FE-15

EFFECT OF HUMIDIFIED HOT AIR FLUIDIZED-BED DRYING ON QUALITY OF PARTIAL PARBOILED RICE

*Theerasak SRIMITRUNGROJ[1], Somchart SOPONRONNARIT[1], Somkiat PRACHAYAWARAKORN[2] and Adisak NATHAKARANAKULE[1]
[1]*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, King Mongkut's University of Technology Thonburi 126 Pracha u-tid Road, Bangkok 10140, Thailand*
Corresponding author: Theerasak SRIMITRUNGROJ. E-mail: trsdev@gmail.com

Keywords: Drying, Fluidization, Parboiled rice, Soaking

ABSTRACT

This research aimed to experimentally investigate quality of paddy dried by hot air and humidified hot air fluidization technique. Quality such as head rice yield (HRY), degree of crystallinity and color of dried paddy were evaluated. The paddy *(Chainat 1)* with initial moisture content of 14% d.b. was soaked in hot water at temperature of 70°C for 5 hours. Then the soaked paddy was dried in a fluidized bed dryer using a humidified air at dried air temperature of 150°C, an air velocity of 4.0 m/s and a bed height of 10 cm. The results showed that when the drying time of paddy in a humidified air drying was taken longer than that in hot air drying. The amount of head rice yield obtained from the humidified hot air was relatively higher than that of hot air drying. The whiteness index (WI) of humidified hot air samples was darker when compared with the color of hot air dried samples. From the XRD analysis, the humidified hot air sample showed a lower percentage of crystallinity than that of the hot air dried product.

INTRODUCTION

Normally, the commercial process to produce the parboiled rice is divided into 3 steps. : soaking or steeping, steaming and drying. The first step is to soak the paddy in water at 70°C for 3-6 hours or 80°C for 1-3 hours until the rice properly absorbed the water. For gelatinization, this step will fill the water into the gap between the husk and the seed. The starch seed will be swelled and the volume is increased. Next step is the streaming process. In this step, the paddy is heated in order to gelatinized. Normally, the soaked rice was streamed for 15-30 mins at 100-105°C. The last step is to dry the rice. After streaming step, the rice has the high moisture content around 45-50 % d.b. At the high moisture level it needs to reduce the moisture content of the rice to 14-16% d.b. Drying the rice can be done by shade drying or hot air. However, the cost of the parboiled rice by the conventional method is high and complicated because there are too many steps as mentioned above. For this reason, there is a research to study how to streaming and drying steps can be combined in one unit operation.

Wathanyoo et al., [1] studied the drying of very high moist paddy with hot air and superheated stem fluidized bed. It was found that the gelatinization occurred faster paddy dried by superheated steam than that dried by hot air. In addition to the heating media, drying temperature affect the degree of starch gelatinization. Higher degree of starch gelatinization was obtained at the higher drying temperature [2,3,4].

The above observations may imply that drying of parboiled paddy using superheated steam provided more completed gelatinization of rice starch. Ratanamechaiskul et al., [5], studied the use of humidified hot air fluidized bed technique to dry nutritious parboiled brown rice. The results showed that the degree of gelatinization was 41 %, for paddy at an initial moisture content of 33% d.b. using drying temperature of 150°C and 6.4% relative humidity. In addition, the humidified hot air provides a higher degree of starch gelatinization in rice than non-humidified hot air, because the drying rate in humidified hot air is relatively lower, thereby allowing rice starch to be gelatinized for a longer period of time.

From the above reason, the aim of this investigation was to study the effect of humidified hot air fluidization technique on the head rice yield, whiteness index and degree of crystallinity.

MATERIALS AND METHODS

Experimental set-up

A schematic diagram of a hot air fluidized bed dryer and its accessories was shown in Fig. 1. The system consisted of three major components: a cylindrical drying chamber with an inner diameter of 20 cm and a height of 140 cm, a 12 kW electrical heater with a temperature controller, and a backward-curved-blade centrifugal fan, which was driven by a 1.5 kW motor. Exhaust air could be recycled, if needed, by means of two butterfly valves at air outlet and recycle tube.

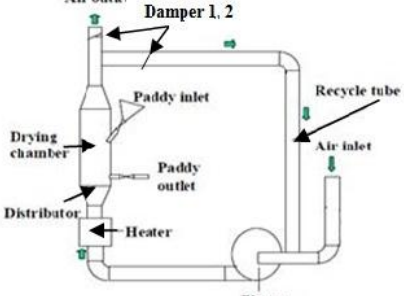

Fig. 1 A schematic diagram of a batch hot air fluidized bed dryer.

Fig. 2 showed a schematic diagram of a humidified hot air fluidized bed dryer. The main accessories of this system were all the same as a batch hot air fluidized bed dryer but installing additional 21 kW boiler tank for producing saturated steam at 106 kPa, 103^{o}C and temperature was controlled by a PID controller with an accuracy of $\pm 1^{o}$C.

