Research article

Influence of Germinated Brown Rice Production by Water Spraying Method on Its Qualities

Thatchapol Chungcharoen[1], Sansanee Sansiribhanb[2]*, Ronnachart Munsin[3], Ratiya Thuwapanichayanan[4], Arkom Palamanit[5], Phanphruek Sukkeaw[1] and Kittisak Phetpan[1]

[1]*Department of Engineering, King Mongkut's Institute of Technology Ladkrabang, Prince of Chumphon Campus, Chumphon, Thailand*
[2]*Applied Physics Program, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok, Thailand*
[3]*Department of Mechanical Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna, Chiang Mai, Thailand*
[4]*Department of Farm Mechanics, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand*
[5]*Department of Specialized Engineering, Faculty of Engineering, Prince of Songkla University, Songkhla, Thailand*

Received: 18 May 2022, Revised: 8 August 2022, Accepted: 21 October 2022

DOI: 10.55003/cast.2022.03.23.007

Abstract

This study was aimed to compare the production time (germination and drying process) and quality of germinated brown rice (GBR) obtained from the water spraying-based GBR production (Sprayed-GBR) system and the water soaking-based GBR production (Soaked-GBR) system. The results showed that the Sprayed-GBR, in the germination process, required 2.5 h for spraying in a water spraying step to obtain paddy with the moisture content of 30% (w.b.) and 26 h in an incubation step to obtain the 90% germination percentage. This led to a shorter germination time compared to the Soaked-GBR, which required a germination time of 50 h for a 90% germination percentage. After germination, the moisture content of the Sprayed-GBR was lower than that of the Soaked-GBR. This provided a shorter drying time in the Sprayed-GBR (27 min) drying process compared with the Soaked-GBR (33 min). For GBR qualities, the Sprayed-GBR could decrease the unpleasant odor problem by providing a smaller number of attached microorganisms after germination (Shade drying), leading to a significantly higher score in the odor and the overall acceptability than the Soaked-GBR. This indicated that the Sprayed-GBR got more consumer acceptance. Moreover, the head rice yield value of the Sprayed-GBR was not different from that of the Soaked-GBR. However, the Sprayed-GBR provided a significantly lower GABA content and a significantly higher percentage of fissured kernels than the Soaked-GBR.

Keywords

germinated brown rice;

unpleasant odor problem;

water spraying method;

quality

*Corresponding author: Tel.: (+66) 624492351
E-mail: sansanee.sa@ssru.ac.th

1. Introduction

Water soaking is an important method that is always used to promote germination in the production of germinated brown rice (GBR) [1, 2]. It produces endogenous enzymes, especially hydrolytic enzymes, leading to the breakdown of proteins into peptides and amino acids [3], and resulting in the accumulation of compounds. γ-aminobutyric acid (GABA) is one of the most interesting bioactive compounds in the GBR [4] because various health benefits can result from its physiological activities; GABA can prevent cancer cell proliferation, regulate blood pressure and heart rate, and prevent chronic alcohol-related diseases [5, 6]. Hence, the paddy is soaked in the water to enhance the GABA content of the GBR, in which the soaking time depends on several factors such as rice varieties, water temperature, and the pH of soaking water [7-9]. This step can be the main cause of the increase in microorganism accumulation, leading to an unpleasant smell in the GBR [10]. This problem results in a lower quality of the GBR product. Therefore, some researchers tried to improve the germination process for GBR production by soaking in circulating water through the paddy [11]. Compared with soaking in stagnant water, germination under the circulating method could decrease germination time. However, the method still provided an unpleasant smell of GBR.

As mentioned above, this research focuses on decreasing the unpleasant smell of GBR in the germination process using a water spraying method instead of the water soaking method. For the water spraying technique, a GBR production prototype machine was used as the main equipment for germination and drying to decrease the moisture content after germination. The germination process under the water spraying technique was divided into 2 main steps: spraying the water onto the paddy to obtain the appropriate moisture content and incubating it to obtain the germinated paddy. Hot air and a halogen lamp were used as the media for drying. Therefore, this research aimed to compare the production time and qualities of the GBR obtained from the two different techniques: the water spraying-based GBR production (Sprayed-GBR) and the conventional water soaking-based GBR production (Soaked-GBR).

