KEYWORDS

Intermittent microwave
Seed drying
Wheat
MOTP (microwave on time percentage)

ABSTRACT

The purpose of present study was to characterize the intermittent microwave drying of wheat seeds. Results revealed that microwave on time percentage (MOTP) and initial moisture content were the main parameters which influenced the intermittent microwave drying rate and the germination capacity of dried seeds. Best intermittent microwave drying (power: 800 W; seed sample weight: 100 g, microwave on time in each cycle: 32 s) without significantly decreasing the germination rate was obtained at initial moisture content ≤ 20.3% along with 20% MOTP. While, if initial moisture content of seeds was ≤ 16.7%, the seeds can be dried more rapidly using MOTP 30% without affecting germination capacity. The results obtained from this study would provide technical basis to select optimal wheat seed processing and design seed drying equipments.

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1 Introduction

Microwave drying has the advantages of high thermal efficiency, shorter drying time and improved product quality compared to conventional hot air drying (Sunjka et al., 2004; Stanislawski, 2005; Vadivambal & Jayas, 2007). Food industry is now the major field using microwave energy (Vadivambal & Jayas, 2007). Microwave drying has been extensively investigated by many researchers as an efficient means of drying cereal grains for food purposes (Vadivambal & Jayas, 2007; Hemis et al., 2012).

In addition, several researches also worked on microwave drying of seeds for seeding purpose. The materials investigated include seeds of cotton (Gossypium hirsutum L.; Conkerton et al., 1991), wheat (Triticum aestivum L.; Campana et al., 1986; Manickavasagan et al., 2007; Hemis et al., 2012), corn (Zea mays L.; Zhang & Zhang, 2009; Nair et al., 2011) and rape (Brassica campestris L.; Lüpńska et al., 2009). Compared to foods, seeds have more thermal sensitivity, and little overheating can lead the loss of germination capacity (Lüpńska et al., 2009; Hemis et al., 2012). Furthermore, the nature of non-uniform heating pattern of microwave also limits the application of microwave in seed drying (Manickavasagan et al., 2007). Manickavasagan et al. (2007) identified that germination capacities of samples from hot spots in the microwave drier were significantly lower than those from the normal heating zone.

To avoid the adverse effect of uneven heating, pulsed or intermittent microwave drying can be used as an alternative, it allows redistribution of temperature and moisture profiles within the product during microwave off time (Soysal et al., 2009). Nair et al. (2011) reported that optimum method of drying for corn seeds to maintaining a high germination rate was 4 W/g intermittent microwave drying (a cycle of 20 s, with 12 s on and 8 s off), which took 110 min to dry from 33% moisture content to 16% (wet basis). But for wheat seeds, information regarding intermittent microwave drying is in scarcity.

Present study was undertaken to investigate the dynamics of moisture content during the process of intermittent microwave drying, and the germination rate of wheat seeds after drying. We determined the effects of the microwave on time percentage (MOTP, microwave on time) (microwave on time+ off time) x100%) and initial seed moisture content on seed dehydration and germination rate. The results obtained from this study would provide technical basis to select optimal wheat seed processing and design seed drying equipments.

2 Materials and Methods

2.1 Seeds Materials

In the present study, seeds of winter wheat (Triticum aestivum L.) variety Shannong 15 were used. After initial moisture content was measured using capacitance method moisture determination meter PM888 (Kett, Japan), seeds were rewetted to about 20% of moisture content (wet basis), which is roughly equivalent to the moisture content when wheat was harvested. Then, some seed samples were naturally dried to moisture content of about 19% and 16%, respectively. Finally, three seed samples, with moisture content of about 20, 19 and 16% were sealed in double-ply bags at 4 °C for further use.

2.2 Experiment design

Drying experiment of 100 g seed sample was performed at the condition of different MOTPs, different drying times and different seed initial moisture contents in the microwave. All samples were taken out from 4 °C refrigerator and maintained at room temperature overnight before drying experiment.

A home-style microwave oven (G90D23CSL-Q6, Galanz, China) was used in the present study, with 800 W output power and 2450 MHz working frequency. For each cycle, microwave on time was 32s (constant), while off time variable, which was determined according to ten different MOTPs (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or 100%).

Microwave drying of 100 g wheat seed was performed with a flat layer on the circular sieve with a radius of 11 cm. Moisture content after drying was calculated by the following equation:

\[ \text{y} = \frac{1}{1-(\text{x} \times \text{m}_1/\text{m}_2)} \]

where y represents moisture content after drying; x presents moisture content before drying; \( \text{m}_1 \) represents the seed weight before drying; and \( \text{m}_2 \) represents the seed weight after drying.

Germination test was conducted using sand bed. Wheat kernels (100 seeds) were placed on about 2 cm wet sand (containing about 60-80% saturated water content of dried sand) in a 16 \( \times \) 13 cm germination box, and then were covered by about 1 cm wet sand. The germination box was then kept at 25 °C for seven days. The germinated seeds were then counted and germination rate was calculated. The germination test was replicated for four times.

