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Published by the Faculty of Engineering, Khon Kaen University, Thailand

The improvement of germination method for producing the germinated brown rice using a water spraying system with a revolved sieve

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Received 6 August 2024
Revised 4 November 2024
Accepted 7 November 2024

Abstract

Water soaking is an important method in germinated brown rice (GBR) production that causes fermentation, leading to an unpleasant smell of GBR. In this research, a water spraying system with a revolved sieve is applied to produce the GBR. The increased speed and time of spray break led to higher moisture content and water absorption. The spray break of 30 min and revolved speed of 15 rpm provided the shortest time to obtain the paddy with a moisture content of 30% (w.b.). The incubation pattern with a revolved sieve and water spray provided the shortest incubation time for 90% germination. When producing the GBR with a water spraying system with a revolved sieve (GBR-WSSRS), it had a lower number of microorganisms compared to the GBR with a water soaking (GBR-WS), leading to higher scores of overall acceptability. However, the GBR-WSSRS had a lower GABA content than the GBR-WS.

Keywords: Germinated brown rice, Water spraying system, Germination method, Moisture content, Quality

1. Introduction

Germinated brown rice (GBR), the specific novel rice product, is widely consumed worldwide [1, 2]. Compared with white rice or brown rice, GBR is rich in many bio-functional compounds, especially the γ-aminobutyric acid (GABA) [3-6]. As well-known, this bio-functional compound promotes several health benefits such as alleviating pain and anxiety, regulating blood pressure and heart rate, and inhibiting cancer cells from spreading [7-11]. Many Studies have reported that germination can increase the GABA content in the rice grain, and the method used for promoting the germination of the rice grain is water soaking [12-15]. Water soaking is an essential conventional method to promote the germination of rice grain. Normally, the rice grains are soaked in the water to germinate for a certain period depending on the water temperature, rice variety, and germination method [16-18]. During soaking in water, rice grain germination occurs when rice grains' moisture content reaches approximately 30% wet basis (w.b.) [19-21]. With this high moisture level, the growth of microorganisms can be induced and cause fermentation in GBR [3, 22]. To achieve the GBR with high GABA, the rice grain needs to soak in water for a long time. This provides a vigorous fermentation, leading to an unpleasant smell of GBR and resulting in a product of lower quality. [2, 23]. Hence, the water was changed during germination to alleviate the fermentation problem [24, 25]. Kaosa-ard and Songsermpong [16] soaked the paddy in water for 72 hours and changed the water every 4 hours. Chungcharoen et al. [12] changed the water every 4 hours for germinating the Chai Nat 1 rice variety, which was soaked in water for 60 and 72 hours for paddy and brown rice, respectively. However, the GBR still had an unpleasant smell. In addition, the long soaking time also provides a high moisture content in GBR, leading to an extended drying duration and variable product quality. Therefore, finding a technique that can improve the germination method for producing the GBR is important.

In this research, the water spraying system with a revolved sieve has been applied in the germination method instead of the water-soaking method. There are 2 steps for germination using a water spraying system with revolved sieve such as water spraying and incubating. Water is sprayed into the rice grains until rice grains' moisture content reaches approximately 30% wet basis (w.b.) and then incubated in the sieve without water-soaking until the rice grains' germination percentage reaches approximately 90%. These would reduce the spoilage of rice grains occurring in the water soaking method, leading to decreased fermentation in the GBR and resulting in the decrease of unpleasant smell. In addition, the water spraying system with a revolving sieve may also impact the GABA content during the germination process. This germination pattern could decrease the germination time, leading to lower production of bio-functional substances. However, the shorter germination time would result in lower moisture content in GBR, leading to a reduced drying duration of GBR. The GABA content of GBR may not differ when compared with GBR using the water-soaking method.

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doi: 10.14456/easr.2024.69

Thus, the main objectives of the present study are to germinate a rice grain using the water spraying system with a revolved sieve instead of the water-soaking method by investigating the effects of water spraying pattern and sieve rotation speed (in the water spraying step) on the moisture content and water absorption and the effect of incubation patterns (in the incubation step) on moisture content and germination percentage. Moreover, the qualities of GBR produced from the appropriate conditions such as the number of microorganisms, GABA content, and sensory were also determined and compared with those of GBR prepared with the water-soaking method.

