International Journal of Agricultural Technology 2026 Vol. 22(4):1779-1792
DOI: https://doi.org/10.63369/ijat.2026.22.4.1779-1792
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Characteristics, physical and nutritional properties of the new thai rice variety with parboiled processing

Krupoo, P.[1], Kruapoo, W.[2], Santibenchakul, S.[1], Promsomboon, S.[1], Promsomboon, P.[3] and Sooksawat, N.[4*]

[1]Department of Science and Mathematics, Faculty of Science and Technology, Rajamangala of Technology Tawan-ok, Bangpra, Sriracha, Chonburi, 20110, Thailand; [2]Department of Physics, Faculty of Science, Burapha University, Mueang, Chonburi, 20131, Thailand; [3]Department of Plant Production Technology, Faculty of Agriculture and Natural Resources, Rajamangala University of Technology Tawan-Ok, Bangpra, Sriracha, Chonburi, 20110, Thailand; [4]Department of Agricultural Engineering and Technology, Faculty of Agriculture and Natural Resources, Rajamangala of Technology Tawan-ok, Bangpra, Sriracha, Chonburi, 20110, Thailand.

Krupoo, P., Kruapoo, W., Santibenchakul, S., Promsomboon, S., Promsomboon, P. and Sooksawat, N. (2026). Characteristics, physical and nutritional properties of the new thai rice variety with parboiled processing. International Journal of Agricultural Technology 22(4):1779-1792.

Abstract Thailand recently registered the 'Kum Bangpra' rice variety as a new, improved variety for purple rice. The processing of parboiled Kum Bangpra rice to improve the rice quality in terms of its physical properties, cooking properties, and nutritional value are evaluated. The parboiled conditions were varied on soaking time, soaking temperature, and steaming time. Based on the results, soaking the rice at 90°C for 90 minutes and then steaming the rice under pressure for 20 minutes produced the significantly highest yields of brown rice at 77.85% and head rice at 72.16%. The physical properties were determined, and the cooking properties were affected by varying the parboiled conditions, with the amylose content varying in the range 18.90–21.52%, while the gel consistency value was in the range of 29.00–57.17. Evaluation of the nutrients in the parboiled Kum Bangpra rice showed a higher iron mineral content than the untreated Kum Bangpra rice. Thus, the development of parboiled processing options for this rice variety could be beneficial for human health.

Keywords: Purple rice, Parboiled rice, Physical properties, Cooking properties, Nutritional value

Introduction

In recent years, purple rice has gained popularity for its unique hue and nutritional value. The purple rice has become popular in Thailand for its health advantages and unique color. Purple rice, often known as "black rice," is cultivated in Thailand, especially in the north and northeast. "Kum" is the Thai word for black rice. Anthocyanins, antioxidants in purple rice bran, give the rice

* **Corresponding Author:** Sooksawat, N.; **Email:** najjapak_so@rmutto.ac.th

its stunning color and have anti-inflammatory, anti-cancer, and heart-protective qualities. In addition, rice bran contains gamma oryzanol, which lowers cholesterol and triglycerides and raises HDL, lowering blood sugar and raising insulin in diabetics (Boers *et al*., 2015). Thus, dark purple rice is famous as a nutritious meal and may be used in Thai sweets, ice cream, purple food coloring, and instant tea. Anti-aging soap, shampoo, and spa treatments use black sticky rice seed extract to cure dark spots and freckles (Tanghiranrat *et al*., 2021).

The 'Kum Bangpra' rice variety (*Oryza sativa* L.) is a new purple pericarp variety from a local rice variety (Bangpra BP2012-009). It was developed and named by Rajamangala University of Technology Tawan-ok, Chonburi province, Thailand. Its outstanding characteristics include being adaptable, able to grow well, and resistant to disease and insects. The paddy rice is straw-colored, has a slender grain shape, and a dark purple grain with a gelatinization temperature at 67^{o}C (Promsomboon and Promsomboon, 2019). The cooked rice is soft and sticky and contains GABA, protein, fiber, omega 3, gamma oryzanol, and antioxidants.

