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DRYING OF PARBOILED PADDY USING AN IMPINGING STREAM DRYER

*Pimpan PRUENGAM[1], Somkiat PRACHAYAWARAKORN [2], Sakamon DEVAHASTIN[3] and Somchart SOPONRONNARIT[1]

[1]*Division of Energy Technology,School of Energy, Environment and Materials, King Mongkut's University of Technology Thonburi, 126 Pracha u-tid Road, Bangkok 10140, Thailand*

[2]*Department of Chemical Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, 126 Pracha u-tid Road, Bangkok 10140, Thailand*

[3]*Department of Food Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, 126 Pracha u-tid Road, Bangkok 10140, Thailand*

Corresponding author: Pimpan PRUENGAM. E-mail: pimpan_koi@hotmail.com

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ABSTRACT

In order to reduce the time for drying parboiled paddy, an impinging stream drying technique is proposed. Different strategies for drying parboiled paddy via the use of an impinging stream dryer were also evaluated. The effects of drying air temperature and tempering time on the head rice yield (HRY) and whiteness index (WI) of the dried parboiled rice were studied; parboiled rice was prepared from Suphan Buri 1 with an initial moisture content in the range of 46-50% d.b. The drying experiments were carried out at drying air temperatures of 130, 150 and 170 °C, inlet air velocity of 20 m/s, impinging distance of 5 cm and paddy feed rate of 40 kg_{dry_paddy}/h. Parboiled paddy was dried for two cycles; after each cycle of drying, paddy was tempered either for 15, 30, 60 and 120 min. After impinging stream drying, paddy was ventilated by ambient airflow until the final moisture content reached 16% d.b. Moisture reduction of paddy during each cycle of drying was noted to increase with an increase in the drying temperature. The HRY of paddy undergone any number of drying cycle at any drying temperature and tempering time was still maintained at a similar level to that of the reference rice. However, the WI of paddy was relatively lower than that of the reference rice when the paddy was tempered for longer than 60 min.

INTRODUCTION

Rice is a main staple food and is one of the important exported products of Thailand. Recently, several value-added rice products have received much attention, with parboiled rice among the most interesting product. Based on the total export statistics of Thai rice products in 2011, parboiled rice is one of the major products accounting about 31.01% [1].

To produce parboiled rice, paddy is first soaked, then steamed and dried. After soaking and steaming, paddy contains very high moisture content (about 46 to 50% d.b.); this moisture must be removed via a suitable

process to a safe level of 14 - 16% d.b. Many drying techniques can be used to reduce the moisture content of steamed paddy, including fluidized and spouted bed dryers. The moisture content of paddy after drying should not be lower than 23% d.b. to avoid kernel fissuring [2]; subsequence dehydration to the safe moisture level is normally performed by air ventilation.

Impinging stream dryer (ISD) is a novel alternative that can be applied to remove the surface moisture from a particulate material. ISD is particularly attractive for first-stage drying of a high-moisture material [3]. Nimmol and Devahastin [4] indeed applied ISD to the drying of paddy. It was found that the dryer could reduce the moisture content of paddy by 3.4-7.7% d.b. within a very short period of time (about 2.5 s). Thanasookprasert et al. [5], further studied the use of an ISD to dry paddy. Paddy was dried more than one cycle, with tempering to reduce the moisture gradients within the paddy kernels after each drying cycle. The results showed that the head rice yield of paddy was excessively low, with the values after the first and second cycle lower than the head rice yield of a reference rice by 44% and 49%, respectively. The large moisture gradients, which led subsequently to stresses and fissuring, could not be effectively relaxed through tempering.

The above-mentioned observations may imply that an ISD is not quite appropriate for paddy, parboiled paddy, on the other hand, may be more suitable for an ISD as this type of paddy has already been cooked; starch gelatinization that take place during steaming may also lead to a kernel structure that can withstand more moisture-indeed stresses that would occur in a kernel during impinging stream drying. To the best of our knowledge, no study has so far been made to study the use of an ISD to dry parboiled paddy, either for only one cycle or multi cycles, with and without tempering in between the cycles.

The main objective of this research was to investigate the effect of drying air temperature during impinging stream drying of parboiled paddy. The effect of tempering time between the drying cycles on the head rice yield (HRY) and whiteness index (WI) of finished parboiled rice was also investigated.

MATERIALS AND METHODS

Materials

Paddy (harvested in Octorber 2012) of Suphan Buri 1 variety was purchased from the Ratchaburi Rice Research Center; the initial moisture of paddy was about 14% d.b. Paddy was cleaned and then soaked in hot water at a temperature of 70 °C for 5 h before draining and tempering at ambient temperature for 1 h. The next step of the parboiling process is steaming. Paddy was steamed for 10 min during which the temperature inside the steaming chamber was around 120 °C. The steamed paddy was ventilated with ambient air for 30 min; the moisture content of parboiled paddy was in a range of 46 to 50% d.b.

