Effect of Drying Temperature on Quality of RD6 Variety Brown Parboiled Glutinous rice

Petcharat Jaiboon[1,a] and Somchart Soponronnarit[2,b]

[1]*Program of Physics, Faculty of Science and Technology, Sakon Nakhon Rajabhat University, Sakon Nakhon, 47000, Thailand*

[2]*School of Energy, Environment and Material, King Mongkut's University of Technology Thonburi, Bangkok, 10140, Thailand*

E-mail: petcharat@snru.ac.th[a], isomarit@kmutt.ac.th[b]

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Abstract

The aim of this research was to investigate an effect of drying temperature on quality of Rice Department; RD6 variety brown parboiled glutinous rice. RD6-paddy was soaked at temperature of 70 ± 5°C in an insulated tank for 3 hrs; the ratio between paddy and hot water was 1.0:1.3, then drained and tempered for 30 min. The initial moisture content of paddy was 50-52% (dry basis, d.b.). Two hundred fifty grams (250 g) of moist parboiled paddy was dried by fluidized bed dryer using superheated steam as a media at temperature of 110, 130 and 150°C. The velocity of superheated steam was 2.3 m/s until the moisture content of paddy down to 21-23% (d.b.). After that, the parboiled paddy was shade-dried until the moisture content to 14-16% (d.b.) and kept at 5°C in a refrigerator for quality tests, i.e., head brown parboiled rice yield, color, microstructure and thermal property. It was found that, head brown parboiled rice yield was increased when dried at high temperature whereas its color in terms of *L**, *a** and *b** were decreased. Drying at over temperature of 130°C revealed fully degree of gelatinization and the starch granules was fused themselves in brown parboiled glutinous rice. The results showed higher head brown parboiled rice yield increased as drying temperature increased.

Keywords: Color, Fluidized bed drying, Head brown rice yield, Parboiled glutinous rice

Introduction

Rice Department 6 (RD6) is one of famous cultivar of glutinous rice. It is produced and consumed in the north and north-eastern part of Thailand. RD6 is used as a raw material for producing a wide variety of product such as sweet rice cake and rice pudding and also consumed in the form of steamed rice. Parboiling process is a hydrothermal treatment of paddy that improves the milling, nutritional, and organoleptic attributes of rice. The process involves soaking or steeping, steaming, and drying. Soaking rice at room temperature is conventional and widely practiced but takes a long time to reach a moisture content of around 43% (d.b.). Warm- or hot-water soaking is a common method to shorten soaking time and the soaking temperature below the starch gelatinization is recommended to minimize kernel splitting and subsequent leaching of solids and phytochemicals [1]. Drying with superheated steam in a fluidized bed dryer can include the step of steaming and drying which can save drying time and prevent the yellowing of rice grains that easily occurs at high temperature [2]. Teachapairoj et al. [3] reported that soaked rice with high temperature of water and drying with a superheated steam fluidized bed dryer could be improved high head rice yield. Despite many researchers having reported the advantages of parboiling process and superheated steam fluidized bed drying, the information of brown parboiled glutinous rice dried with superheated steam in a fluidized bed dryer is very limited. Therefore, the aim of this study was to investigate the effect of various drying temperatures with superheated steam fluidization technique on the quality of RD6 variety brown parboiled glutinous rice, i.e., head brown parboiled rice yield, color, thermal property and microstructure.

Materials and methods

3.1 Materials

The RD6 paddy (*Oryza sativa* L.) was procured from the Rice Research Institute, Sakon Nakhon province, Thailand. The initial moisture content of provided paddy was 12-13% (d.b.). The paddy was soaked in hot water at a temperature of 70 ± 5°C in an insulated tank. The ratio between paddy and hot water was 1.0:1.3 and soaking time was 3 hrs. Then it was drained and tempered for 30 mins to created uniform gradient of moisture content. The moisture content of soaked paddy was about 50-52% (d.b.). It was determined according to Soponronnarit and Prachayawarakorn [4].

3.2 Equipment

A drying system was developed by the Faculty of Engineering, Mahasarakham University, Thailand. The system consists of a boiler, a pressure regulator, a steam conveying pipeline, a drying chamber, a backward curve fan, an auxiliary heater, a fresh-air supply valve, a steam-flow valve, and control system as shown in Figure 1. This system can be run in the hot air mode or the superheated steam mode by controlling a fresh-air supply valve and a steam-flow valve.