2. Materials and methods

2.1 Paddy sample

Suphanburi 1 paddy variety (*Oryza sativa L.*) sample with an initial moisture content of 11% wet basis (w.b.) used in this study was purchased from the Rice department, Ratchaburi, Thailand. It was harvested in 2020 and had already been stored for three months prior to the experiment.

2.2 Experimental set-up

The prototype of a germinated rice production machine using a water spraying system with a revolved sieve, shown in Figure 1, was used to produce the GBR. It consists of the following parts: a rectangular germination chamber with an overall dimension of 50 cm × 70 cm × 30 cm, a stainless steel cylindrical sieve with 27 cm diameter and 50 cm length, three spray nozzles fixed on a stainless steel horizontal axis which were installed at the center of sieve, 1HP water motor pump, 1HP motor for revolving sieve using the belt, a blower connected to an electrical heater with 6 kW for drying and halogen lamp.

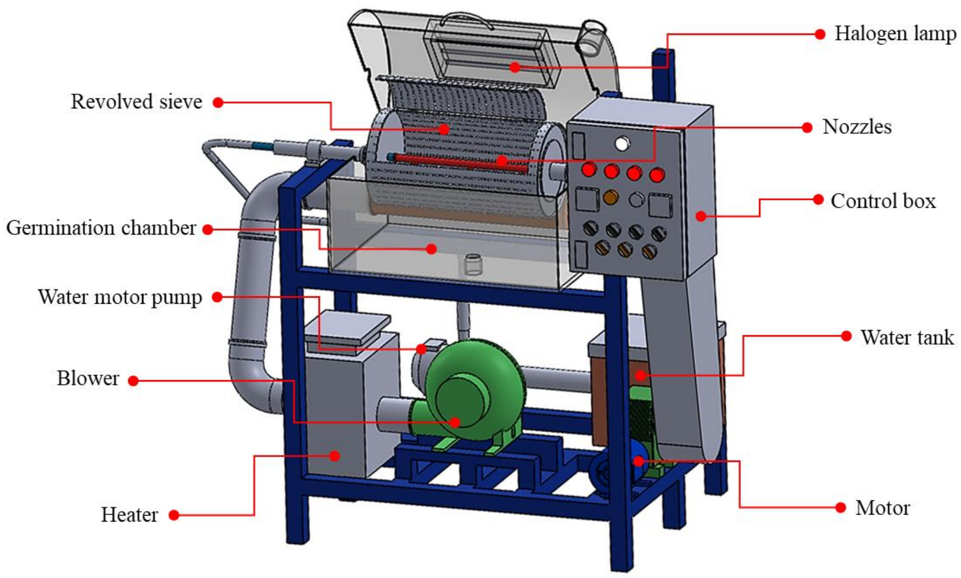


Figure 1 Schematic diagram of germinated rice production machine using water spray system with revolved sieve [26].

2.3 Preparation of germinated samples in the germination method

The germination method of germinated rice production machine using a water spraying system with revolved sieve was divided into 2 main steps: a water spraying step to obtain the saturated paddy with the moisture content of 30% wet basis (w.b.) and an incubating step to obtain the germinated paddy with 90% germination. For the water spraying step (shown in Figure 2), the 2 kg of paddy sample was placed into the sieve within darkness at 35°C and 90% air humidity, and water at room temperature was sprayed into the paddy at a water spraying rate of 7 L/min for a minute. A flowmeter controlled the spraying rate of water. The sieve was also revolved at the same time. The rotation speeds of the sieve were varied at 5, 10, and 15 rpm. After that, the spraying system and sieve rotation were stopped. The times of spray break were varied at 15, 30, and 45 minutes. The procedure was repeated until the moisture content of the paddy reached 30% wet basis (w.b.), which is the reasonable rice moisture for germination [19]. The appropriate condition providing the paddy with the moisture content of 30% wet basis (w.b.) was selected and used for the incubation step.

In the incubating step (shown in Figure 3), the 2 kg of saturated paddy, following the appropriate condition obtained from the water spraying step, was incubated in the sieve with 3 incubation patterns including fixed sieve, revolved sieve, and revolved sieve combined with the water spraying system. The sieve was revolved for a minute every 12 hours using an appropriate sieve rotation from the water spraying step. The water at room temperature was sprayed at the spraying rate of 7 L/min for a minute every 12 hours as same as the sieve rotation. The procedure was repeated until the germination percentage of the paddy reached 90%. The appropriate condition providing the 90% germinated paddy with the shortest incubating time was selected to produce the GBR.