2. Materials and Methods

2.1 Paddy sample

The Suphanburi 1 paddy variety with an initial moisture content of 11% (w.b.) was obtained from the Rice Department, Ratchaburi, Thailand, and was stored for more than three months prior to an experiment.

2.2 Experimental set-up

The sprayed-GBR production prototype machine, shown in Figure 1, consists of a germination chamber (50 cm × 70 cm × 30 cm), a revolving sieve (27 cm diameter and 50 cm length), three nozzles attached to the stainless steel horizontal axis, 1HP water motor pump, 1HP motor for revolving sieve, and 6 kW blower connected to an electrical heater and halogen lamp.

2.3 Preparation of GBR samples

2.3.1 Germination process

For the Sprayed-GBR, a 2 kg of paddy sample was added for the moisture content adjustment by spraying with water every 30 min until the paddy moisture content reached 30% (w.b.), which is appropriate for the paddy germination [12]. The water temperature of 40°C and a spraying rate of 7 L/min were constantly set throughout the experiment. Simultaneously, the sieve was also revolved at 15 rpm for a minute. These conditions provided the shortest time to obtain appropriate moisture content. After that, the sample was incubated to obtain the germinated paddy within the sieve. During the incubation step, water spraying into the revolving sieve was also performed using the same conditions as the germination. The incubation time was set for 12 hours to maintain the moisture content of the paddy, and the water spraying step was repeated every 12 h until the germination percentage of the paddy reached 90%. For the Soaked-GBR, a 2 kg of paddy sample was soaked in 7 L of 35°C water (the highest germination rate for this variety) until the germination percentage of the paddy reached 90%. Based on the latter method, the water was changed every 4 h to limit the number of bacteria during soaking [13].

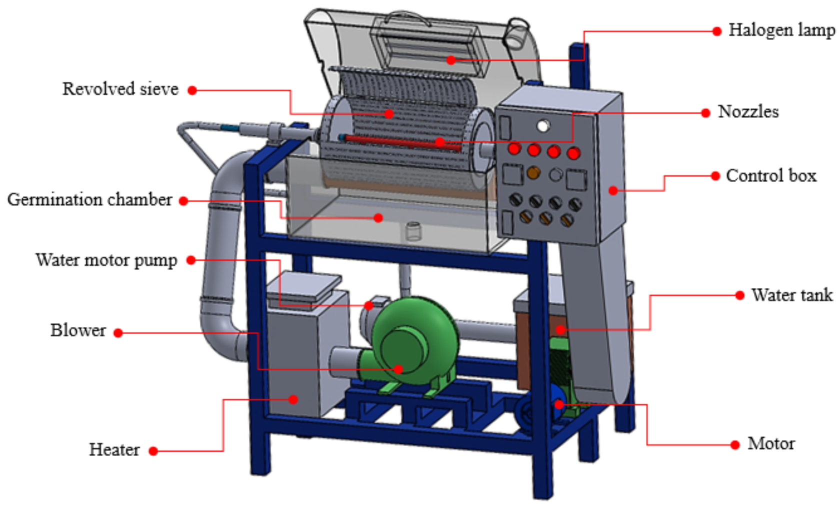

Figure 1. Schematic diagram of the prototype

2.3.2 Drying process

For both Sprayed-GBR and Soaked-GBR, the germinated paddy sample was dried using hot air combined with a halogen lamp until the moisture content was approximately 18% (w.b.). The drying temperature of 130°C, halogen power of 2,000 W, and air velocity of 6.5 m/s were set as the drying conditions, and the sieve was also rotated at 15 rpm throughout the drying process.

2.4 GBR qualities

This research's five quality indicators consisted of GABA content, fissured kernels, head rice yield (HRY), microbiological populations, and sensory attributes. The GABA content was determined by high-performance liquid chromatography (HPLC) (Agilent 1100 Series, Agilent Technologies, Palo