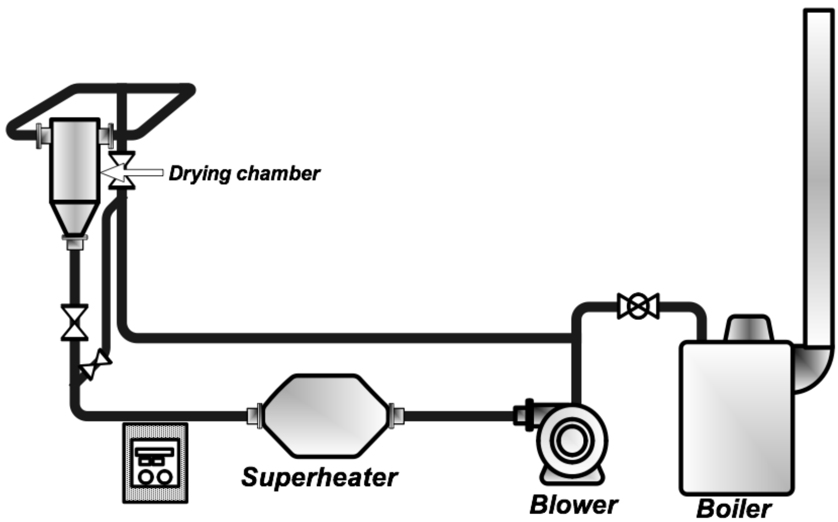


Figure 1. A schematic of the experimental dryer consists of a boiler, a pressure regulator, a steam conveying pipeline, a drying chamber, a backward curve fan, an auxiliary heater, a fresh-air supply valve, a steam-flow valve and control system

During the superheated steam drying, saturated steam was produced by the boiler. The steam generator generated the saturated-steam at about 200 kPa (absolute pressure) with the corresponding temperature of 120°C. Its pressure was reduced nearly to atmospheric pressure when the steam passed through the pressure regulator, a backward curve fan was conveying the drying media through the system. It was driven by a 2 kW, 3 phase electric motor with the media flow rate controlled by a frequency inverter. The media flow rate was measured using pitot static tube together with multifunction meter (Testo 454). The media was adjusted to the preselected temperature by the auxiliary heaters with a maximum heating capacity of 15 kW that was automatically controlled by proportional-integral detector controller with an accuracy of ±1°C before passing through the drying chamber.

3.3 Drying conditions

Samples were dried by a superheated steam fluidized bed dryer with temperatures of

110, 130 and 150°C at a superficial air velocity of 2.3 m/s until its moisture content reached around 21-23% (d.b.). After that, the sample was shade-dried until the final moisture content of the sample was around 16% (d.b.). It was kept in a sealed plastic bag at 4-6°C for 2 weeks before quality analysis.

3.4 Qualities test

3.4.1 Head brown parboiled rice yield

The paddy was dehusked to obtain brown rice by a bench-top dehusker (Otake, model no. FC2K, Tokyo, Japan). The sample was separated into broken and whole grains by an indent cylinder (Satake, model no.TRG-05A, Hiroshima, Japan). Head brown rice yield was calculated by dividing the mass of whole by an initial paddy mass.

3.4.2 Degree of gelatinization

The thermal properties of glutinous rice flour were investigated using Differential Scanning Calorimeter (DSC) (Perkin Elmer, model DSC-7, Norwalk, CT). Flour samples (3 mg) were weighed in balance of resolution 10^{-4} g and placed into an aluminium DSC pan; 10 μL of distilled water was added, and the pan was hermetically sealed. The samples were left to stand for 1 h at room temperature (25°C) before DSC scanning. The instrument was calibrated using indium and an empty aluminium pan was used as a reference. All samples were heated from 40 to 100°C at a scanning rate of 10°C /min. The major parameters of each DSC profile were described as onset temperature, peak temperature and conclusion temperature. From the DSC profile, the transition enthalpy was determined and the degree of gelatinization (DG) of glutinous rice flour was then calculated by the following equation as studied by Elbert et al [5]. :

$$DG(\%) = \left(1 - \left[\frac{\Delta H}{\Delta H_c}\right]\right) \times 100 \qquad (1)$$

Where DG is the degree of gelatinization, ΔH is the transition enthalpy of treated glutinous rice (J/g (dry matter)) and ΔH_c is the transition enthalpy of reference before soaking glutinous rice (J/g (dry matter)). All experiments were performed in duplicate and the average values were reported.