Besides the germination method using the water spraying system with a revolved sieve, the soaking method was also produced for comparison. The 2 kg of paddy sample was soaked in 7 liters of water at room temperature until the germination percentage of the paddy reached 90%. The water was changed every 4 hours.

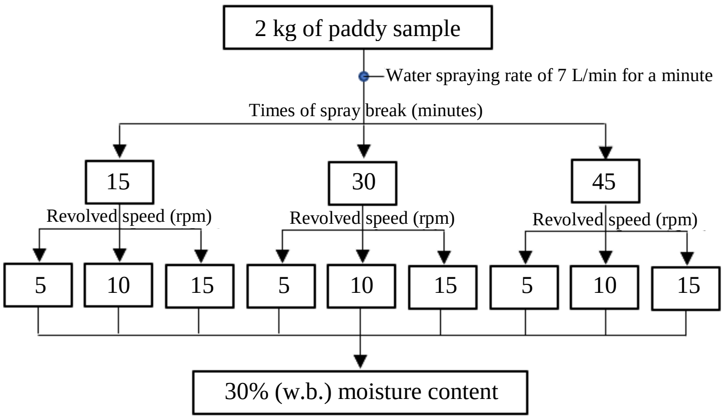


Figure 2 Overall procedure for water spraying step.

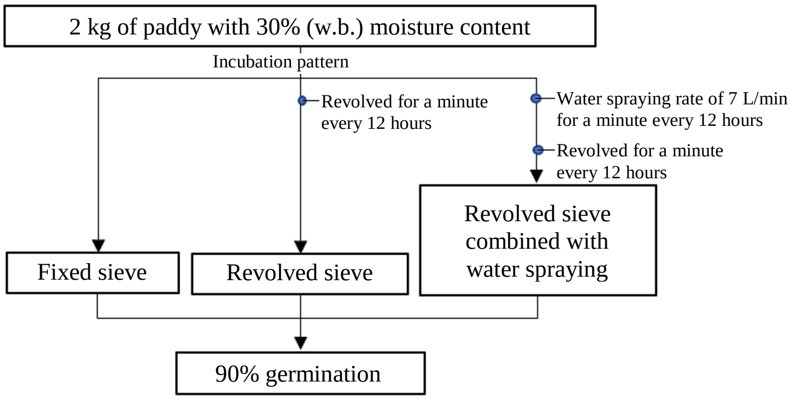


Figure 3 Overall procedure for incubating step.

2.4 Preparation of dried germinated samples

Both germinated paddy prepared with the water-soaking method and the water spraying system were dried to a moisture content of 18% (w.b.). The drying conditions were set at a hot air temperature of 130°C combined with a halogen power of 2,000 W, and a superficial air velocity was set at 6.5 m/s. During drying, the sieve was revolved at 15 rpm. In addition, shade-dried germinated rice was compared with the dried germinated rice. This sample was taken to shade dry using ambient air until the moisture content reached 18% (w.b.).

2.5 Quality analysis

Three quality indicators reported in the average value of three replications consisted of the number of microorganisms, GABA content, and sensory evaluation. The number of microorganisms was determined according to the standard method of AOAC (2000) [27]. The GABA content was measured by high-performance liquid chromatography (HPLC) (Agilent 1100 Series, Agilent Technologies, Palo Alto, CA) according to the method proposed by Banchuen et al. [28]. For sensory evaluation, fifty untrained panelists from King Mongkut's Institute of Technology Ladkrabang, Prince of Chumphon Campus, Thailand, were invited to evaluate the cooked samples, and the 9-point hedonic scale was used for evaluating the sensory which was proposed by Chungcharoen et al. [12].