3 Results

3.1 Determination of the range of MOTP

To determine the range of proper MOTP for intermittent microwave drying, the seed moisture content and germination rate were measured after drying under the condition of ten different MOTPs (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or 100%). The initial moisture content was 20.3%, and the total treatment time (including total microwave on and off time) was 5, 10 and 15 min. The results showed that the final seed moisture content decreased as MOTP or total microwaving time increased (Figure 1A). In addition, germination rate was obviously decreased when MOTP was above 30% among all the three time points (Figure 1B). Therefore, during intermittent microwave drying, MOTP...
should not be above 30%, so that the germination rate was not significantly affected.

3.2 Effects of the MOTPs 10%, 20% or 30% on the seed dehydration and germination rate

Under the condition of MOTP 10%, 20% or 30%, samples were taken every five minutes until the moisture content was decreased from the initial 20.3% to about 13%. The seed moisture content and germination rate were measured at different time points of microwave drying. In order to reach 13% of moisture content, it requires about 25 min, 40 min or 100 min when the MOTP was 30%, 20% or 10%, respectively (Figure 2A), suggesting that seed dehydration speed was significantly affected by MOTP. In addition, until seeds were drying to about 13% of moisture content, germination rate was not significantly affected under the condition of 10% or 20% MOTP (Figure 2B). While in case of 30% MOTP, the germination rate was greatly affected after the seeds were dehydrated for 25 min (Figure 2B).

Figure 1 A
Figure 1 B
Figure 1 Effect of different MOTPs under three microwaving times (5min, 10 min and 15min) on moisture content (A) and germination rate (B) of wheat seeds.

Figure 2 A
Figure 2 B
Figure 2 Effect of different MOTPs on the moisture content (A) and germination rate (B) of wheat seeds.
3.3 Effects of initial moisture content on the seed dehydration and germination rate

To determine the effects of initial moisture content on the seed dehydration and germination rate, the samples with three different initial moisture contents, 20.3%, 19.2% and 16.7%, were used. Under the condition of 20% or 30% MOTP, the samples were taken every 5 min until the moisture content was decreased to about 13%. Seeds dried with 30% MOTP require shorter time to reach 13% moisture content compared to MOTP 20% when the initial moisture content was identical (Figure 3). When the seeds were dried with MOTP 20%, the initial moisture content did not significantly influence the germination rate (Figure 4A). These results indicated that seeds with an initial moisture content≤ 20.3% can be rapidly dried by intermittent microwave of 20% MOTP without affecting the germination rate. However, when the seeds were dried with MOTP 30%, the germination rate was significantly affected by the initial moisture content (Figure 4B). The germination rate of the dried seeds with an initial moisture content of 16.7% was not significantly different to the control seeds. However, the germination rate of the dried seeds with initial moist content 20.3 and 19.2% was dramatically decreased (Figure 4B). These results indicated that under the condition of 30% MOTP, seeds with an initial moisture content of 16.72% can be more rapidly dried by intermittent microwave without significantly affecting the germination rate, and that seeds with more initial moisture content should not be dried under this condition.

4 Discussions

Drying is one of the key steps in the seed processing, and a key factor relating to seed quality. Microwave drying is an alternative method due to its higher thermal efficiency. But, biomaterials for seed purpose are very thermal sensitive, some drawbacks of microwave drying, such as overly rapid temperature increase and the uneven drying patterns, inhibit its application in seed drying (Manickavasagan et al., 2007; Vadivambal and Jayas, 2007; Łupińska et al., 2009).
To avoid the adverse effect of microwave, a pulsed or intermittent microwave drying manner is proposed, and the applications in seed drying have also been reported (Zhang & Zhang, 2009; Nair et al., 2011). During intermittent microwave drying, to control the product’s temperature, time of power on/off is an important parameter (Orsat et al., 2007). In the present study, we used the term MOTP for this parameter. When MOTP was above 30%, germination rate of dried seeds decreased dramatically. So, MOTP should not be above 30%. Among the three MOTPs for further investigated, 10% or 20% MOTP did not obviously damage the germination capacity when wheat seeds were dried from initial moisture content 20.3% or less to about 13% (for shorter drying time, 20% of MOTP was recommended); but 30% MOTP greatly affected the seed quality when initial moisture content was 20.3% and 19.3%. While, when initial moisture content was 16.7%, the wheat seed germination capacity was not significantly affected by 30% MOTP.

As for the effect of initial moisture content before microwave drying on seed germination rate, a few previous reports were available. Present study is in conformity with the finding of Manickavasagan et al. (2007) who have reported a significant reduction in germination rate with the decreasing of moisture content in microwave treated seeds. It was concluded by the finding of study that high moisture seeds were more heat-sensitive.

When wheat was harvested in time, the moisture content was about 20%. So, the intermittent microwave drying procedure should be: drying with 20% MOTP firstly, and then, when moisture content dropped to 16.7% or lower, 30% MOTP was recommended for shorter drying time.

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References


