periods at various time steps on moisture contents were investigated. The experiments were conducted until the final moisture content reached 14% or did not change over three consecutive time steps. The moisture contents of paddy at the power-on time of 30 seconds and power-off time of 60 seconds, a pulsation period of 30/60, at different microwave powers were shown in Figure 1.

The results showed that the moisture contents decreased with time. Drying is faster in operating at higher microwave power. The same trends were observed the experiments with the power-on time of 30 seconds and power-off time of 120 seconds, a pulsation period of 30/120, as shown in Figure 2. This is due to the fact that the higher power leads to more energy absorption in paddy grains. A previous study (Cheepsathit and Pattala, 2005) showed that the product temperature of a pulsation period of 30/60 is higher than that of 30/120. Higher temperature leads to higher temperature gradients which allow water to accelerate during power-on time. High temperature also results in an increased diffusion of water during power-off time. Longer off times result in a temperature decrease which is due to evaporative cooling and heat losses from convection and radiation from paddy. Thus the energy was consumed efficiently. The results from a present work were similar to the previous study (Yongsawasdigul and Gunasekaran, 1996).

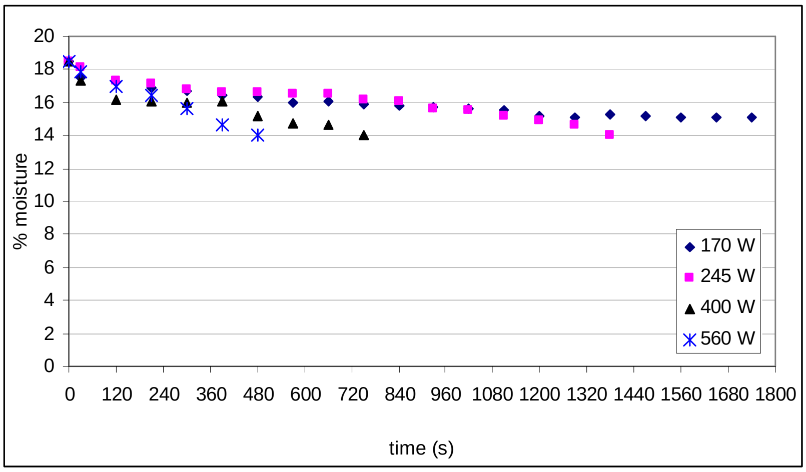


**Figure 1** Effects of microwave incident powers with a pulsation period of 30/60

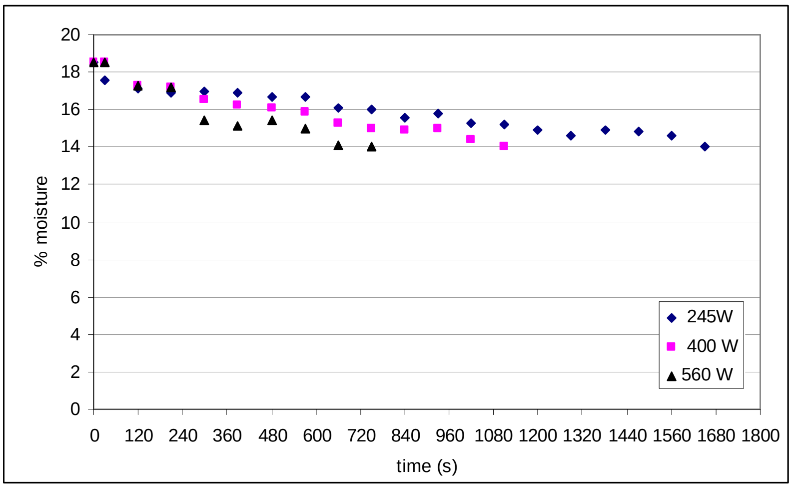


**Figure 2** Effects of microwave incident powers with a pulsation period of 30/120

The effects of power-off times on the moisture change were done by comparing Figures 1 and 2 for the same power of 245 W. The results showed that the moisture content for a pulsation of 30/60 decreased faster than that of a pulsation of 30/120. The results agreed with the previous study (Cheepsathit and Pattala, 2005) which showed that the shorter power-on time and longer power-off time lead to less energy input. This condition allows water to redistribute with in paddy grains. Diffusion of water during power-off time can accelerate water removal.