Alto, CA) following the method proposed by Banchuen *et al*. [14]. The HPLC was equipped with a Supelcosil-LC-DABS 4.6 mm i.d.×150 mm column. Acetonitrile was used as the mobile phase with a flow rate of 1 mL/min and injection volume of 5 µL. The column temperature and the ultraviolet detector were set at 35°C and 465 nm, respectively. Based on visual observation, fissured kernels were randomly selected from 100 rice kernels in triplicate. The HRY was determined according to the method proposed by Srisang *et al*. [15]. One hundred and twenty-five grams of paddy samples were dehulled using a hulling machine (Ngeksenghuat, model P-1, Bangkok, Thailand) and the unbroken brown rice kernels were separated with a test rice grader. The HRY was calculated by dividing the mass of unbroken brown rice kernels by the total paddy mass before dehulling and presented in the percentage form. Microbial analyses were conducted using the standard method of AOAC [16]. The total plate count method was used for estimating the number of bacteria. Agar (12-15 mL), sterilized in an autoclave at a temperature of 121°C for 15 min, was poured into each of the three plates, and then cooled to a temperature of 45°C. After that, 1 mL of a mixed solution of 50 g flour sample and 450 mL Butterfield's phosphate-buffered dilution water was poured into the three plate count agars. These were cooled until they hardened and incubated instantly at a temperature of 35°C for 48 h. For estimating the numbers of yeast and mold, 15-20 mL of dichloran rose bengal chloramphenical (DRBC) agar was poured into each of the three plates, and 1 mL of the mixed solution was added into the three DRBC plate count agars. These were incubated instantly at 25°C for 5-7 days. Sensory evaluation was performed using the 9-point hedonic scale according to the method proposed by Chungcharoen *et al*. [17]. Each sample was served to 50 panelists to evaluate the cooked rice samples in terms of appearance, odor, taste, texture, and overall acceptability.

2.5 Statistical analysis

Quality analysis data were analyzed by one-way analysis of variance (ANOVA), and the means were compared by the Duncan's multiple range test (DMRT) at a significance level of 0.05. All statistical calculations were performed using SPSS software, version 14.

3. Results and Discussion

3.1 Germination process

3.1.1 Germination process of Soaked-GBR

Figure 2 shows the germination percentage and moisture content of the germinated paddy samples produced by the conventional method (Soaked-GBR). The germination percentage increased with soaking time (Figure 2A). Soaking the paddy samples in the 35°C water caused them to germinate at around 12% at 24 h and germination reach 90% at 50 h. Moisture content also increased when the soaking time increased (Figure 2B). The moisture content of germinated paddy after soaking at 24 h was 30.8% (w.b.). This result was similar to that reported by Kim and Jeon [12], whose study focused on the appropriate moisture for grain germination, and found that it was 30% (w.b.) for rice germination. The moisture content of the paddy sample reaching 90% germination at the soaking time of 50 h was 37.27% (w.b.). The longer germination time in the Soaked-GBR may be because of the smaller amount of oxygen. In water, oxygen, an essential factor required for germination, has very low solubility. This led to the difficult germination in rice seed [18], leading to a longer germination time.

3.1.2 Germination process of Sprayed-GBR

Figure 3 shows the changes in moisture content and water absorption of the paddy sample produced by the water spraying method (Sprayed-GBR) in the water spraying step at the temperature of 40°C. The initial moisture content of the paddy was 11% (w.b.). After spraying, the moisture content increased with the number of sprays (Figure 3A), especially at the first time of spraying; the moisture

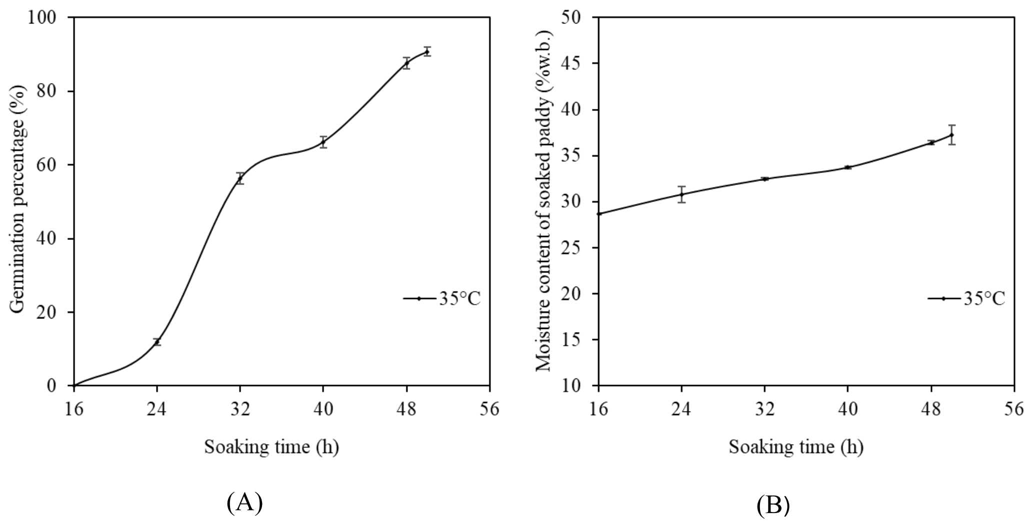

Figure 2. Germination percentage (A) and moisture content (B) of germinated paddy with the water soaking method at the water temperature of 35°C

