Modified Steaming Method for Parboiled Rice Production

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***Abstract*—A modified steaming method (steam using the revolved sieve; SRS) was applied to produce parboiled rice and the qualities of parboiled rice, namely, thermal properties (enthalpy; ΔH and degree of starch gelatinization: DG), head rice yield (HRY) and whiteness index (WI) were investigated under various steaming times and temperatures. The experimental results indicated that time and temperature during steaming step affected the parboiled rice qualities significantly. Prolonged time and increase of temperature during steaming provided the higher initial moisture content and grain temperature of rice sample after steaming, leading to longer time in drying process for decreasing the moisture content in the rice sample to 22% (d.b.). This provided the decrease of ΔH, leading to increase in the DG and resulting in the higher HRY and lower WI values.**

***Index Terms*—modified steaming, revolved sieve, parboiled rice, quality**

I. Introduction

Parboiled rice is a popular rice form which is important exported rice product of Thailand and it is a main staple food of people in many parts of the world, particularly South Asian countries. Its important characteristics are higher head rice yield and nutritional components when comparing with brown rice or white rice [1], [2]. Normally, the conventional method of parboiling process for parboiled rice production consists of soaking, steaming and drying step [3]. Steaming is important step which increase the degree of starch gelatinization [4], leading to a high milling yield. Conventional method for steaming is performed by blowing the saturated steam into the rice sample which was placed on the sieve which was fixed. This method provides the difficulty of steam distribution into the rice sample bed, leading to longer steaming time for complete starch gelatinization [5].

In this work, because the steaming method with revolved sieve technique, which provides excellent mixing between the sample and steam, is selected for parboiling process. From the previous work, it has been reported that the uniform steaming distribution into the paddy bed in the short time occurs when the steaming with revolved sieve is applied for producing parboiled rice [6]. There are many factors affecting the parboiled rice quality using steaming method with revolved sieve. The time and temperature during steaming step are two main factors which affected the change of parboiled rice quality. However, the information of quality change of parboiled rice under those factors using steaming method with revolved sieve has not well been documented.

The aim of this research was therefore to determine the effects of time and temperature during steaming on the qualities of parboiled rice steamed by using the revolved sieve (SRS), including thermal property, Head Rice Yield (HRY) and Whiteness Index (WI).

II. Material and Methods

A. Material

Paddy (Suphanburi 1 cultivars) which has amylose content of 25-30% used in this study and obtained from the Rice Seeds Center, Ratchaburi, Thailand. An initial moisture content of this rice variety was about 12% (d.b.). The paddy had already stored for a month prior to an experiment.

B. Experimental Setup

The Diagram of steaming process using the revolved sieve is presented in Fig. 1. It included a stainless steel cylindrical sieve (30 cm in diameter and 30 cm in length) which has 4 fins inside the sieve as shown in Fig. 2; a pulley driven by a 0.75 kW motor, and a boiler (500 kg/h capacity). Inlet steaming temperature was monitored by a temperature gage which was connected to steaming chamber. Valves were used to adjust the amount of steam which was flowed through the steaming chamber and blown out from steaming chamber.

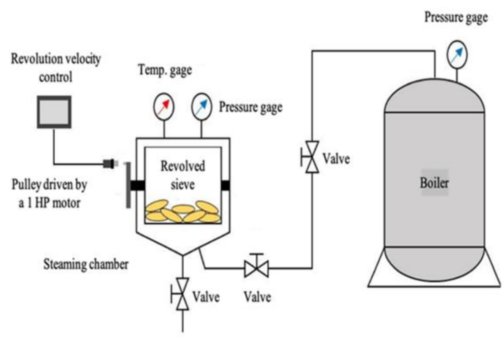

Figure 1. Diagram of steaming process using the revolved sieve.

A hot air fluidized bed dryer which was shown in Fig. 3 was applied to dry the sample after steaming. Its system

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included a cylindrical drying chamber with 20 cm diameter and 100 cm height, 15 kW electrical heaters which was controlled by a temperature controller and a blower driven by a 1.5 kW motor.