3.4.3 Microstructures

The microstructures of the reference and dried by superheated steam grains were observed by a Scanning Electron Microscope (SEM) (JSM-5600, model no. JSM-5600LV, Tokyo, Japan). The glutinous rice kernel was broken cross-sectionally in half by hand then attached to an SEM stub, and coated with gold by a sputter coater. The coated sample was then photographed at an accelerated voltage of 15 kV. The inspected location of the kernel was between the kernel surface and the endosperm center.

3.4.4 Color

The color of sample was measured by a Hunter Lab ColorFlex (Reston, VA), using a D65 light source and a 10° standard observer. The results are expressed as L^*, a^* and b^* values. The L^* value measures whiteness and varies from 100 for a perfect white to 0 for black. The a^* value represents redness (+) or greenness (-) and b^* value represents yellowness (+) or blueness (-). The measurement was performed in triplicate. The total color difference (ΔE^*) from a reference color ($L_0^*, a_0^*, \text{and}\, b_0^*$) to a target color ($L_1^*, a_1^*, \text{and}\, b_1^*$) in the CIELAB space is given by:

$$\Delta E^* = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right]^{1/2} \qquad (2)$$

Where

$$\Delta L^* = L_1^* - L_0^*, \Delta a^* = a_1^* - a_0^*, \Delta b^* = b_1^* - b_0^*$$

3.4.5 Statistical analysis

The data are reported the average of triplicate observations. The data were subjected to one-way analysis of variance (ANOVA) with a significance level of 95% was done and Duncan's test was applied to determine the differences between the means using SPSS® software.

Results and discussion

4.1 Head brown parboiled rice yield

Head brown parboiled rice yield of reference glutinous rice and dried samples at different superheated steam temperatures are shown in Table 1. It was found that, the head brown parboiled rice yield of dried samples was significantly higher than that of shade-dried sample. Drying at temperature of 150°C showed highest yield of 63.4 and significantly differed from another dried samples. This result indicated that starch gelatinization during high-temperature drying resulted in stronger kernels, which could resist the shear force during the de-husking process [6]. There was not a reported of the standard head rice of commercial brown parboiled rice as well as head rice yield due to quality of milling [7].

Table 1. Head brown parboiled rice yield of glutinous rice at different drying conditions

Drying conditions	Head brown parboiled rice yield (%)
Reference, RD6	46.8 ± 1.4^a
SHS 110°C, RD6	57.3 ± 0.8^b
SHS 130°C, RD6	58.8 ± 0.4^b
SHS 150°C, RD6	63.4 ± 0.8^c

RD6, rice department 6; SHS, superheated steam

Different superscripts in the same column mean that the average values are significantly different at $p \leq 0.05$.

4.2. Color

The whiteness of shade-dried and dried samples decreased darkness, while redness and yellowness of RD6 rice kernels increased as shown in Table 2. Dried samples showed *L**, *a** and *b** values from reference sample whereas Δ*E** was not different among dried samples group.

Table 2. Color of brown parboiled glutinous rice at different drying conditions

Drying conditions	*L**	*a**	*b**	Δ*E**
Reference, RD6	60.0 ± 0.2^{a}	4.60± 0.3^{a}	22.5± 0.4^{a}	0
SHS 110°C , RD6	55.1 ± 01^{b}	5.1 ± 0.1^{b}	25.2 ± 0.1^{b}	5.67
SHS 130°C , RD6	55.0 ± 0.3^{b}	5.2 ± 0.1^{b}	24.9 ± 0.4^{b}	5.62
SHS 150°C , RD6	55.2 ± 0.9^{b}	5.3 ± 0.2^{b}	25.4 ± 0.5^{b}	5.63

RD6, rice department 6; SHS, superheated steam

Different superscripts in the same column mean that the mean values are significantly different at $p \leq 0.05$.

Color changes during parboiling are caused by diffusion of husk and bran pigments and non-enzymatic millard browning reaction products. Moreover, rice bran or rice hull pigments can affect parboiled rice color as they leach out during soaking in excess water and diffuse into the endosperm during steaming [8]. In this study, the drying with superheated steam in a fluidized bed dryer can include the steaming and drying step in a parboiling process that can be save time and prevent the yellowing of rice grains, which easily occurs at high temperature [3, 9]. Although, the standard color of commercial brown parboiled rice has not been recorded and depended on parboiled rice's consumer of each country, Naivikul [7] measured the color of commercial parboiled rice in the form of *L**, *a** and *b** values was 62.12 ± 0.36, 1.89 ± 0.09 and 24.64 ± 0.31, respectively.