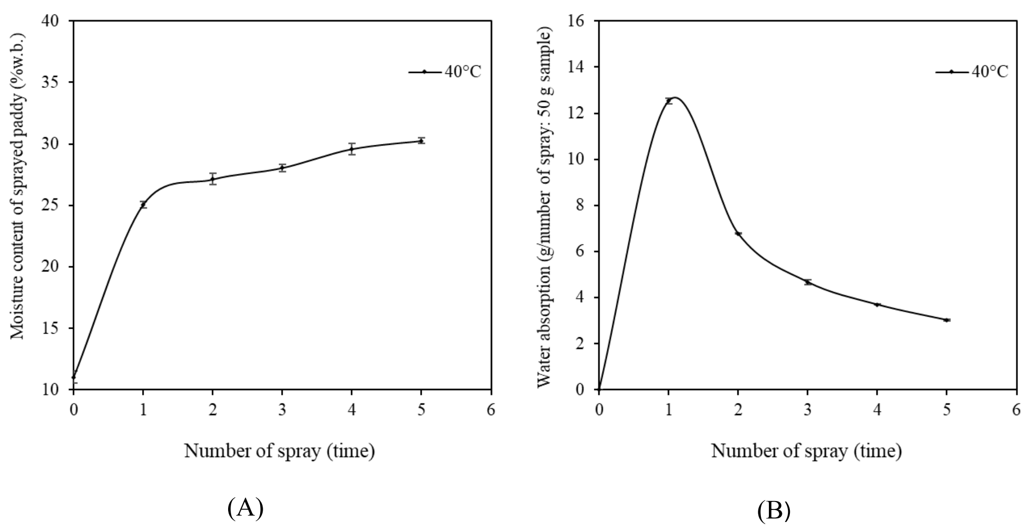

Figure 3. Moisture content (A) and water absorption (B) of paddy with the water spraying method in a water spraying step

content rapidly increased from 11 to 25% (w.b.) and slowly increased afterwards to approximately 30% (w.b.). This result corresponds to the water absorption (Figure 3B), showing high water absorption in the first stage and slow water absorption in later stages. Similarly, Ejebe *et al*. [19] reported the fast water absorption rate of the rice varieties from Nigeria during the early soaking period and slower water absorption rate later. In our experiment, five times of spraying were needed to obtain the paddy with a moisture content of 30% (w.b.). Figure 4 shows the changes in moisture content and germination percentage of the paddy samples produced by the water spraying method (sprayed-GBR) in the incubation step to obtain the germinated paddy using an incubation pattern with the rotated bed combined with the spraying system. The moisture content increased when the incubation time increased because the water spraying was applied during incubation (Figure 4A). At the end of the incubation (90% of germination), the moisture content of the germinated sample was 34.93% (w.b.), which was lower than that obtained by the use of the soaking method. As shown in Figure 4B, the paddy sample germination was around 32% after 16 h of incubation and then rose continuously. To obtain the 90% germination percentage required 26 h of incubation time. The experimental results indicated that the Sprayed-GBR had decreased germination time compared with the Soaked-GBR. Using the sprayed-GBR, the required germination time was about 28.5 h (2.5 h for the first time spraying in the water spraying step and 26 h for the incubation step). It was a shorter germination time than the Soaked-GBR, which needed a germination time of 50 h.