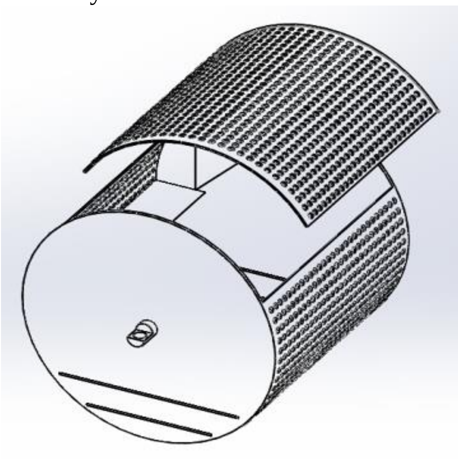


Figure 2. Cylindrical sieve.

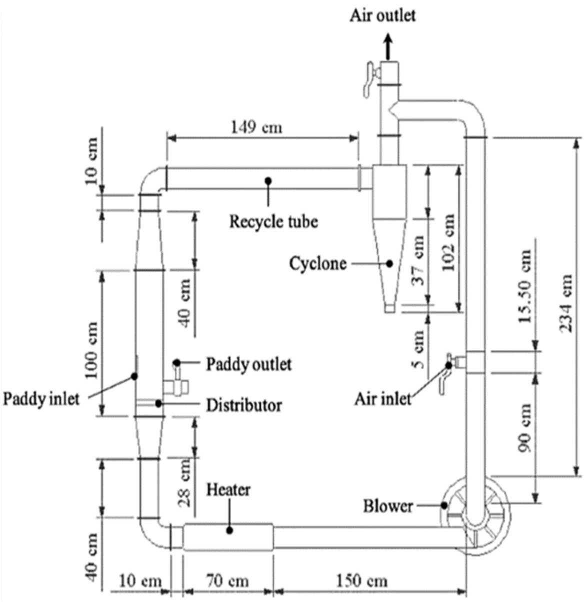


Figure 3. Schematic diagram of fluidized bed dryer with hot air.

C. Experimental Design

In soaking process, paddy sample was added to water which was controlled temperature at 70 ℃ and kept soaking for 5 hours. Then, the soaked paddy sample was stored in closed containers for 1 hour. After that, soaked sample (bed height of 9 cm) was put into a revolved sieve which was revolved at 10 rpm under the steaming times of 5, 10 and 15 min and steaming temperatures of 103, 110 and 118 ℃. In case of conventional steaming method, the sieve was fixed and the soaked sample was steamed at steaming temperature of 103 ℃ for 20 min. This condition provided the complete gelatinization and was used for comparing with modified steaming method. Then, the steamed paddy was taken out from the steaming chamber and it was dried in the dryer (fluidized bed) at 130 ℃ for decreasing the moisture content of steamed sample to 22% (d.b.). After that, the dried sample was tempered in a closed container for 30 minutes at the kernel temperature exiting from the dryer. Finally, the tempered paddy was dried in the shade to a moisture content of 13-15% (d.b.).

D. Quality Determinations

The thermal property was measured according to the method of Manful *et al*. [7] by using a differential scanning calorimeter (DSC). The head rice yield (HRY) was measured according to the method of Taghinezhad *et al*. [8]. It was calculated from the amount of white rice weight remaining as head rice after milling divided by the amount of paddy sample weight. The whiteness index (WI) was determined with a digital whiteness meter.

E. Statistical Analysis

The analysis of variance (ANOVA) was performed in a full factorial design by using Duncan's Multiple Range Test (DMRT). All determinations of experimental results were done at least in triplicate and all results were evaluated by mean at a confidence level of 95%. All statistical calculations were performed using SPSS software, version-14.

III. Results and Discussion

Fig. 4 showed the changes of moisture content (MC) and grain temperature (GT) in the rice sample steamed at steaming temperature of 118 ℃ under various steaming times and dried by a fluidized bed drying with hot air at 130 ℃. It was found that the steaming time affected the initial MC and GT before drying. The initial MC and GT were increased when increasing steaming time. This also occurred in the sample steamed at steaming temperatures of 103 and 110 ℃ (data not shown). The increases of initial MC and GT were due to the amount of steam. The long steaming time provided the larger amount of steam which was contacted between paddy and steam, leading to higher moisture and heat absorption and resulting in the higher initial MC and GT. However, the higher initial MC and GT caused the slower changes of MC and GT during drying.

