

# Evaluation of physical and cooking quality of parboiled germinated brown rice using a coaxial two-impinging stream dryer

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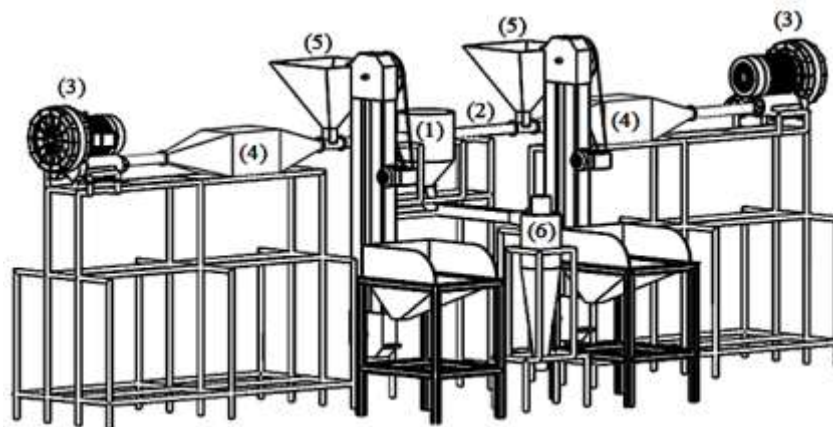
**Abstract.** The coaxial two-impinging stream dryer was developed and experimentally used for parboiled germinated paddy drying. The physical quality such as moisture content, color and cracking were investigated. In addition, the cooking quality such as texture properties and rehydration were evaluated as well. The drying parameters were conducted for drying temperatures of 50, 60, 70 and 80°C, drying air velocity at 28 m/s and  $44.14 \pm 14$  %d.b. for initial moisture content. The experimental result found that the final moisture content was reduced to about 38.36, 36.15, 31.80 and 30.70 %d.b. for drying temperatures at 50, 60, 70 and 80°C, respectively. The cracking was little occurred, which was less than  $2.73 \pm 0.27\%$  for all drying conditions. From the investigation of color changes, it is found that the *L*-, *a*-, and *b*- values were negligible changed in the range between  $44.537 \pm 0.548$  to  $46.608 \pm 0.743$ ,  $-3.117 \pm 0.460$  to  $-3.182 \pm 0.345$ , and  $6.174 \pm 0.585$  to  $6.861 \pm 0.406$ , respectively. The values of total color difference change ( $\Delta E$ ) were approximately  $45.079 \pm 0.530$  to  $47.220 \pm 0.786$ . The increase of drying air temperature affected the increase of textural properties. Separately, considering the following maximum values of hardness, gumminess, adhesiveness, cohesiveness and chewiness were about  $686.15 \pm 4.89$ ,  $445.50 \pm 54.07$ ,  $-0.070 \pm 0.03$ ,  $0.625 \pm 0.02$ ,  $6090.72 \pm 743.0$ , respectively. The rehydration percentages were ranged from  $60.333 \pm 6.72\%$  to  $65.105 \pm 6.24\%$  for drying temperature at 80°C.

**Keywords:** Parboiled rice, impinging stream dryer, nutritional quality, cooking quality, texture property.

## INTRODUCTION

Rice (*Oryza sativa* L) is one of the most important staple foods and also leading food crops in the world especially in South East Asia (Titaporn *et al.*, 2018). The total rice production in Asia contributes 90% of worldwide in which India, along with China, are accounted for 55%, besides it is found that approximately 20% of total rice production are processed into parboiled rice (Chaitanya *et al.*, 2015). The work of Ayamdoo *et al.* (2013) reveals that the parboiled rice is carried out in the three Northern and Volta regions of Ghana. With reference to Naruebodee *et*

*al.* (2019), it reveals that the parboiled rice was created in many countries, particularly in Asia, Europe and America. The demand of parboiled rice has been increased because of its reputation for nutritional excellence and the health claim associated with eating this type of rice (Vikrant *et al.*, 2018). The better recovery after milling, grain translucent, breakage resistance and easy removal of hull during milling are advantageous of parboiled rice (Chaitanya *et al.*, 2015; Elbert *et al.*, 2000; Bhattacharya, 1985). The parboiling is a crucial process, which improves



**Figure 1.** Schematic diagram of the coaxial two-impinging stream dryer includes: (1) a drying chamber (2) inlet pipes (3) two high-pressure blowers (4) two sets of electric heaters (5) feeders (6) cyclone

the rice quality, particularly the increase of head rice yield.