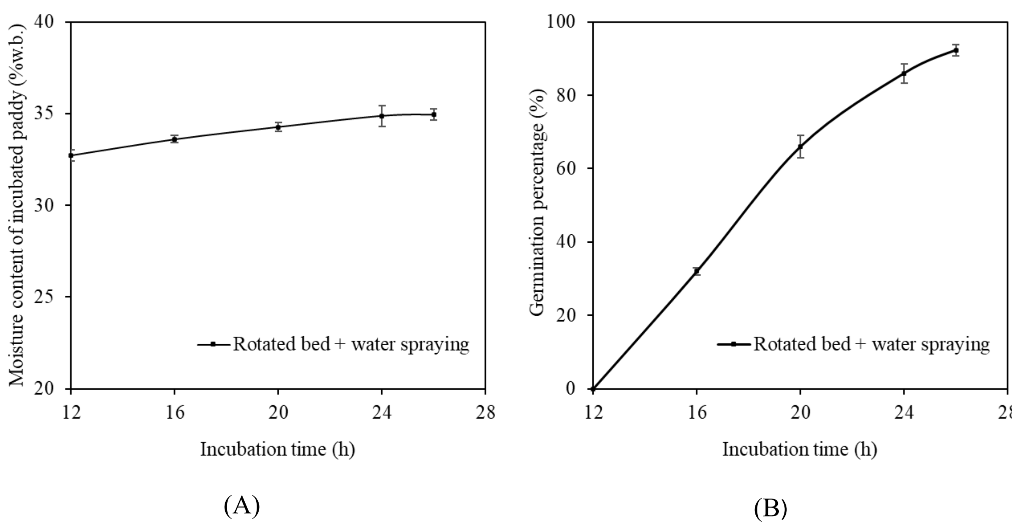

Figure 4. Moisture content (A) and germination percentage (B) of paddy with water spraying method in an incubation step

3.2. Drying process

Figure 5 shows the paddy sample's moisture contents and grain temperatures during the drying process using hot air drying (130°C) combined with a halogen lamp (2,000 W). The changes in moisture content and grain temperature for both Sprayed-GBR and Soaked-GBR had the same pattern. With the increase in drying time, the moisture content continuously decreased (Figure 5A), whereas the grain temperature continuously increased (Figure 5B). The Sprayed-GBR exhibited a lower moisture content than the Soaked-GBR, whereas the grain temperature of the Sprayed-GBR was higher at every drying time than the Soaked-GBR. The lower moisture content of the Sprayed-GBR was due to the lower initial moisture content, leading to a higher increase in the grain temperature and shorter drying time. The drying times for reducing the moisture content to 18% (w.b.) in Sprayed-GBR and Soaked-GBR were 27 min and 33 min, respectively. The experimental results indicated that the drying time for the Sprayed-GBR was less than that needed for the Soaked-GBR.

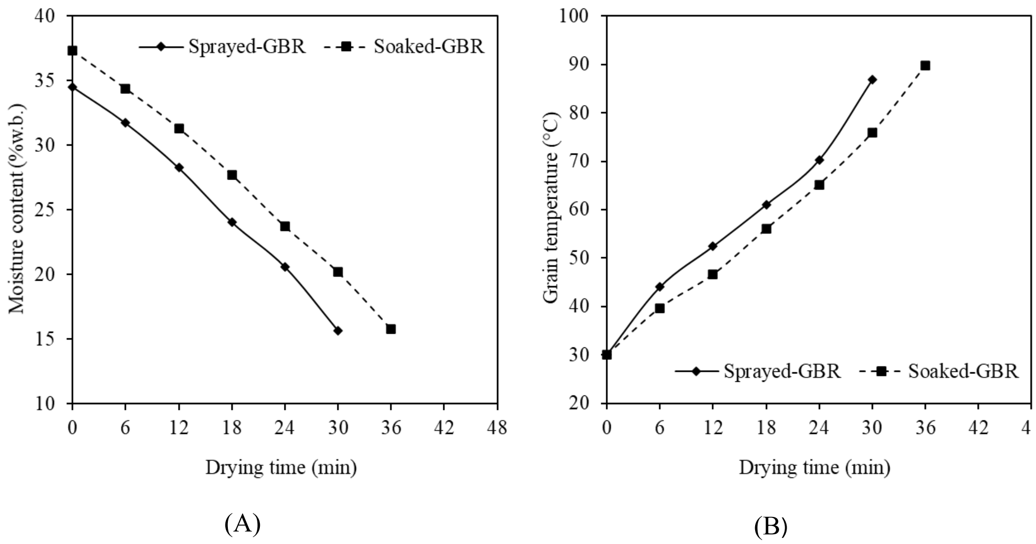

Figure 5. Moisture content (A) and grain temperature (B) of the sample during the drying process