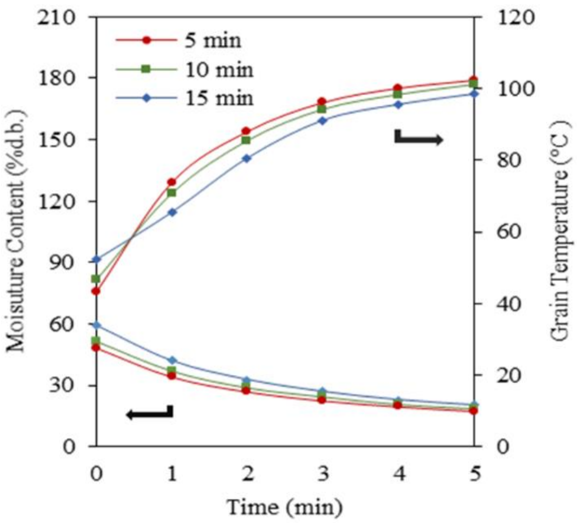


Figure 4. The MC and GT of parboiled rice steamed at steaming temperature of 118 ℃ under various steaming time.

When comparing the changes of MC and GT at steaming time of 10 min under various steaming temperatures (shown in Fig. 5), the initial MC and GT of sample steamed at high steaming temperature was higher than that of sample steamed at low steaming temperature. This is because the high steaming temperature led the higher rates of water and heat absorption [9]. In cases of steaming times at 5 and 15 min, the higher initial MC and GT were observed with the similar pattern of 10 min steaming time (data not shown).

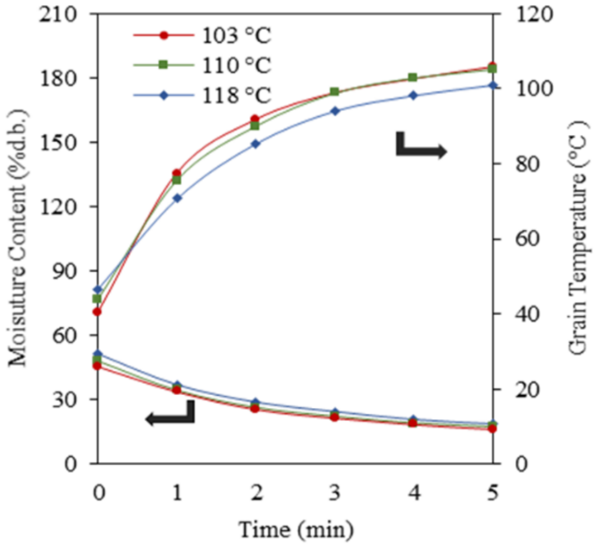
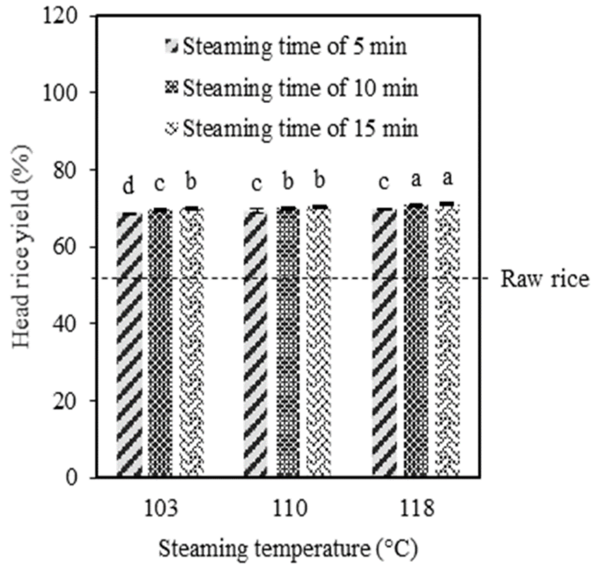


Figure 5. The MC and GT of parboiled rice steamed at steaming time of 10 min under various steaming temperature.