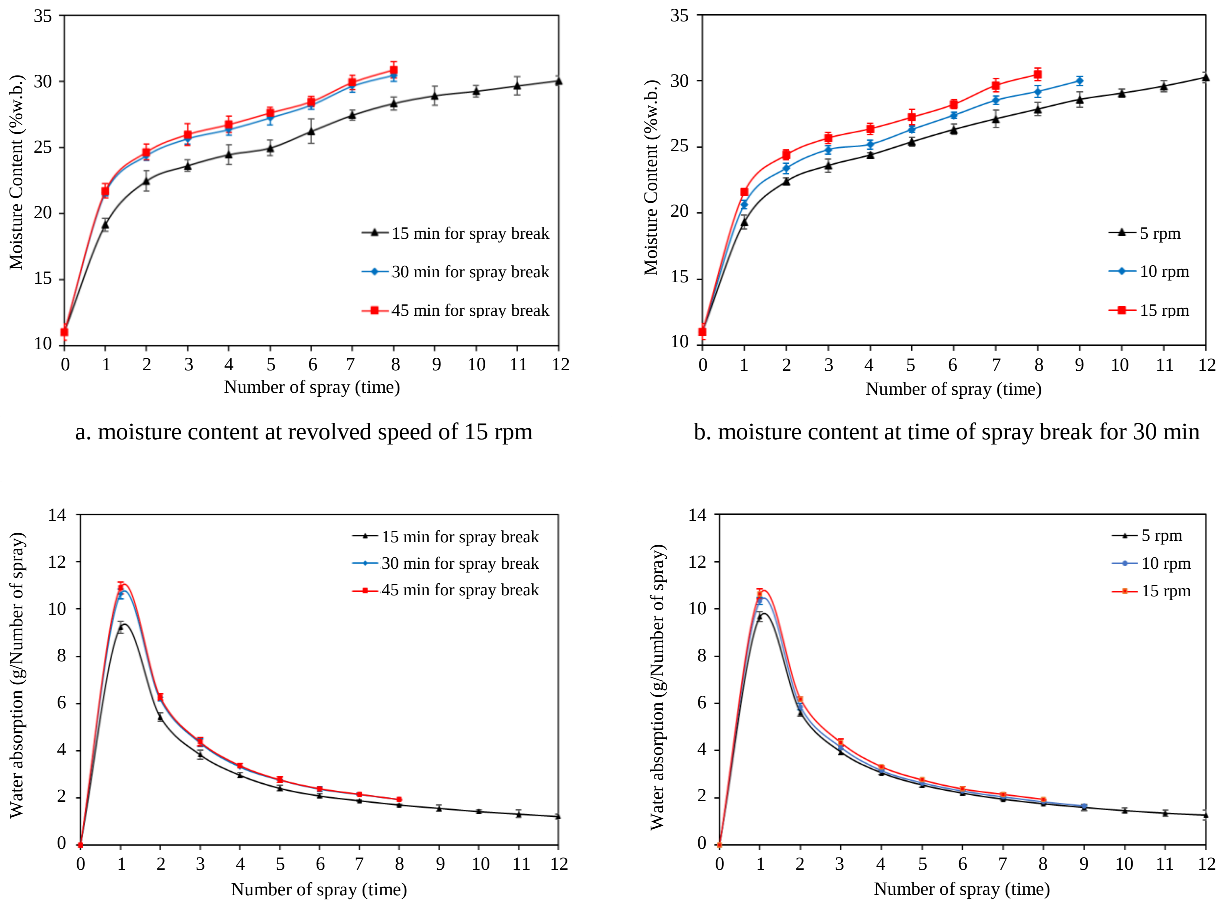
2.6 Statistical analysis

All data were analyzed by one-way analysis of variance (ANOVA), and the results are reported as mean values with standard deviations. Duncan's multiple range test (DMRT) was used to establish differences among mean values at a confidence level of 95%. All statistical calculations were performed using SPSS software, version-14.

3. Results and discussion

3.1 The changes in moisture content and water absorption in a water spraying step

The moisture content and water absorption of paddy at various revolved speeds and times of spray break are shown in Figure 4. The experimental result showed that the moisture content of paddy (shown in Figures 4a and 4b) rapidly increased at the first time of water spraying and slowly increased afterward in the next water spray. This result corresponded to the water absorption result (shown in Figures 4c and 4d), showing the high water absorption in the first stages and following the slower water absorption in later stages. A similar result was found by Ejebe et al. [29] and Hanucharoenkul et al. [30], who reported that a fast water absorption rate was observed during the early soaking period. Then, the water absorption was gradually slow. When considering the effect of the time of spray break on the moisture content and water absorption of paddy, as shown in Figures 4a and 4c, it was found that at the revolved speed of 15 rpm, the moisture content and water absorption of paddy at spray break of 15 min were significantly lower than those of paddy at spray breaks of 30 and 45 min. In contrast, the paddy's moisture content and water absorption at 30 and 45 min spray breaks were not different. This pattern was also observed at revolved speeds of 5 and 10 rpm (data not shown). For the revolved speed effect, it was found that the more revolved speed applied, the more moisture content and water absorption of the paddy gained, as shown in Figures 4b and 4d. This pattern also occurred in another spray break (data not shown). The higher moisture content at a higher revolved speed resulted from the interaction between the rice sample and water. The contact between the rice sample and water increased with the higher revolving speed, resulting in a more uniform water distribution throughout the bed and leading to a higher moisture content. A similar result was found by Srisang and Chungcharoen [31], who reported that increasing the rotation speed could enhance steam distribution throughout the rice sample during parboiling. To obtain the paddy with the moisture content of 30% (w.b.), it required 12 times of the spray with 15 min spray breaks and 8 times with 30 and 45 min spray breaks, respectively at a revolved speed of 15 rpm, as shown in Figure 4a. This revolved speed provided less number of sprays than the other revolved speeds (5 and 10 rpm). When considering the spray break of 30 and 45 min, the spray break of 30 min had more efficiency in increasing the moisture content of the paddy with saving time (4 hours) than the spray break of 45 min (6 hours). Therefore, the spray break of 30 min and the revolved speed of 15 rpm were appropriate conditions to prepare the sample for the incubation step.