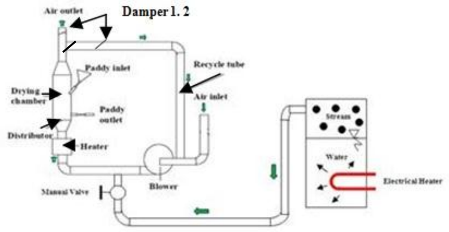

Fig. 2 A schematic diagram of a batch humidified hot air fluidized bed dryer.

Materials

The experiment was carried out as follow. The paddy *(Chainat 1)* with initial moisture content of 14% d.b. was soaked in hot water at temperature of 70^{o}C for 5 hours. The moisture content of paddy after soaking ranged between 50 and 53% d.b. The paddy was dried in the fluidized bed dryer using temperature of 150^{o}C, air velocity of 4.0 m/s, 4-5 % relative humidity and the bed height of 10 cm. After drying, paddy kernel were gently ventilated by ambient air until their temperatures become ambient and their moisture content reached 16% d.b. The product was kept in cool storage at 4–6^{o}C for 2 weeks before carrying out quality analysis which were head rice yield (HRY), whiteness index (WI) and degree of crystallinity.

Moisture evaluation

The moisture content of paddy was determined by drying paddy in a hot air oven at a temperature of 103^{o}C for 72 hours, according to the approved method of the AACC method [6]

Head rice yield evaluation

250g sample was dehusked by a rubber roller, polished by a Satake rice polisher and graded by a rice grader to determine the head rice yield. In this case, the head rice yield is defined as milled rice having kernel length of at least three-fourths of its original length.

Color evaluation

Color of polished waxy rice was measured by HunterLab ColorFlex (Reston, VA) using a D65 light source, large viewing area and the observer angle of 10^{o} Before each color measurement, the spectrophotometer was calibrated with a standard white plate (X = 78.50, Y = 83.40, Z = 87.63). The color values were expressed as L* (lightness/darkness), a* (redness/greenness) and b* (yellowness/ blueness).The whiteness index (WI) was then calculated by the following equation [7].

$$WI = 100 - \left[(100 - L^*)^2 + (a^*)^2 + (b^*)^2 \right]^{0.5} \quad (1)$$

X-ray diffraction analysis

X-ray diffraction (XRD) patterns of dried rice flour were obtained using a Bruker AXS D8 DISCOVER XRD (Bruker AXS GmbH, Karlsruhe, Germany) under the following conditions: 40 kV and 40 mA with CuK α radiation at a wavelength of 0.1546 nm with a scanning rate of the diffraction angle (2θ) of 2^{o}/min. A sample of 0.5g of dried waxy rice flour was placed in a holder. The relative intensity of the diffraction peak was recorded in the scattering range (2θ) of 4–40^{o} and the crystallinity (X_c) of the sample was calculated by:

$$X_c = \frac{A_c}{A_c + A_a} \times 100\% \quad (2)$$

where A_c and A_a are the areas of crystalline and noncrystalline regions, respectively.

RESULTS AND DISCUSSION

Drying kinetics

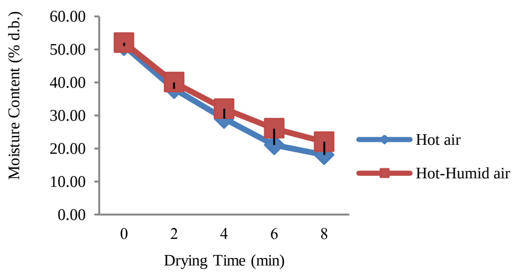

Fig. 2 Moisture content of paddy dried in humidified hot air and hot air at 150°C

Fig. 2 showed the evaluation of moisture content of paddy dried by humidified hot air and hot air at 150^{o}C. It was found that moisture content of paddy dried by humidified hot air decreased more slowly than hot air drying. Since, the water vapor in humidified hot air drying condensed during the early period of drying resulting in slightly longer drying time in the humidified hot air drying.

HRY

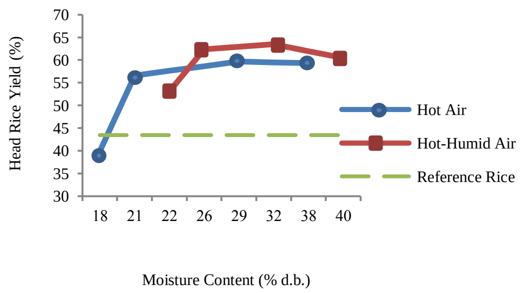

Fig. 3 Change of head rice yield at the final moistures content (during temperature 150^{o}C)

Fig. 3 showed the relationship between the HRY and final moisture content. The results showed that the HRY in the humidified hot air drying was higher than that dried in hot air drying. In the humidified hot air, the HRY was dropped rapidly at the final moisture content of 26% d.b. because paddy kernels experience moisture gradients; these gradients led to the development of stress inside the kernels, which damaged the kernels.