There is ongoing research on developing Kam Bangpra rice varieties and products (Chinaworn *et al*., 2023). For example, gluten-free cake made from Kum Bangpra (Sopanangkul *et al*., 2023), substitutes Kam Bangpra rice flour for wheat flour in the cake formula. Ratanacoon *et al*. (2023) studied the chemical composition of Kum Bangpra rice bran, rice bran oil, and reported that the bran oil and rice bran contained high amounts of bioactive compounds and proteins. Kum Bangpra rice bran extract could be used in the development of cosmeceutical and nutraceutical products.

Parboiled rice is partially precooked using a hydrothermal process which is very popular in India, Africa, and Western Europe, while 40% of supply is an important market in Southeast Asia (Bhattacharya, 2004). There are many variations in the traditional process of producing parboiled rice. The basic process starts with cleaning the paddy rice and soaking it in water until the moisture content is approximately 30% (Oli *et al*., 2014), followed by steaming or boiling until cooked, before drying to 12–14%, using either sun drying or in a dryer. Finally, it is milled to remove the husk.

During the soaking process, nutrients from the pericarp penetrate and remain within the grains. This makes parboiled rice more nutritious than white rice. One study reported that parboiled rice had increased levels of some phytochemical compounds (Hu *et al*., 2017). In addition, changes in the structure of the cells of the parboiled rice grains result in this rice being digested and absorbed into the body more slowly than normal rice (Boers *et al*., 2015; Pathiraje *et al*., 2011). Therefore, parboiled rice is another food product that is suitable for people with diabetes who want to closely control their blood sugar level.

Parboiled rice is yellow to light brown in color and because the rice grains are cooked with heat, cracks within the grains are bridged, resulting in a high head rice yield (HRY) (Bhattacharya, 2013). When cooked, the rice grains are crumbly, not sticky, and have a unique smell that is generated during the soaking process. Different parboiled processes result in the divergent properties of the rice. For example, soaking in cold water requires 24–48 hours of soaking time, causing the growth of anaerobic bacteria, lactic acid bacteria, staphylococcus, and yeast to cause an unpleasant smell and taste, whereas the process of soaking in hot water reduces the odor arising from fermentation because it shortens the soaking time (Miah *et al*., 2002), and results in parboiled rice that is decolorized more than soaking in cold water (Oli *et al*., 2014). Furthermore, Igathinathane *et al*. (2005) reported that soaking at above the gelatinization temperature caused rapid and excessive moisture absorption.

Compared to normal rice, parboiled rice is easier to mill, has a higher milling quality, contains less broken rice, can be stored for a long time, and is rich in vitamins B and E (Sripum *et al*., 2017). However, parboiled rice has an odor, a unique taste, and a higher production cost than normal white rice. In recent years, the slow digestibility of parboiled rice has received increasing attention from manufacturers and food scientists; nonetheless, parboiled rice made from colored-rice has not been well understood (Zhang *et al*., 2022). Therefore, this research was studied the feasibility of producing parboiled rice from Kum Bangpra rice, a purple-black rice that is rich in important nutrients.

Materials and methods

Rice samples

Paddy rice of the Kum Bangpra rice variety (*Oryza sativa* L.) was obtained from Chonburi province in eastern Thailand, having been harvested in the early winter of 2020. This paddy rice was passed through a paddy rice cleaning sieve twice to remove straw, withered seeds, other plant seeds, dust particles, stones, and small impurities, before passing the sieved rice through an exhaust fan-type paddy cleaning machine one more time to separate out withered seeds that were still contaminants. The final product was kept in plastic bins at room temperature.

Study of rice soaking factors

A sample (200 g) of paddy rice was soaked in 300 mL of hot water at an initial temperature of 80, 90, or 100 °C, with 2 g samples of the paddy rice seed being measured for the moisture content (MC) at 10, 20, 30, 45, 60, 90, 120, 180, 240, and 300 minutes. The MC was measured using a hot-air oven at 135 °C for 24 hours based on AACC Method 44-19.01 (AACC, 2010) and calculated according to the equation:

$$MC = (\text{weight} - \text{dry weight}) \times 100 / \text{weight} \quad (1)$$

The moisture value was plotted to provide a graph of the water absorption capacity of Kum Bangpra rice when soaked in water at temperatures of 80, 90, and 100 °C in order to determine the soaking time that resulted in the Kum Bangpra paddy rice being saturated with water at each temperature based on an MC of about 30% (Miah *et al*., 2002).