a. moisture content at revolved speed of 15 rpm

b. moisture content at time of spray break for 30 min

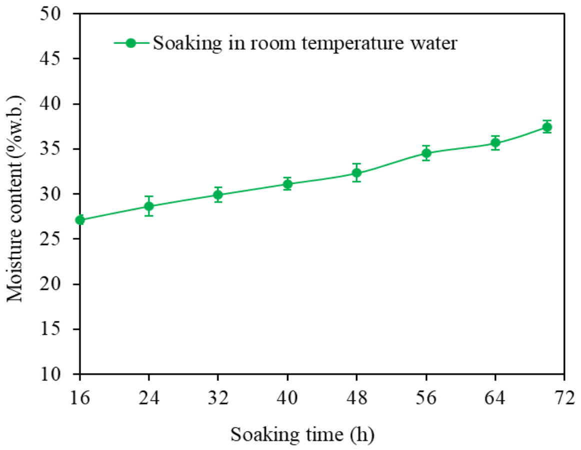
c. water absorption at revolved speed of 15 rpm

d. water absorptionat time of spray break for 30 min

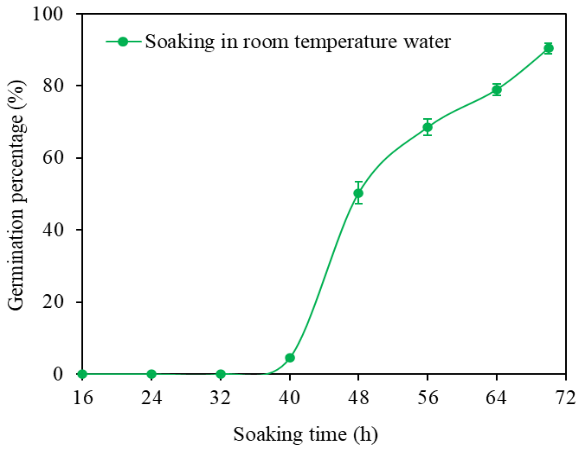
Figure 4 The changes in moisture content and water absorption of paddy.