Parboiled germinated brown rice is produced by steaming germinated paddy rice. The germination process preserves increase the nutritional values and bioactive compounds, especially the increase of GABA, vitamin E, niacin and lysine, magnesium, and nearly 2-fold for phenolic acids (Kansuda *et al.*, 2016).

From the literature review about the typical methods that have been used to dry paddy in Thailand and other countries such as a fluidized-bed dryer (Sakchai *et al.*, 2011), a spouted-bed dryer (Mehdi *et al.*, 2020), a pneumatic dryer (Marcelo *et al.*, 2016), and an impinging stream dryer (Chatchai and Sakamon, 2010). The basic principle of an impinging stream dryer is the flow of two streams of gas and at least one containing wet particle. These two streams flow on the same axis but in the opposite direction. The two streams then collide at the midpoint, which is known as the impingement zone. In this zone, the high shear force and turbulence and the lead to the excellent conditions of intensifying heat, mass and momentum transfer are occurred (Chatchai and Sakamon, 2010).

On the basis of principles and reasons mentioned above, the aim of this research is to investigate the physical quality and texture properties of parboiled germinated brown rice under the coaxial two-impinging stream dryer. Namely, the moisture content change, cracking, color, rehydration, hardness, gumminess, adhesiveness, cohesiveness, and chewiness are evaluated.

## MATERIALS AND METHODS

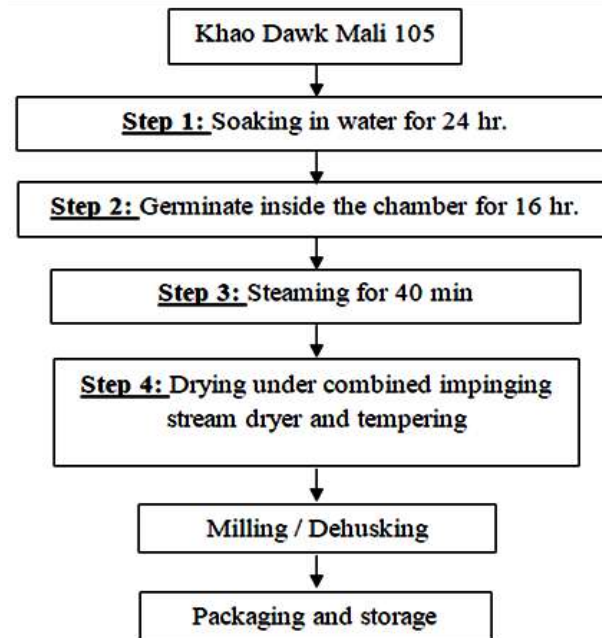
### Experimental set-up

Figure 1 shows a schematic diagram of the coaxial two-

impinging stream dryer for the experimentally use in this study. The highlight of this dryer is the quick reduction of the moisture content of parboiled germinated rice. The main components of dryer, including (1) a drying chamber with the inner diameter of 0.35 m, (2) 0.0508 m diameter pipe and 0.05 m impinging zone, (3) two high-pressure blowers, were used to supply the drying air to the drying chamber, each rated at 1.5 kW, 200 mbar maximum static pressure and 210 m<sup>3</sup>/h air flow rate, (4) two sets of electric heaters, each rated at 7 kW, (5) feeders, and (6) cyclone. The drying temperature was controlled by PID controller. The drying air velocity was measured by hot-wire anemometer (Testo-anemometer) with an accuracy of  $\pm 0.1$  m/s.

### Procedure and process of parboiling germinated brown rice

The parboiled germinated brown rice is produced by streaming germinated paddy rice from Khao Dawk Mali 105 (*Oryza sativa* L. cv., KDML 105), Thai rice varieties grown in Thung Kula Ronghai in the Northeast region of Thailand. The procedure and process of parboiled germinated brown rice was prepared according to the traditional method of Ban Mai Sai-Ngam integrated agriculture community enterprise located in Na-Siao subdistrict, Mueang district, Chaiyaphum province, Thailand. For this method in brief, the paddy was cleaned before soaking in the room temperature water for 24 h. After that, it was germinated inside the chamber for about 16 h, and from the observation it appeared a small bud at rice germ with a length of about 0.5 to 2 mm. Then the germinated paddy was steamed approximately for 40 min and then the parboiled germinate paddy was dried by the coaxial two-impinging stream dryer. At final step, the parboiled germinated paddy was de-husked. The procedure and process of parboiled germinated brown



**Figure 2.** Procedure and process of parboiled germinated brown rice according to Ban Mai Sai-Ngam integrated agriculture

rice is shown in Figure 2.