Impinging stream dryer

Parboiled paddy was dried with an impinging stream dryer using hot air as the drying medium [6]. A schematic diagram of the impinging stream dryer used in this study is shown in Figure 1. The dryer consists of a stainless steel drying chamber, with the distance between the openings of the inlet air pipes within the drying chamber of 5 cm. A high pressure blower rated at 5.5 kW supplied the air to the system. The inlet air velocity was fixed at 20 m/s via the use of two globe valves. The inlet air temperature was controlled by two electric heaters, each rated at 6 kW. The drying experiments were carried out at the drying air temperatures of 130, 150 and 170°C; the hot-air temperature was measured and recorded continuously by type K thermocouples connected to a data logger (Yokogawa, model μR100, Tokyo, Japan). The paddy feed rate of 40 kg_{dry_paddy}/h, which was adjusted by means of a voltage regulator, which is used to control the speed of an DC electric motor rated at 117 kW that is used in turn a star feeder, was used. Parboiled paddy was dried in two cycles, with tempering between each drying cycle; the tempering time was varied at 15, 30, 60 and 120 min. Finally, paddy was ventilated by an ambient airflow at 0.15 m/s until the final moisture content of paddy reached around 16% d.b. All experiments were performed in triplicate. After drying, a dried paddy sample was kept in a sealed plastic bag at 4–6 °C for 2 weeks before quality analysis. The overall experimental design is illustrated in Figure 2.

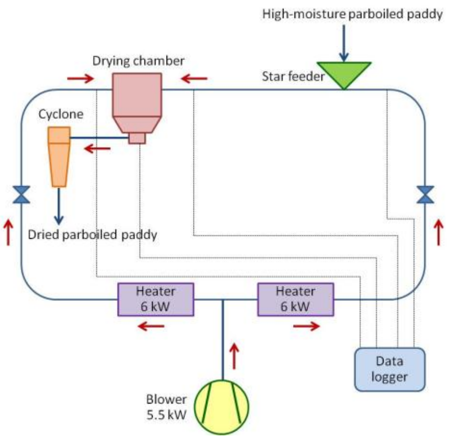

Fig. 1 A schematic diagram of hot-air impinging stream dryer

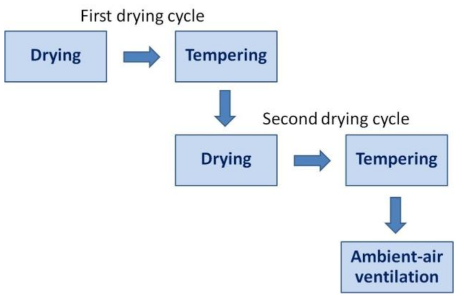

Fig. 2 Experimental design which includes drying and tempering steps

The quality of dried parboiled paddy obtained from the above processes was compared with that of a reference sample, obtained by drying in a tray dryer at 45°C.

Characteristics of paddy

The moisture content of paddy was determined by drying 30 g of paddy in an electric air oven (Memmert, model ULE500, Schwabach, Germany) at a temperature of 103 °C for 72 h according to AACC method [7]. The measurement was carried out in triplicate and an average value is reported.

250 g of a dried parboiled paddy sample was shelled by a rubber roll sheller (Ngeksenghuat, model P-1, Bangkok, Thailand), milled to remove bran using a miller (Ngeksenghuat, model K-1, Bangkok, Thailand) and graded using an indent cylindrical separator (Ngeksenghuat, model I-1, Bangkok, Thailand). The head rice yield was then determined [8-9]. Head rice is defined as milled rice having a kernel length of at least 75% of the original length. The head rice yield is then defined as the mass of parboiled rice that remains as head rice after complete milling divided by the mass of the original parboiled paddy sample.

In addition to the head rice yield, the whiteness index of parboiled paddy was examined. A dried parboiled rice samples was measured for its color by a spectrophotometer (model ColorFlex, HunterLab Reston, VA, USA) with a D65 illuminant and an observer angle of 10°. The color was described using the CIE (Commission Internationale de l'Eclairage, 1976) L^*, a^*, b^* color system. Before each measurement, the spectrophotometer was calibrated against a standard white plate having a standard value of L^* = 93.19, a^* = -1.12 and b^* = 1.33. Parboiled rice kernels were randomly selected and filled into a glass sample cup and their color was measured. The whiteness index of a sample was then calculated using the following equation:

$$\mathrm{WI} = 100 - [(100 - L^*)^2 + (a^*)^2 + (b^*)^2]^{0.5}$$

where L^*, a^* and b^* are the lightness, redness/greenness and yellowness/blueness of sample, respectively. The measurement was performed in ten individual replicates and an average value is presented.

RESULTS AND DISCUSSION

Reference rice quality

Reference rice quality was analysed after tray drying and the following results were obtained:

• Head rice yield (HRY) = 71.1 ± 0.4%
• Whiteness index (WI) = 55.4 ± 0.1

Moisture Content

The moisture content of paddy decreased with an increase in the drying temperature as shown in Figures 3-5. Drying in the first cycle provided a higher drying rate than the second drying cycle at all tested drying temperatures as can be seen in Table 1. Impinging stream dryer could reduce the moisture content paddy drying the first cycle by 4.88-8.67% d.b., while the moisture content reduced by 3.75-5.76% d.b. during the second cycle of drying. This is because the moisture content of a sample was higher during the first drying cycle, leading to a higher driving force for mass transfer and hence a higher drying rate. It is noted that the residence time of a sample during the first and second cycles was practically the same.