The effects of microwave power and pulsation period on milled rice were shown in Table 1. The experimental data indicate that both microwave power and pulsation period affect head rice yield and broken fractions. For the pulsation period of 30/60, higher microwave powers resulted in lower head rice yield and higher broken fraction. These results were due to the higher energy absorption of the paddy grains which leads to a sharp increase in grain temperature. Though a rapid increase of temperature results in the higher rate of water removal, it causes an increase in brittleness of milled rice. The results are similar to previous studies conducted on a fluidized bed dryer (Soponronarit et al.,1996; Taweerattanpanich et al., 1999) The microwave powers show an insignificant effect on head rice yield and broken fractions for a pulsation period of 30/120. The head rice yield from this work is lower than a previous study because the final moisture is lower (Wiset et al., 2001). Excessively low moisture content may possibly cause high fraction of broken kernels.

**Table 1** Effects of microwave power and pulsation period on milled rice.

| **Pulsation Period** | 30/60 s/s | | | | 30/120 s/s | |
|---|---|---|---|---|---|---|
| **Microwave Power** | 170W | 245W | 400W | 560W | 245W | 400W |
| **Sample** | **Weight (g)** | | | | | |
| Rice paddy | 300.0 | 300.0 | 300.0 | 300.0 | 292.5 | 300.0 |
| Milled rice | 196.6 | 192.5 | 192.5 | 193.8 | 184.5 | 194.0 |
| Head rice | 127.9 | 124.5 | 100.0 | 46.2 | 109.0 | 113.0 |
| Rice Broken | 69.3 | 68.0 | 92.5 | 147.6 | 75.5 | 81.0 |
| Head rice/rice Broken | 1.8 | 1.8 | 1.1 | 0.3 | 1.4 | 1.4 |
| % Broken | 35.1 | 35.3 | 48.1 | 76.2 | 40.9 | 41.8 |

Experimental data for elongation, volume expansion, and water absorption were presented in Table 2. The results showed that microwave-vacuum drying technique showed an insignificant difference in before- and after-cooking elongation ratio. Microwave power did not show a significant effect on elongation, volume expansion, and water absorption. Higher elongation and volume expansion ratios were due to larger amount of water absorbed after cooking.

Gelatinization temperature is the temperature at which the rice absorbs water and then starch granules swell irreversibly. It also indicates a milled rice quality. The ASV of milled rice using microwave-vacuum drying technique with a power of 175 W, a pulsation period of 30/60 s/s was 6.50±0.41 while that rice dried with the conventional process was 6.4±0.45. The results showed that a drying process showed insignificant effect on gelatinization temperature. This experiment also showed that Pathumthani rice has low gelatinization temperature below 70 ºC. The results are consistent with a previous study which showed that most tropical *indica* varieties have intermediate or low gelatinization temperature (Shu et al., 2006). Such low gelatinization temperature implies that the rice is not soft and can not disintegrate when overcooked. It also requires less cooking and water than rice with higher gelatinization temperature. The powers showed insignificant effect on gelatinization temperature.

**Table 2** Experimental data for elongation, volume expansion, and water absorption

| Drying Methods | After Cooking : Before Cooking Ratio | | |
|---|---|---|---|
| | Elongation | Volume expansion | Water absorption |
| Conventional | 1.64 | 2.19 | 2.45 |
| 175 W (30/60) | 1.64 | 2.03 | 2.38 |
| 400 W (30/120) | 1.64 | 2.03 | 2.41 |

## 4. Conclusion

Microwave-vacuum drying offers a feasible alternative for drying paddy. As shown in this study, the rate of drying varies with microwave powers since the higher power leads to higher energy absorption. The study of the effect of the pulsation showed that the moisture content for a pulsation of 30/60 decreased faster than that of 60/120. The results also showed that elongation of cooked rice for both drying processes was not different while volume expansion and water absorption for a microwave-vacuum drying were lower than that of conventional process.

## 5. Acknowledgement

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