3.3. Qualities of GBR

Table 1 shows the number of microorganisms on brown rice, Sprayed-GBR, and Soaked-GBR. Only bacteria (1.8×10^6 CFU/g) and mold (4.5×10^2 CFU/g) were found on the brown rice, and they increased when the sample was germinated by both methods. The Soaked-GBR (Shade drying) had higher counts of bacteria and molds than the Sprayed-GBR (Shade drying). This may be because the Soaked-GBR had a higher moisture content than the Sprayed-GBR. At higher moisture level, the growth of microorganisms can be easier induced. Moreover, the Soaked-GBR stayed at a high moisture level for a long time (during soaking for germination), leading to the longer growth period of microorganisms. This result confirmed that the water spraying technique could reduce the accumulation of microorganisms during germination. After drying, the microorganisms (bacteria and molds) were remarkably decreased in the Sprayed-GBR and Soaked-GBR samples compared with the Shade-dried samples. The numbers of bacteria and molds in the Sprayed-GBR were higher than those in the Soaked-GBR. This was probably due to the shorter drying time of the Sprayed-GBR. However, the amounts of microorganisms in both the Sprayed-GBR and the Soaked-GBR were at the level acceptable by food safety standards according to the Thai Agricultural Standard for germinated brown rice [20].

The sample qualities, such as GABA content, percentage of fissured kernels, and head rice yield (HRY) are presented in Table 2. When the sample was germinated, the GABA contents and fissured kernel percentages of GBR significantly increased while the HRY of GBR significantly decreased. The GABA content increased from 1.49 mg/100 g for brown rice to 10.63-12.62 mg/100 g for the GBR samples because of enzymatic activity. The hydrolytic enzymes (α-amylase and βamylase) hydrolyzed starch into lower molecular weight polymers, leading to the generation of bio-functional substances and an increase of GABA generation [21, 22]. The extreme increase of fissured kernels in GBR was caused by the moisture gradient inside the rice grain, germinating (water soaking or water spraying), and drying. It induces stress formation inside the GBR [23, 24]. The HRY value of the GBR was lower than that of the brown rice because of morphology

Table 1. Number of attached bacteria, yeast, and mold on the brown rice, sprayed-GBR, and soaked-GBR.

Sample	Number of microorganisms		
	Bacteria (CFU/g)	**Yeast (CFU/g)**	**Mold (CFU/g)**
Brown rice	1.8×10^6	<10	4.5×10^2
Sprayed-GBR (Shade drying)	2.1×10^6	<10	1.0×10^6
Soaked-GBR (Shade drying)	4.2×10^6	<10	2.5×10^6
Sprayed-GBR	2.7×10^3	<10	7.3×10^1
Soaked-GBR	1.3×10^3	<10	6.5×10^1

Table 2. Qualities of brown rice and GBR produced by different methods

Sample	GABA content (mg/100 g brown rice)	Percentage of fissured kernels (%)	Head rice yield (%)
Brown rice	1.49 ± 0.06^c	19 ± 1^c	67.45 ± 0.22^a
Sprayed-GBR	10.63 ± 0.08^b	59 ± 3^a	65.64 ± 0.63^b
Soaked-GBR	12.62 ± 0.06^a	49 ± 2^b	66.27 ± 0.42^b

Note: Means in the same column with different superscripts are significantly different ($p<0.05$).

modification in GBR. The starch granules in GBR were packed loosely, resulting in less compaction and weaker kernel strength [25]. There were significant differences between the Sprayed-GBR and Soaked-GBR samples in terms of the GABA content and percentage of fissured kernels. The GABA content of the Sprayed-GBR was lower than that of the Soaked-GBR, whereas the percentage of fissured kernels was higher than the Soaked-GBR. The lower GABA content in the sprayed-GBR may be due to the length of time during the phase of water uptake. The sprayed-GBR needed a shorter time for water uptake, leading to less bioactive compound accumulation during germination and lower GABA content [26]. The more significant fissure in the Sprayed-GBR was related to the water absorption rate during germination. The Sprayed-GBR had a faster water absorption rate than the Soaked-GBR, leading to a more significant moisture gradient. This caused higher stresses and led to a higher percentage of fissured kernels [27].