### Drying conditions

The parboiled germinated paddy dried by the coaxial two-impinging steam dryer reduced the moisture content before de-husking. The drying parameters were conducted at drying temperatures of 50, 60, 70 and 80°C, and drying air velocity at 28 m/s. These experimental dryings were combined with a tempering period at ambient for 20 min for tempering duration. The initial moisture content of parboiled germinated paddy was approximately  $44.14 \pm 14$  %d.b.. The moisture content was determined by drying triplicate samples in a hot-air oven at 103°C, 72 h (ASA 1990), and calculated on dry basis (d.b.).

### Determination of physical qualities of parboiled germinated brown rice

#### Cracking

The cracking of parboiled germinated brown rice was inspected visually by sorting out the cracked kernel with fluorescent light using a 200-gram sample (Sakchai *et al.*, 2011). The cracking (Cr) can be calculated by the following equation:

$$\text{Cr (\%)} = (W_c / W_s) \times 100 \quad (1)$$

Where  $W_c$  and  $W_s$  are the weight of creaked grains and weight of the samples, respectively.

### Color measurement of parboiled germinated brown rice

The color of the parboiled germinated brown rice was measured by a Hunter Lab colorimeter (MiniScan XE Plus, Henter Associates Laboratory, Inc., USA) and described in the  $L$ - (light-dark spectrum),  $a$ - (green-red spectrum) and  $b$  color (blue-yellow spectrum). The total color difference ( $\Delta E$ ) change was calculated as shown in Equation 2 (Sakchai *et al.*, 2011).

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (2)$$

### Textural properties of parboiled germinated brown rice

The textural properties of cooked parboiled germinated brown rice samples were measured by the texture analyzer (TA-XT plus) as shown in the Figure 3. Before testing, the sample was cooked in the aluminum cylindrical, using sample to water ratio of about 1:1. The cooked samples, comprising of 12 grains were placed on a plate. The cylindrical probe, with a diameter of 50 mm, was used for testing cooking characteristics such as hardness, gumminess, adhesiveness, cohesiveness and

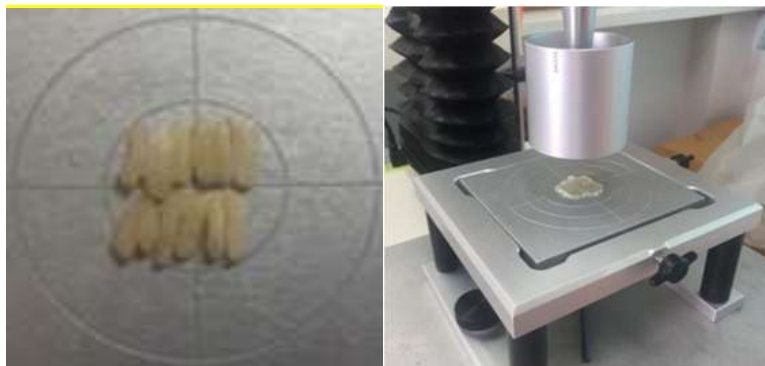


Figure 3. Texture analyzer.

Table 1. The moisture content of parboiled germinated paddy under different conditions.

Drying temperature, °C	Moisture content, %d.b.					
	Initial moisture content	Tempering between drying states				
		1	2	3	4	5
50	44.84	42.63	41.90	39.35	38.76	38.36
60	45.69	41.28	40.41	38.98	37.46	36.15
70	44.76	40.41	36.811	36.17	34.94	31.80
80	44.87	39.76	35.39	34.17	33.69	30.70

chewiness. The probe was compressed at a pretest speed of 1 mm/s and posttest speed of 10 mm/s. The hardness value was defined as a maximum compressive force at 85% strain of force deformation curve.

#### Rehydration ratio of parboiled germinated brown rice

Rehydration ratio of parboiled germinated brown rice sample was determined by immersing a cube of sample into a constant temperature water bath at 90°C for 5 min, using rice to water ratio of about 1:10 by weight, then rinsing excess water with blotter, and then weighing. The rehydration ratio was calculated by using the weight of sample before and after rehydration as follows (Jong-Whan *et al.*, 2011):

$$\text{Rehydration ratio} = (w_2 - w_1) / w_1 \quad (3)$$

Where  $w_1$  and  $w_2$  is the initial and final weight of the parboiled germinated brown rice sample, respectively.