4.3. Thermal properties

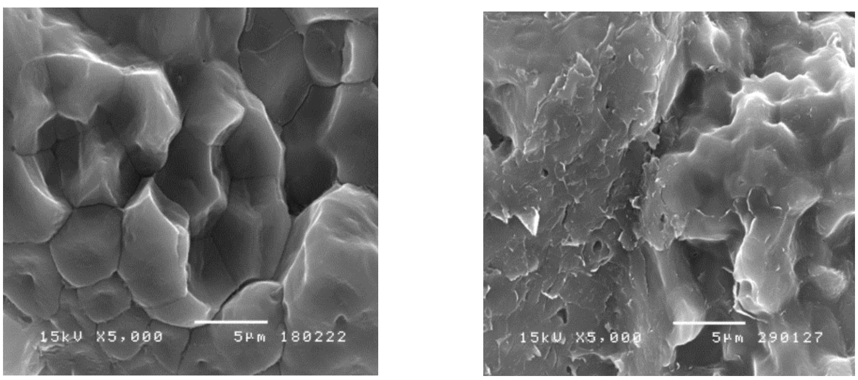
The thermal properties of reference and dried samples are presented in Table 3. The onset temperature (T_o), peak temperature (T_p) and conclusion temperature (T_c) corresponding to gelatinization of flour slightly decreased at drying temperature of 110°C whereas, at higher drying temperature of rice samples, the transition temperatures could not be detected. This is due to high drying temperature could destroyed the starch granule in glutinous rice kernels and fully gelatinization occurred when drying at over 130°C as shown in Figure 2.

Table 3. Thermal property of brown parboiled glutinous rice flour at different drying conditions

Drying conditions	Transition temperature (°C)			ΔH	DG
	T_o	T_p	T_c	(J/g)	(%)
Reference, RD6	67.4	74.3	81.1	9.5	0
SHS 110°C, RD6	67.0	74.2	81.4	2.2	76.8
SHS 130°C, RD6	-	-	-	-	100
SHS 150°C, RD6	-	-	-	-	100

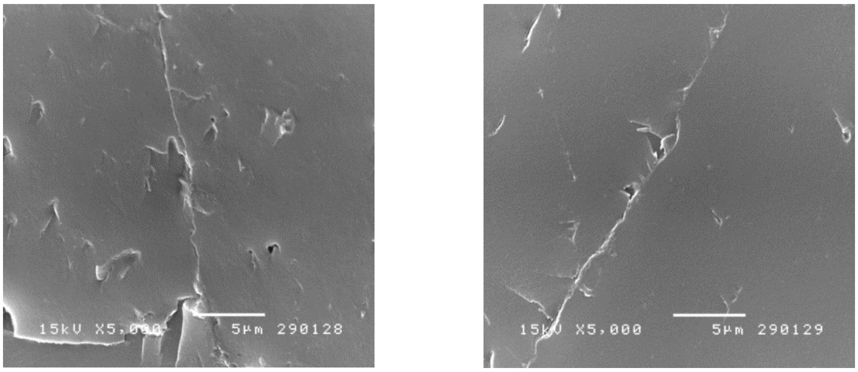
4.4. Microstructure

Figure 2 showed microstructures of reference and dried RD6-brown parboiled glutinous rice kernels. The reference sample displayed the starch granule characteristically irregular polygons with diameter in 2-9 micron. After drying at 110°C, the starch granules of glutinous rice samples were fused to some parts of the kernel with the degree of gelatinization (DG) of 76.8% (Table 3). Drying at temperature of 130 and 150°C displayed fully starch gelatinization, therefore the transition temperature and enthalpy disappeared and DG was 100% (Table 3 and Figure 2). The fully gelatinization resulted in a smaller fraction of broken glutinous rice kernels that are shown in Table 1.



Reference (RD6) SHS 110°C (RD6)

Figure 2. Microstructure of brown parboiled glutinous rice at various drying conditions



SHS 130°C (RD6) SHS 150°C (RD6)

Figure 2. Microstructure of brown parboiled glutinous rice at various drying conditions (Cont.)

Conclusions

High temperature of superheated steam in a fluidized bed dryer could improve head brown parboiled rice yield of RD6. Drying at temperature of 150°C showed highest yields of 63.4. The *L**, *a** and *b** values of dried samples decreased significantly compared to reference. The T_o, T_p and T_c decreased at drying temperature of 110°C, whereas drying at temperature over 130°C led to fully starch gelatinization as shown by SEM. Therefore, the suitable of superheated steam fluidized bed temperature drying for good qualities of brown parboiled glutinous rice was 150°C.

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