3.2 The changes in moisture content and germination percentage in an incubation step

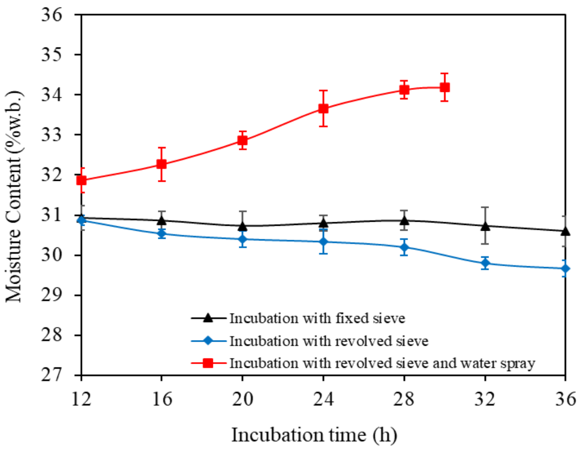
The moisture content and germination percentage of paddy at various incubation patterns are shown in Figure 5. For the water-soaking method used for comparison to a water spraying method (shown in Figures 5a and 5b), the moisture content and germination percentage of paddy increased with soaking time. The paddy started to germinate when soaking in water for 40 hours. The moisture content of the paddy at this soaking time was about 30% (w.b.). After that, the paddy germinated to 90% when soaking in water for 70 hours, and the moisture content of the paddy was about 38% (w.b.). The germ length of germinated paddy was about 1 mm. From the results, the germination time of paddy germinated to 90% using the water-soaking method was longer than that of paddy germinated to 90% using the water spraying system with a revolving sieve (as shown in Figure 5d). This is probably due to the oxygen which is the major germination factor [32]. The oxygen concentration in water is lower than in air, which slows down the germination of paddy using the water-soaking method [33, 34], resulting in longer germination time. When considering the incubation pattern as shown in Figures 5c and 5d, it was found that incubation with a fixed sieve provided the germinated paddy (3%) after incubating for 16 hours, and the germinated paddy was increased to 90% when incubating for 36 hours. This incubation pattern decreased moisture content when the time increased, leading to germinated paddy with varied germ lengths. Some germ lengths varied from 1-3 mm (about 15% of germinated paddy). This was obviously observed when using the incubation pattern with the revolved sieve. The rotation of the sieve provided more contact between the rice sample and air, leading to more water evaporation in the exterior of the rice grains and resulting in the difference in moisture content between the interior and exterior of the rice grains. This caused a greater decrease in moisture content during incubation (Shown in Figure 5c) and a lower germination percentage (Shown in Figure 5d) when compared with the incubation pattern with a fixed sieve. In addition, the moisture content gradient within the rice grains also caused the higher germinated paddy with germ lengths varied from 1-3 mm (about 25% of germinated paddy). However, the incubation time provided the 90% germination was still 36 hours. The moisture content was increased during incubation in the incubation pattern with a revolved sieve and water spray. This provided the highest amount of germinated paddy when compared with other incubation patterns simultaneously, leading to the shortest incubation time for germination (30 hours). Moreover, obtained germinated paddy from the incubation pattern with the revolved sieve and water spray was also uniform germ length. From the experiment data, the incubation with the revolved sieve and water spray was an appropriate pattern that was selected to prepare the sample for drying.



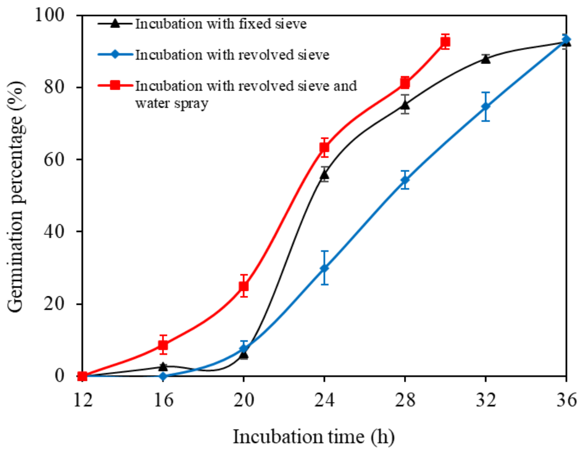
a. moisture content of paddy during water soaking