## RESULTS AND DISCUSSION

### Moisture content of parboiled germinated brown rice

The moisture content of parboiled germinated paddy was investigated under different drying conditions, resulting in the moisture content as shown in Table 1. This table

shows that the average initial moisture content was approximately at  $44.14 \pm 14$  %d.b. In post-drying tempering, the final moisture content was reduced to 38.36, 36.15, 31.80 and 30.70 %d.b. by the increase of drying temperatures at 50, 60, 70 and 80°C, respectively. When the drying of grain kernel is temporarily stopped, the moisture within the grain kernel equalizes due to diffusion. When drying is restarted, the drying rate becomes higher compared to continuous drying. The process of stopping intermittently is called tempering. In addition, Renjie *et al.* (2010) indicated that drying and tempering processes had significant effects on the moisture gradient and rice fissuring as well.

### Cracking of parboiled germinated brown rice

From Table 2, it can be concluded that the parboiled germinated brown rice under the coaxial two-impinging stream dryer negligibly occurred in all drying conditions. Surprisingly, the parboiled germinated brown rice was less than  $2.73 \pm 0.27\%$ , under combined coaxial two-impinging stream dryer and tempering processes. Tempering at high temperature reduced the percentage of fissured kernels and enhanced head rice yield (HRY) independently from the number of drying steps (Aquerreta *et al.*, 2007). The work of Vikrant *et al.* (2018) reveals that the parboiling of paddy resulted in the reduction of breakage imported to kernel because of gelatinization of starch; as a result, the cracks, incomplete

**Table 2.** The cracking of parboiled germinated brown rice.

Drying temperature, °C	50	60	70	80
Cracking,%	2.31 ± 0.23	2.56 ± 0.45	2.73 ± 0.27	2.02 ± 0.31

**Table 3.** The color changes of parboiled germinated brown rice under different drying conditions.

Drying temperature, °C	The value of color changes			
	L	a	b	ΔE
50	45.883 ± 0.536	-3.117 ± 0.460	6.769 ± 0.406	46.352 ± 0.582
60	44.537 ± 0.548	-3.172 ± 0.166	6.174 ± 0.585	45.079 ± 0.530
70	46.088 ± 0.834	-3.162 ± 1.494	6.625 ± 0.489	46.692 ± 0.866
80	46.608 ± 0.743	-3.182 ± 0.345	6.861 ± 0.406	47.220 ± 0.786

**Table 4.** Textural properties of cooked parboiled germinated brown rice.

Drying temperature, °C	Textural properties				
	Hardness	Gumminess	Adhesiveness	Cohesiveness	Chewiness
50	483.31 ± 22.34	356.51 ± 38.45	-2.230 ± 2.18	0.610 ± 0.16	3826.20 ± 203.9
60	560.21 ± 34.39	352.60 ± 14.27	-0.620 ± 0.22	0.602 ± 0.03	4260.03 ± 172.6
70	666.71 ± 27.39	394.24 ± 35.97	-0.070 ± 0.03	0.615 ± 0.01	6090.72 ± 743.0
80	686.15 ± 4.89	445.50 ± 54.07	-0.170 ± 0.16	0.625 ± 0.02	4486.55 ± 373.3

grains filling, and chalkiness are completely healed.

### Color of parboiled germinated brown rice

The color is one of the most important appearance attributes of parboiled germinated brown rice, wherewith it influences consumer acceptability. The value of color changes (*L*, *a*, *b* and ΔE) was evaluated for parboiled germinated brown rice under different drying conditions as shown in Table 3. In this experimental result, it is found that the *L*-values were negligibly changed in the range between 44.537 ± 0.548 to 46.608 ± 0.743, depending on the drying temperature. Similarly, the values of *a*, *b* and ΔE were approximately in the range between -3.117 ± 0.460 to -3.182 ± 0.345, 6.174 ± 0.585 to 6.861 ± 0.406 and 45.079 ± 0.530 to 47.220 ± 0.786, respectively.