Preparation of parboiled Kam Bangpra rice samples

A sample (1 kg) of Kam Bangpra paddy rice was soaked in 1.5 L of hot water at an initial temperature of 80, 90, or 100 °C for each soaking time (modified parboiling process). Then, the soaked rice was steamed under pressure (40–70 kPa; Otto Pressure cooker, PC-225; Thailand) for 10, 15, or 20 minutes (Leethanapanich *et al*., 2016) before sun drying for 5 hours, while turning the rice every hour. Finally, the rice was left at room temperature overnight until the moisture content was 13–14%.

Samples were obtained of Kum Bangpra rice and parboiled rice from 3 different soaking temperatures (80, 90, or 100 °C) and 3 different steaming times (10, 15, or 20 minutes) as shown in **Error! Reference source not found.** 1.

Milling properties

The milling properties were determined by weighing 250 g of rough rice and dehulling it using a laboratory scale dehusker, followed by grading using a sieve sizer to remove the broken rice. Each milling stage was performed with 3 repetitions and the average value was recorded. The head rice was weighed and the brown rice yield (BRY) and the head rice yield (HRY) were calculated using the formulas:

$$BRY = (\text{Brown rice weight} / \text{Rough rice weight}) \times 100 \quad (2)$$

$$HRY = (\text{Head rice weight} / \text{Rough rice weight}) \times 100 \quad (3)$$

Physical properties

The weight of the rough rice and brown rice was measured by sampling 100 grains of rough and brown rice, respectively, and weighing them 3 times. Based on the 100 grains measured, the shape of the rice grains was classified as slender, medium, or bold (Juliano and Villareal, 1993) using the formula:

$$\text{Shape} = \text{Length} / \text{Width} \tag{4}$$

Color analysis

The color value of brown rice and parboiled rice was defined based on the L*, a*, b* values using a colorimeter (Spectrophotometer; Konica Minolta; model CM-3500d). Each sample was measured 3 times and the average value was recorded.

Cooking properties

The amylose content of the Kum Bangpra rice and parboiled rice flour samples was determined by weighing 100 mg of rice flour and adding ethanol and sodium hydroxide solution before stirring with a magnetic stirrer for 10 minutes and then adjusting the volume to 100 mL with distilled water and measuring the color intensity using the Spectrophotometer (Kongseree, 2004). The standard curve was established using potato standard amylose.

The gel consistency of the Kum Bangpra rice and parboiled rice flour samples was investigated using 100 g flour samples and adding ethanol and KOH before soaking in boiling water for 8 minutes and measuring the length of the gel in the tube (Cagampang *et al*., 1973).

The water absorption rate was investigated by boiling 2 g of brown rice in excess water for 26 minutes and removing a rice sample from the boiling water every 2 minutes until 36 minutes. The water absorption rate for each rice sample was calculated using the equation:

$$\text{Water absorption rate} = \text{Cooked rice weight} / \text{Rice weight} \tag{5}$$

The cooking time was determined based on the MC of the cooked rice by drying the cooked rice each time in a hot-air oven at 135 ^{o}C for 2 hours. The brown rice was considered well-cooked when the MC was 69%, while for the parboiled rice this occurred at 63% (Billiris *et al*., 2012).

The volume expansion rate of cooked rice was determined by boiling 20 g of rice in excess water according to the cooking time and then measuring the height and weight of the cooked rice and calculating the volume expansion rate using the formula (Saleh and Meullenet, 2015):

Volume expansion rate = Cooked rice height / Rice height (6)

Nutritional analysis

Analysis of the nutritional value and chemical composition of the Kam Bangpra rice and parboiled rice (selected from the best milling quality) was carried out using external services. The energy obtained from rice consumption (protein, fat, ash, and carbohydrate contents), as well as the amounts of dietary fiber, iron, zinc, and gamma oryzanol were determined at Central Laboratory (Thailand) Co., Ltd., Chachoengsao Branch, while the analysis of anthocyanins, polyphenols, vitamins B1, B2, B6, B12, and folate (B9) was carried out at the Institute of Nutrition, Mahidol University (Modified from AOAC, 2019).