b. germination percentage of paddy during water soaking



c. moisture content of paddy during incubation step

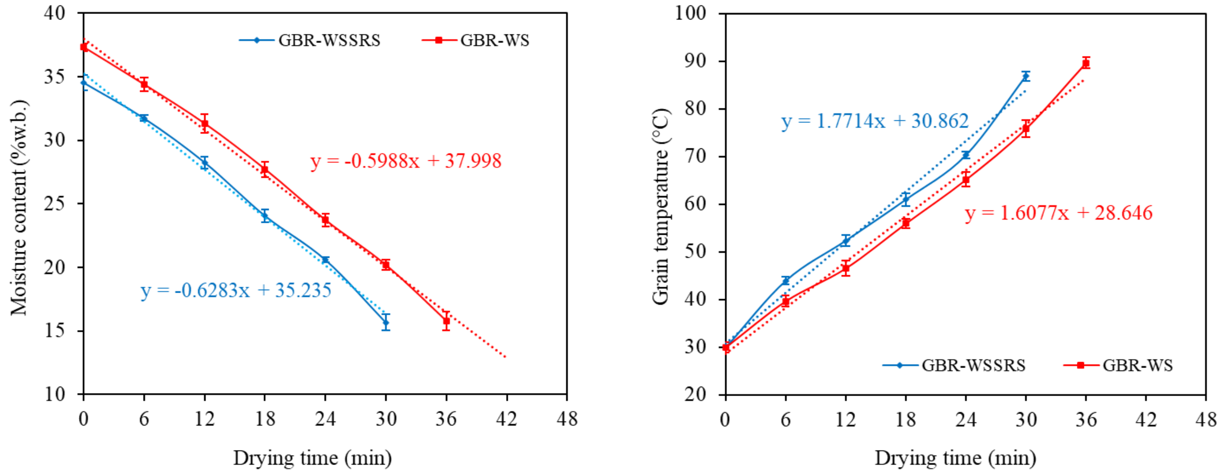


d. germination percentage of paddy during incubation step

Figure 5 The changes in moisture content and germination percentage of paddy.

3.3 Drying characteristics

Figure 6 shows the changes in moisture content and grain temperature of GBR during drying at a hot air temperature of 130°C combined with a halogen power of 2,000 W. The fitted linear regressions with the regression equation for the effect of the drying time on the moisture content and grain temperature at each germination method are also presented in this figure. The moisture content of both GBRs decreased through the drying period. After the germination process, the GBR produced by the water spraying system with the revolved sieve (GBR-WSSRS) had lower initial moisture content (34.53%±0.61 (w.b.)) than the GBR produced by the water-soaking method (GBR-WS) with the initial moisture content of 37.33%±0.29 (w.b.) as shown in Figure 6a. Therefore, the required drying time for reducing the moisture content to 18% (w.b.) in GBR-WSSRS (27 min) was also shorter than the GBR-WS (33 min). When considering the grain temperature (as shown in Figure 6b), it was found that the increase of grain temperature in GBR-WSSRS was faster than that in the GBR-WS through the drying period because of the lower initial moisture content [35]. As shown in Figure 6, the qualitative trends of the moisture-drying time and grain temperature-drying time relation were almost the same for both germination methods (linear trend).



a. moisture content of GBR during drying b. grain temperature of GBR during drying

Figure 6 The changes of moisture content and grain temperature of GBR at a hot air temperature of 130°C combined with halogen power of 2,000 W.

3.4 Quality of GBR

Table 1 shows the quality of brown rice and germinated samples: the number of microorganisms (bacteria, yeast, and mold) and GABA content at different conditions. For the number of microorganisms, brown rice had about 1.8 x 10^6 CFU/g of bacteria and 4.5 x 10^2 CFU/g of mold, but the yeast was not detected. After germination, the numbers of bacteria and mold increased in both shade-dried samples compared to brown rice. A similar result was found by Kim et al. [22] who reported that the microbial counts for germinated brown rice were higher after germination. As shown in Table 1, the numbers of microorganisms in shade-dried GBR-WSSRS (3.2 x 10^6 CFU/g of bacteria and 1.5 x 10^6 CFU/g of mold) were clearly lower than that in shade-dried GBR-WS (7.1 x 10^6 CFU/g of bacteria and 4.4 x 10^6 CFU/g of mold). This may be due to the shorter germination process by the water spraying system with a revolved sieve. After drying, both germinated rice samples had a lower amount of bacteria and mold when compared with shade-dried samples. Moreover, the number of microorganisms (bacteria and mold) in shade-dried GBR-WSSRS (bacteria and mold) was lower than in shade-dried GBR-WS. In addition, the remaining amount of bacteria and mold in the dried samples were safe for consumption. Based on the Thai Agricultural Standard for germinated brown rice, the microorganism count of germinated brown rice after heat treatment and moisture reduction should not be higher than 1 x 10^6 CFU/g for total microorganisms and 500 CFU/g for yeasts and molds [36].

Table 1 Design Number of microorganisms and GABA content of brown rice, GBR (shade drying), and GBR dried at a hot air temperature of 130 °C combined with halogen power of 2,000 W.