Table 3 presents the sensory evaluation results for attributes such as appearance, odor, taste, texture, and overall acceptability of brown rice and GBR produced by different methods. The highest score for the attributed odor, taste, texture, and overall acceptability was for brown rice. The Sprayed-GBR had a higher odor score than the Soaked-GBR, whereas differences in the appearance, taste, and texture between sprayed-GBR and soaked-GBR were not significant. The Sprayed-GBR provided better overall acceptability than soaked-GBR, as indicated by a significantly higher score.

Table 3. Sensory evaluation of brown rice and GBR produced by different methods

Conditions	Appearance	Odor	Taste	Texture	Overall acceptability
Brown rice	6.67 ± 1.8^{a}	7.65 ± 1.4^{a}	7.12 ± 1.4^{a}	6.76 ± 1.3^{a}	7.6 ± 1.1^{a}
Sprayed-GBR	6.78 ± 1.7^{a}	6.20 ± 2.0^{b}	6.45 ± 1.8^{ab}	6.02 ± 1.9^{b}	6.59 ± 1.6^{b}
Soaked-GBR	6.53 ± 1.7^{a}	4.27 ± 2.1^{c}	5.98 ± 2.1^{b}	5.96 ± 1.7^{b}	5.84 ± 1.8^{c}

Note: Means in the same column with different superscripts are significantly different ($p<0.05$).

4. Conclusions

The water spraying-based GBR production (Sprayed-GBR) method involved a shorter production time than the water soaking-based GBR production (Soaked-GBR) method in both germinating and drying processes. It also provided a lower number of attached microorganisms during germination. However, it led to a decrease in the GABA content and an increase in the percentage of fissured kernels. Additionally, the water-soaking and spraying methods showed an insignificant influence on the head rice yield value of the GBR. Based on the sensory assessment, the Sprayed-GBR provided a higher odor score than the Soaked-GBR, leading to a higher overall acceptability score.

5. Acknowledgements

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

References

[1] Songsamoe, S., Khunjan, K. and Matan, N., 2021. The application and mechanism of action of Michelia alba oil vapour in GABA enhancement and microbial growth control of germinated brown rice. *Food Control,* 130, DOI: 10.1016/j.foodcont.2021.108401.

[2] Hussain, S.Z., Jabeen, R., Naseer, B. and Shikari, A.B., 2020. Effect of soaking and germination conditions on γ-aminobutyric acid and gene expression in germinated brown rice. *Food Biotechnology*, 34(2), 132-150.

[3] Singh, A.K., Rehal, J., Kaur, A. and Jyot, G., 2005. Enhancement of attributes of cereals by germination and fermentation: a review. *Critical Reviews in Food Science and Nutrition*, 55(11), 1575-1589.

[4] Liu, L.L., Zhai, H.Q. and Wan, J.M., 2005. Accumulation of γ-aminobutyric acid in giant embryo rice grain in relation to glutamate decarboxylase activity and its gene expression during water soaking. *Cereal Chemistry*, 82(2), 191-196.

[5] Gan, R.Y., Lui, W.Y., Wu, K., Chan, C.L., Dai, S.H., Sui, Z.Q. and Corke, H., 2017. Bioactive compounds and bioactivities of germinated edible seeds and sprouts: an updated review. *Trends in Food Science and Technology*, 59, 1-14.

[6] Poojary, M.M., Dellarosa, N., Roohinejad, S., Koubaa, M., Tylewicz, U., Gómez-Galindo, F., Saraiva, J.A., Rosa, M.D. and Barba, F.J., 2017. Influence of innovative processing on γ-aminobutyric acid (GABA) contents in plant food materials. *Comprehensive Reviews in Food Science and Food Safety*, 16(3), 895-905.

[7] Charoenthaikij, P., Jangchud, K., Jangchud, A., Prinyawiwatkul, W. and Tungtrakul, P., 2010. Germination conditions affect selected quality of composite wheat-germinated brown rice flour and bread formulations. *Journal of Food Science*, 75(6), 312-318.

[8] Karladee, D. and Suriyonga, S., 2012. γ-Aminobutyric acid (GABA) content in different varieties of brown rice during germination. *Science Asia*, 38, 13-17.

[9] Singh, A., Sharma, S. and Singh, B., 2018. Germination behaviour, physico-nutritional properties, and diastase activity of brown rice influenced by germination time and temperature. *Acta Alimentaria*, 47(1), 70-79.