Statistical analysis

Experiments were conducted in triplicate and data were analyzed using the IBM SPSS Statistics 26 software. Analysis of variance was used with significance tested at the 0.05 level to determine the effects of soaking temperature, soaking time, and their interaction on the quality characteristics of Kum Bangpra rice and parboiled rice. Mean differences were evaluated using Duncan's multiple range test.

Results

Study of rice soaking factors

Kam Bangpra rice variety (*Oryza sativa* L.) was in the straw-colored rice group, while the brown rice consisted of mixed colors, including purple, black, red, and straw, which suggested diverse phytochemical profiles and potential health benefits, as shown in Figure 1. The weight of 100 grains was 2.45 g for the paddy rice and 1.93 g for the brown rice with an MC of 12.16%. The grain shape value (3.05) indicated a slender grain shape with a low amylose content (18.90%), indicating that this rice would have a sticky texture when cooked.

After soaking the Kam Bangpra rice in hot water at 80, 90, or 100 ºC, the water absorption graph indicated that the paddy rice was saturated with water or had an MC greater than 30% (Miah *et al*., 2002) at soaking times of 120, 90, and 60 minutes for temperatures of 80, 90, and 100 ºC, respectively. The codes for the various treatments of the Kam Bangpra rice and parboiled Kam Bangpra rice samples are presented in Table 1.


a)


b)

Figure 1. Characteristics of a) paddy rice and b) brown rice of Kam Bangpra variety

Table 1. Rice samples studied in this research

Rice samples	Code	Soaking Temp (°C)	Soaking Time (min)	Steaming Time (min)
Kam Bangpra paddy rice	00000	-	-	-
Parboiled Kam Bangpra rice	08010	80	120	10
Parboiled Kam Bangpra rice	08015	80	120	15
Parboiled Kam Bangpra rice	08020	80	120	20
Parboiled Kam Bangpra rice	09010	90	90	10
Parboiled Kam Bangpra rice	09015	90	90	15
Parboiled Kam Bangpra rice	09020	90	90	20
Parboiled Kam Bangpra rice	10010	100	60	10
Parboiled Kam Bangpra rice	10015	100	60	15
Parboiled Kam Bangpra rice	10020	100	60	20

Milling properties

demonstrates that the BRY generally showed slight enhancement with increasing soaking temperature, while the HRY exhibited considerable variance in response to changes in soaking temperature and steaming duration (Table 2). supporting that soaking paddy at 80 °C for 120 minutes achieved the maximum level of gelatinization, leading to improve head rice production.

Physical properties

The weight of 100 grains of parboiled Kum Bangpra rice was in the range 2.45–2.52 g, whereas the weight of 100 grains of brown rice was in the range 1.93–1.97 g; these results were consistent with a report that the weight of 100 rice kernels was in the range 1.40–2.18 g, depending on the variety and processing methods (Saeed *et al*., 2011). Furthermore, the measurements of length, width, and thickness indicated that the variety had a slender grain shape with an aspect ratio in the range 3.06–3.17.

Color of rice

The color changes in rice due to parboiling were quantified using the CIE L*, a*, and b* values (Table 2), which indicated that soaking temperature and steaming time influenced the quality and attributes of rice grains. The L* (brightness), a* and b* values of parboiled rice had been decreased when compared with non-parboiled rice (control).

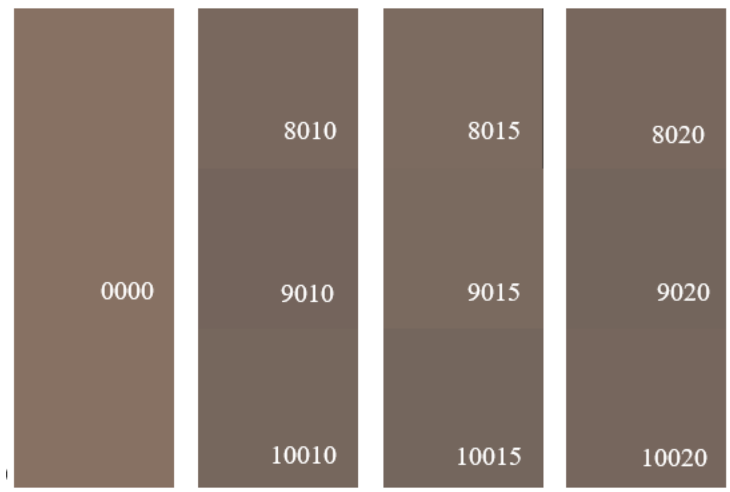

Figure 2. RGB color comparisons of Kam Bangpra rice and parboiled Kam Bangpra rice (see Table 1 for rice code interpretation)