With reference to Kanokkan *et al.* (2009), it reveals that it has been hypothesized that the color change of rice occurred during parboiling are mainly caused by non-enzymic browning of Maillard type. In addition, non-enzymic browning, husk and bran pigments also appear contributing to parboiled rice color. The contribution of pigments to coloration of parboiled rice is supported by the fact that some nutrients (minerals and vitamins) from the bran diffuse into the kernel and other bran compounds (lipids) leach out during parboiling, resulting in the increase of yellow appearance when compared to brown rice (Kimura *et al.*, 1993; Kaneko *et al.*, 2002).

### Textural properties

The textural properties (hardness, gumminess, adhesiveness, cohesiveness and chewiness) of cooked parboiled germinated brown rice samples are presented in Table 4, as one of the most crucial quality attributes of cooked rice. All experimental drying conditions showed that the increase of drying air temperature affected the textural property increase. Therefore, the drying temperature may have an effect on the changes in the internal structure of the grain kernel. The maximum value of hardness, gumminess, adhesiveness, cohesiveness and chewiness were approximately at 686.15 ± 4.89, 445.50 ± 54.07, -0.070 ± 0.03, 0.625 ± 0.02, 6090.72 ± 743.0, respectively.

According to Titaporn *et al.* (2018), the hardness is defined as the required for cebiting through the sample with molars. The increased hardness of parboiled germinated brown rice undergoing the steaming and drying treatment was attributable to the gelatinization of rice starch and the formation of amylase-lipid complex, thus causing starch granules to lose their polygonal shape (Sunan and Jaturong, 2018).

The studies of Sunan and Jaturong (2018) and Chungcharoen *et al.* (2015) found that the germination of brown rice and its texture becomes soft to a certain extent owing to the physiological activity of brown rice itself and activities of various enzymes, resulting in a rice type with soft texture and ease of cooking, in relation to normal brown rice. In contrast, the non-steamed drying

**Table 5.** Percentage of rehydration.

Drying temperature, °C	W <sub>d</sub>	W <sub>t</sub>	% Rehydration
50	13.324 ± 0.951	21.679 ± 1.169	63.029 ± 7.905
60	13.595 ± 0.924	22.338 ± 0.927	64.734 ± 8.786
70	13.703 ± 0.600	22.463 ± 0.819	64.149 ± 8.201
80	13.369 ± 0.734	22.073 ± 1.414	65.105 ± 6.242

rice samples are metabolically active and hence exhibiting high activities of hydrolases, e.g.,  $\alpha$ -amylase, which subsequently affect the hardness value. With the passage of time, the starch and protein in non-steamed drying rice would decompose while plumules and radicles grow excessively, rendering the germinated non-steamed drying brown rice unfit for consumption in addition to a deformation of rice grain shape once cooked.

### Rehydration ratio

Table 5 shows the percentage of rehydration of parboiled germinated brown rice, which is found that the drying at high temperature has better recovery than drying at low temperature because during drying it can rapidly pull the water molecules within the structure better. This phenomenon may result in the larger pore size. At the drying air temperature of 80°C was the maximum rehydration and the percentage value of the rehydration is ranged from 60.333 ± 6.72 to 65.105 ± 6.24.

### CONCLUSIONS

The present study has demonstrated that the coaxial two-impinging stream dryer was experimentally used for parboiled germinated brown rice drying. The physical quality and cooking quality were investigated, consisting of moisture content, cracking, and color. In addition, the textural properties (hardness, gumminess, adhesiveness, cohesiveness and chewiness) and rehydration were evaluated also. Post-drying tempering at 80°C resulted in greater moisture removals and can be achieved up to 30.70% d.b.. The steaming of germinated paddy resulted in the reduction of breakage imported to kernel because of gelatinization of starch. The cracking of parboiled germinated brown rice was less than 2.73±0.27%. The *L*-, *a*-, *b*- and  $\Delta E$ -values were negligibly changed, depending on the drying temperature. The total color difference change ( $\Delta E$ ) was approximately in the range between 45.079 ± 0.530 to 47.220 ± 0.786. The maximum value of hardness, gumminess, adhesiveness, cohesiveness and chewiness were approximately at 686.15 ± 4.89, 445.50 ± 54.07, -0.070 ± 0.03, 0.625 ± 0.02, 6090.72 ± 743.0, respectively. The rehydration of parboiled germinated brown rice found that the drying at high temperature has better recovery than drying at low temperature. The maximum percentage of the rehydration was 65.105 ±

6.24% for drying temperature at 80°C. Although no cracked kernels were visually observed, a study should be conducted in the future to evaluate the quality of parboiled germinated brown rice dried under impinging stream dryer, especially in terms of nutritional qualities and antioxidants.

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