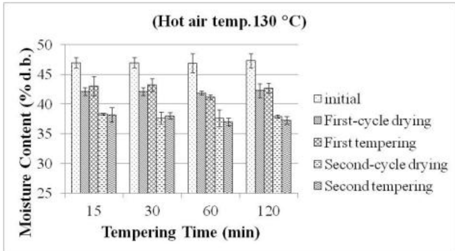

Fig. 3 Variation in moisture content of parboiled paddy at different tempering times and operation intervals (drying temperature of 130°C)

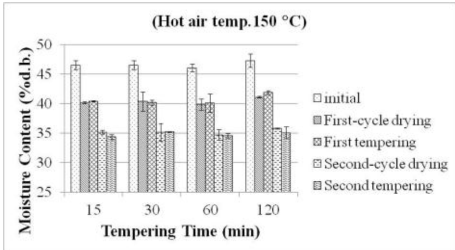

Fig. 4 Variation in moisture content of parboiled paddy at different tempering times and operation intervals (drying temperature of 150°C)

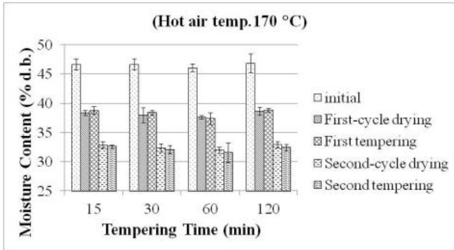

Fig. 5 Variation in moisture content of parboiled paddy at different tempering times and operation intervals (drying temperature of 170°C)

Table 1 Moisture reduction of parboiled paddy

Drying temp.	Tempering time	Cycle #	ΔMC,1	Cycle #	ΔMC,2
130	15	1	4.88	2	3.75
	30	1	4.88	2	4.50
	60	1	4.98	2	4.21
	120	1	5.04	2	4.38
150	15	1	6.37	2	5.03
	30	1	6.17	2	5.28
	60	1	6.21	2	5.19
	120	1	6.25	2	5.30
170	15	1	8.26	2	5.50
	30	1	8.67	2	5.61
	60	1	8.42	2	5.67
	120	1	8.18	2	5.76

ΔMC is the percentage of moisture reduction (% d.b.)

Head rice yield

The relationship between head rice yield and tempering time of parboiled rice at different drying temperatures is presented in Figure 6. The head rice yield was not affected by the drying temperature and tempering time; the head rice yield was in the range of 68.3-71.1%, which was close to the head rice yield of the reference rice.

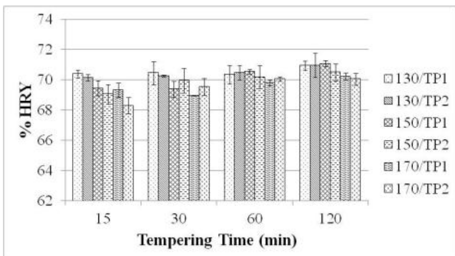

Fig. 6 Variation in head rice yield (HRY) of parboiled rice at different tempering times and hot air temperatures (TP1 = first tempering, TP2 = second tempering)

Whiteness index

The whiteness index decreased with an increase in the tempering time, while the drying temperature not affected the whiteness index. This is because the residence time of paddy in the impinging stream dryer was very short. On the other hand, bran components leached out and diffused into endosperm during tempering, causing the parboiled rice kernels to have a darker color. In the case when the tempering time was shorter than 60 min, the whiteness index of rice obtained from paddy that was dried for only one cycle was in the range of 55.4-56.1; the index of rice obtained from paddy that was dried for two cycles was in the range of 54.6-56.2, which was lower than that of the reference rice. For tempering times shorter than 60 min, the whiteness index of rice obtained from paddy that was dried for only one cycle was in the range of 57.3-59.0, while the index of rice obtained from paddy that was dried for two cycles was in the range of 57.6-58.8.

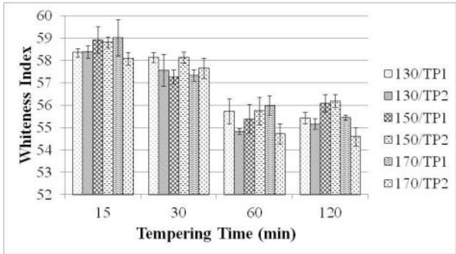

Fig. 7 Variation in whiteness index (WI) of parboiled rice at different tempering times and hot air temperatures (TP1 = first tempering, TP2 = second tempering)

CONCLUSIONS

Moisture reduction level of paddy increased upon increasing of the impinging stream drying temperature. The HRY of rice from paddy dried even for two cycles still maintained similar to that of the reference rice. However, the WI of the impinging-stream dried rice kernels was lower than that of the reference sample if the tempering time was longer than 60 min. Nevertheless,

even after second-cycle drying, the moisture content of parboiled paddy was still high (31-38 % d.b.), so more drying cycles should be investigated in the future.

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