Color

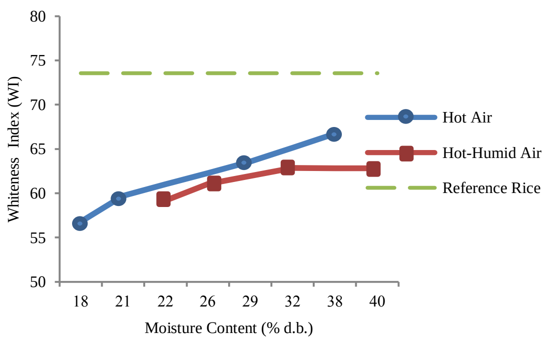

Fig.4 Effect of humidified hot air and hot air drying at 150°C, soaking time 5 hours on WI value.

Fig. 4 showed the relationship between the moisture content of paddy and WI value after drying. It was found that trend of WI of the humidified hot air drying was lower than that of hot air drying because the grain temperature in the humidified hot air was higher than hot air drying, This effect led to faster acceleration of browning reaction [8].

DEGREE OF CRYSTALLINITY

Table 1. Degree of crystallinity of rice sample

Processing Condition	Degree of Crystallinity of A type (%)
Reference	15.12%
Soaking	12.35%
Hot Air	11.41%
Humidified Hot Air	9.01%

Table 1 shows the degrees of crystallinity of reference rice, soaked rice, hot air dried rice, humidified hot air dried rice. Result shows that percentage of degree of crystallinity was 15.12% for the reference rice (before soaking and drying) while the soaked rice was 12.35%. The decrease of crystallinity during soaking step indicated that the crystallinity structure was collapsed. After drying, the degree of crystallinity was lower in the humidified hot air drying than in hot air drying. From these results, it indicated that drying of paddy in the humidified hot air produced higher degree of starch gelatinization than that in hot air drying. Consequently, the head rice yield in the humidified hot air was higher than that in hot air drying.

CONCLUSION

From the experimental study. It was found that the decrease of moisture content of paddy in the humidified hot air drying head rice yield. It was more slowly than in hot air drying. This let to higher degree of starch gelatinization or lower degree of A type crystallinity than the hot air drying. Accordingly, the head rice yield of sample dry in the humidified hot air became higher. The color of milled rice dried in humidified hot air drying was darker than that in hot air drying. From this study, it recommended that paddy showed not reduce the moisture content lower than 26% d.b. in order to obtain high.

ACKNOWLEDGMENTS

The authors express their sincere appreciation to the National Science and Technology Development Agency (NSTDA) and the Faculty of Engineering at King Mongkut's University of Technology North Bangkok for supporting the study financially.

REFERENCES

1. Wathanyoo Rordprapat, Adisak Nathakaranakule, Warunee Tia, Somchart Soponronnarit., “Comparative study of fluidized bed paddy drying using hot air and superheated steam”, Journal of Food Engineering, Volume 71, Issue 1, November 2005, Pages 28-36.
2. Chaiyong Taechapairoj, Isares Dhuchakallaya, Somchart Soponronnarit, Somboon Wetchacama,Somkiat Prachayawarakorn, “Superheated steam fluidised bed paddy drying”, Journal of Food Engineering, Volume 58, Issue 1, June 2003, Pages 67-73.
3. Somchart Soponronnarit, Adisak Nathakaranakule, Athikom,Jirajindalert, Chaiyong Taechapairoj.,“Parboi ling brown rice using super heated steam fluidization technique”,Journal of Food Engineering, Volume 75, Issue 3, August 2006, Pages 423-432.
4. Chaiyong Taechapairoj, Somkiat Prachayawarakorn, Somchart Soponronnarit.,“Modelling of parboiled rice in superheated-steam fluidized bed”, Journal of Food Engineering, Volume 76, Issue 3, October 2006, Pages 411-419.
5. Chaiwat Rattanamechaiskul, Somchart Soponronnarit, Somkiat Prachayawarakorn and Patcharee Tungtrakul., “Optimal Operating Conditions to Produce NutritiousPartially Parboiled Brown Rice in a Humidified Hot Air Fluidized Bed Dryer”,Drying Technology, Volume 31, Issue 4, March 2013, Pages 368-377.
6. AACC (1995). Approved method of the American association of cerealchemists (9th ed.). MN: American Association of Cereal ChemistsSt. Paul.
7. J.J. Chen, S. Lu, C.Y. Lii., “Effect of milling methods on the physicochemical characteristics of waxy rice in Taiwan”,Cereal Chemistry, Volume 76,1999, Pages 796–798.
8. Somchart Soponronnarit, Mattaneeya Chiawwet, Somkiat Prachayawarakorn, Patcharee Tungtrakul, Chaiyong Taechapairoj., “Comparative study of physicochemical properties of accelerated and naturally aged rice”, Journal of Food Engineering, Volume 85,Issue 2, March 2008, Pages 268–276.