[10] Chungcharoen, T., Prachayawarakorn, S., Soponronnarit, S. and Tungtrakul, P., 2012. Effect of drying temperature on drying characteristics and quality of germinated rices prepared from paddy and brown rice. *Drying Technology*, 30(16), 1844-1853.

[11] Pilawut, S., Buranapet, T., Saen-sakdi, J., Sirila, C., Jeephet, V. and Muenkaew, P., 2019. Comparison of soaking procedures in stagnant water and circulating water through paddy of brown rice germination on GABA quantity and other qualities. *Proceedings of the 20th TSAE National Conference*, Pattaya, Thailand, March 14-15, 2019, pp. 236-241.

[12] Kim, S.H. and Jeon, Y.S., 2010. Critical seed moisture content for germination in crop species. *The Journal of the Korean Society of International Agriculture*, 12(3), 159-164.

[13] Kaosa-ard, T. and Songsermpong, S., 2012. Influence of germination time on the GABA content and physical properties of germinated brown rice. *Asian Journal of Food and Agro-Industry*, 5(04), 270-283.

[14] Banchuen, J., Paiboon, T., Buncha, O., Phaisan, W. and Piyarat, S., 2010. Increasing the bio-active compounds contents by optimizing the germination conditions of Southern Thai brown rice. *Songklanakarin Science and Technology*, 32(3), 219-230.

[15] Srisang, N., Prachayawarakorn, S., Soponronnarit, S. and Chungcharoen, T., 2021. An innovative hybrid drying technique for parboiled rice production without steaming: an appraisement of the drying kinetics, attributes, energy consumption, and microstructure. *Food and Bioprocess Technology*, 14, 2347-2364.

[16] AOAC, 2000. *Official Methods of Analysis*. Washington, DC: Association of Official Analytical Chemists.

[17] Chungcharoen, T., Prachayawarakorn, S., Soponronnarit, S. and Tungtrakul, P., 2015. Effects of germination time and drying temperature on drying characteristics and quality of germinated paddy. *Food and Bioproducts Processing*, 94, 707-716.

[18] Magneschi, L. and Perata, P., 2009. Rice germination and seedling growth in the absence of oxygen. *Annals of Botany*, 103, 181-196.

[19] Ejebe, C., Kwofie, E.M. and Ngadi, M., 2019. Hydration characteristics of selected varieties of paddy rice from Nigeria. *Advances in Chemical Engineering and Science*, 9, 65-75.

[20] National Bureau of Agricultural Commodity and Food Standards, 2012. *Thai Agricultural Standard. TAS 4404-2012. Good Manufacturing Practices for Germinated Brown Rice.* [online] Available at: https://www.acfs.go.th/standard/download/eng/GMP_GERMI NATED_ BROWN_RICE-ENG.pdf.

[21] Pradeep, S.R., Mallesshi, N.G. and Guha, M., 2011. Germinated millets and legumes as a source of gamma-aminobutyric acid. *World Applied Sciences Journal*, 14(1), 108-113.

[22] Hyun-Jung, C., Su-Hae, J., Hong-Yon, C. and Seung-Taik, L., 2009. Effects of steeping and anaerobic treatment on GABA (gamma-aminobutyric acid) content in germinated waxy hull-less barley. *Food Science and Technology*, 42, 1712-1716.

[23] Srisang, N., Varanyanond, W., Soponronnarit, S. and Prachayawarakorn, S., 2011. Effects of heating media and operating conditions on drying kinetics and quality of germinated brown rice. *Journal of Food Engineering*, 107, 385-392.

[24] Kowalski, S.J. and Mielniczuk, B., 2006. Drying-induced stresses in macaroni dough. *Drying Technology*, 24, 1093-1099.

[25] Chatchavanthatri, N., Junyusen, T., Moolkaew, P., Arjharn, W. and Junyusen, P., 2020. Effect of soaking and sprouting treatment on germination rate of paddy. *E3S Web of Conferences*, 187, DOI: 10.1051/e3sconf/202018704016.

[26] Watchararparpaiboon, W., Laohakunjit, N. and Kerdchoechuen, O., 2010. An improved process for high quality and nutrition of brown rice production. *Food Science and Technology International*, 16, 147-158.

[27] Yang, W., Jia, C., Siebenmorgen, T.J., Pan, Z. and Cnossen, A.G., 2003. Relationship of kernel moisture content gradients and glass transition temperatures to head rice yield. *Biosystems Engineering*, 85, 467-476.