Sample	GBR qualities			
	Number of microorganisms			GABA content (mg/100 g brown rice)
	Bacteria (CFU/g)	Yeast (CFU/g)	Mold (CFU/g)	
Brown rice	1.8 x 10^6± 28,308^c	<10	4.5 x 10^2± 76^c	1.49±0.06^e
GBR-WSSRS (Shade drying)	3.2 x 10^6 ± 47,435^b	<10	1.5 x 10^6± 21,125^b	7.91±0.08^b
GBR-WS (Shade drying)	7.1 x 10^6 ± 61,157^a	<10	4.4 x 10^6± 41,458^a	8.69±0.17^a
Dried GBR-WSSRS	1.1 x 10^3± 92^e	<10	3.8 x 10^1± 3^e	6.56±0.07^d
Dried GBR-WS	1.8 x 10^3 ± 113^d	<10	4.9 x 10^1± 5^d	7.45±0.03^c

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

In terms of GABA content (as shown in Table 1), it was found that the GABA content of brown rice was about 1.49±0.06 mg/100 g brown rice, which was significantly lower than that of shade-dried sample; the GABA contents of shade-dried GBR-WSSRS and shade-dried GBR-WS were about 7.91±0.08 and 8.69±0.17 mg/100 g brown rice, respectively. The higher GABA content in the shade-dried sample was due to increased hydrolytic enzymes after germination [9], generating bio-functional substances, which increases GABA. The shade-dried GBR-WSSRS had a lower amount of GABA compared to the shade-dried GBR-WS may be due to the shorter time for germination, leading to less activation of glutamate decarboxylase (GAD) during germination [37]. When the germinated sample was dried using hot air at a temperature of 130°C combined with a halogen power of 2,000 W, the GABA content of samples was significantly decreased relative to those of the shade-dried samples due to the drying process [38]. The GABA content was subject to decomposition caused by heat [39]. In addition, the GABA content of dried GBR-WSSRS was still lower than that of dried GBR-WS. However, the GABA content in GBR-WSSRS can increase using appropriate water temperature for germination [40].

The sensory evaluation of brown rice, GBR-WSSRS, and GBR-WS are shown in Table 2. The GBR-WSSRS had significantly higher sensory evaluation scores, especially in terms of odor and taste, than the GBR-WS; however, the appearance and texture of GBR-WSSRS and GBR-WS were not different. The higher quality of the GBR-WSSRS resulted from the lower number of microorganisms, leading to a weaker fermentation odor and better taste. Moreover, the odor, taste, and texture of GBR-WSSRS were not different when compared with brown rice. These results provided higher scores of overall acceptability in the GBR-WSSRS compared to the GBR-WS. In addition, the panelists did not report differences in texture between brown rice and GBR, but this property was significantly different for commercial GBR. Non-differences in the score for the texture of GBR compared to brown rice may be a result of the harder texture of rice after drying using hot air combined with a halogen. Hot air removes moisture from the outside of the rice grain, while halogen removes moisture from the inside at the same time. This process provides starch gelatinization in the interior and exterior of the rice grains, resulting in a harder texture for GBR [41]. Moreover, the longer drying times further enhance the hardness of GBR.

Table 2 Sensory evaluation of brown rice and GBR dried at a hot air temperature of 130 °C combined with halogen power of 2,000 W.

Conditions	Appearance	Odor	Taste	Texture	Overall acceptability
Brown rice	6.76 ± 1.5^a	6.50 ± 1.8^a	6.68 ± 1.7^a	6.32 ± 1.8^a	7.04 ± 1.1^a
GBR-WSSRS	5.98 ± 2.0^b	6.24 ± 1.8^a	6.69 ± 1.5^a	6.58 ± 1.5^a	6.86 ± 1.3^a
GBR-WS	5.72 ± 1.7^b	4.34 ± 2.3^b	5.40 ± 1.9^b	6.08 ± 1.7^a	5.56 ± 1.7^b

$^{a, b}$ Means in the same column with different superscripts are significantly different ($p<0.05$)

4. Conclusions

A water spraying system with a revolved sieve can decrease the germination time (4 hours for the water spraying step and 30 hours for the incubating step) to obtain the paddy with a germination percentage of 90% when compared with the water-soaking method (70 hours). For the water spraying system with a revolved sieve, the moisture content and water absorption were increased when increasing the revolved speed and time of spray break, and the paddy with the moisture content of 30% (w.b.) can germinate in the short time when using the incubation pattern with a revolved sieve and water spray. Moreover, the water spraying system with a revolved sieve gave fewer microorganisms in the GBR than the water-soaking method, leading to a weak, unpleasant smell of the GBR, resulting in higher overall acceptability scores. However, the GABA content of GBR produced by the water spraying system with a revolved sieve (GBR-WSSRS) was lower than that of GBR produced by the water-soaking method (GBR-WS).

5. Acknowledgements

The authors would like to thank the King Mongkut's Institute of Technology Ladkrabang, which has received funding support from the NSRF.

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