TABLE I. THE ΔH VALUE AND DG OF PARBOILED RICE STEAMED AT VARIOUS STEAMING TIMES AND TEMPERATURES

Sample	Steaming time (min)	Steaming temp. (℃)	ΔH (J/g)	DG (%)
Raw rice	-	-	9.28	-
Parboiled rice with conventional steaming method	20	103	0.00	100.00
Parboiled rice with modified steaming method	5	103	2.09	77.46
		110	1.94	79.15
		118	1.66	82.07
	10	103	0.38	95.87
		110	0.26	97.20
		118	0.00	100.00
	15	103	0.00	100.00
		110	0.00	100.00
		118	0.00	100.00

Table I shows the thermal properties of paddy sample steamed at various steaming times and temperatures. The enthalpy (ΔH) of raw rice was about 9.28 J/g. When the paddy was steamed and dried, the ΔH was decreased when comparing with the raw rice, indicating that the steaming and drying process provided the occurrence of starch gelatinization [10]. It was also found that the ΔH decreased when increasing the steaming time and temperature. Moreover, the ΔH values in case of parboiled rice steamed for 15 min were 0 at every steaming temperature as well as parboiled rice steamed for 10 min at 118 ℃. These implied that the starch gelatinization was completed. In addition, the ΔH was directly related to the degree of starch gelatinization (DG), the lower ΔH had the higher DG value. When comparing the DG value of parboiled rice with conventional steaming method, the parboiled rice with modified steaming method can decreased the time for complete gelatinization.



a, b, c, d Means with different letters indicate significantly difference ($p<0.05$)

Figure 6. Head rice yield percentage of parboiled rice steamed at various conditions.

Fig. 6 showed the percentage of head rice yield (HRY) in the parboiled rice steamed at various steaming times and temperatures. As expected, the HRY value of parboiled rice at every condition (68.53-71.09%) had higher than that of raw rice which was about 53.23%. This was due to starch granule modification during steaming and drying [11]. Moreover, it was found that the HRY value depended on the steaming time and temperature. The percentage of HRY was increased following the steaming time and temperature because of the higher DG as previously shown in Table I, leading to the increase in strength of rice [12]. The highest HRY values were obtained in paddy samples at steaming temperature of 80 ℃ for steaming times of 10 and 15 min which were about 70.80 and 71.09%, respectively. For the HRY value of parboiled rice with conventional steaming method, it was about 70.50% which was not different when comparing with the HRY value of parboiled rice with modified steaming method at steaming temperature of 103 ℃ for 15 min. this confirmed that the modified steaming method has the potential for increasing the quality of parboiled rice although the steaming time was decreased.

TABLE II. THE WHITENESS INDEX (WI) OF PARBOILED RICE STEAMED AT VARIOUS CONDITIONS

Sample	Steaming time (min)	Steaming temperature (℃)	Whiteness index
Raw rice	-	-	72.16±0.46^{a}
Parboiled rice with conventional steaming method	20	103	30.25±0.03^{k}
Parboiled rice with modified steaming method	5	103	39.33±0.03^{b}
		110	37.65±0.01^{c}
		118	35.08±0.02^{g}
	10	103	37.48±0.02^{d}
		110	35.38±0.02^{f}
		118	33.20±0.02^{i}
	15	103	35.44±0.01^{e}
		110	33.51±0.02^{h}
		118	31.05±0.02^{j}

$^{a\text{-}j}$ Means in the same column with different superscripts are significantly difference ($p<0.05$)

The behaviour of the Whiteness Index (WI) in parboiled rice under various conditions is shown in Table II. The WI of raw rice was 72.16. When the raw rice was subjected to steam and dry, the results clearly showed that the WI of sample was decreased to a range of 31.05-39.33 depending upon the time and temperature during steaming; the WI was decreased with the increase of steaming time and temperature. This is because of the Maillard type non-enzymatic browning [13]. When comparing the WI value of parboiled rice with conventional steaming method, the parboiled rice with modified steaming method provided the higher WI value in all conditions. This is because of the shorter steaming time. As shown in Table II, all WI values of parboiled rice were in the standard of light parboiled rice in commercial market which should be higher than 32.2 [14] except the parboiled steamed at steaming temperature of 118 ℃ for 15 min.

IV. CONCLUSIONS

The results of this research demonstrated that the time and temperature during steaming strongly affected parboiled rice qualities such as thermal properties (enthalpy; ΔH and degree of starch gelatinization: DG), head rice yield (HRY) and whiteness index (WI). The ΔH of sample was decreased when increasing the steaming time and steaming temperature whereas the DG was increased. These thermal property changes caused the higher HRY value in the parboiled rice sample. Moreover, the WI value of parboiled rice sample was decreased with increase of steaming time and steaming temperature.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Thatchapol Chungcharoen conducted the research and Wrote the paper; Anupong Meekotekong and Warunee Limmun analyzed the data; Naruebodee Srisang provided the conceptualization and formal analysis; all authors had approved the final version.

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