Cooking properties

The cooking properties of both the Kam Bangpra rice and parboiled Kam Bangpra rice samples are shown in Table 3. The amylose content varied in the range 18.90–21.52%, while the gel consistency values were in the range 29.00–57.17. Soaking at either 80°C or 90°C resulted in an increased amylose content, which contributed to a firmer texture upon cooking. Rice soaked at 80°C for 15 minutes had an amylose content of 20.95%, with a gel consistency of 42.83, indicating an equilibrium between stickiness and firmness. The water absorption rate indicated the efficiency which rice absorbed moisture during cooking and hence influencing its final texture. The water absorption rates were in the range 2.41–2.79, with higher values indicating a softer texture.

The volume expansion of cooked rice was in the range 2.50–2.92 times its initial volume. Increased volume expansion is often beneficial for providing more servings, making rice more economically viable. Rice soaked at 100°C for 20 minutes had the highest expansion (2.92), indicating an optimal synergy of soaking and steaming conditions to enhance yield.

Table 2. Milling properties, physical properties and color of Kam Bangpra rice and parboiled Kam Bangpra rice

Code	BRY (%)	HRY (%)	Weight of 100 grains (g)		Shape	Color		
			Rough rice	Brown rice		L*	a*	b*
00000	75.76±0.08a	51.55±1.03a	2.45±0.03a	1.93±0.03ab	3.06±0.03a	49.41±1.05d	6.26±0.50c	11.25±0.55d
08010	77.84±0.08def	48.87±1.70b	2.50±0.06abc	1.94±0.04ab	3.09±0.05ab	45.32±1.13abc	5.29±0.57b	8.11±0.80abc
08015	77.87±0.05ef	49.04±1.69c	2.50±0.03abc	1.93±0.04ab	3.12±0.03abc	46.47±1.64c	4.80±0.85ab	8.71±1.02c
08020	77.96±0.04f	56.99±0.50d	2.48±0.05abc	1.94±0.04ab	3.11±0.04abc	45.04±2.30abc	4.72±0.53ab	8.09±1.98abc
09010	77.63±0.19bc	57.57±0.95de	2.49±0.08abc	1.93±0.06a	3.14±0.03bc	43.59±0.85a	4.85±0.50ab	6.94±0.74a
09015	77.55±0.15bcd	48.15±1.17c	2.48±0.07ab	1.95±0.04ab	3.14±0.04bc	45.87±2.14bc	4.45±0.70a	8.32±1.20bc
09020	77.85±0.12def	72.16±0.51h	2.46±0.05ab	1.94±0.03ab	3.17±0.03c	43.93±1.20a	4.10±0.32a	7.13±1.28ab
10010	77.61±0.06cde	58.21±2.32f	2.52±0.05bc	1.94±0.06ab	3.13±0.08abc	44.64±1.22ab	4.37±0.38a	7.66±0.79abc
10015	77.67±0.61bc	64.63±0.34g	2.48±0.06ab	1.96±0.07ab	3.16±0.06bc	44.25±1.51ab	4.10±0.69a	7.39±1.39ab
10020	77.55±0.08b	56.93±0.40ef	2.54±0.07c	1.97±0.03b	3.14±0.09bc	44.46±0.98ab	4.75±0.74ab	7.50±0.75abc

BRY, brown rice yield; HRY, head rice yield; a, b, c, d, e, f, g, and h, values (mean ± standard deviation) with different lowercase superscripts are significantly different among parboiled conditions. The statistical analysis was used with a significance level of 0.05.

Table 3. Cooking properties of Kam Bangpra rice and parboiled Kam Bangpra rice

Code	Amylose (%)	Gel consistency (cm)	Cooking time (min)	Water absorption rate	Volume expansion of cooked rice
00000	18.90±0.42a	29.00±1.00a	38.00±0.00f	2.79±0.11c	2.65±0.14bc
08010	19.27±0.33ab	53.33±2.16f	31.67±0.82ab	2.45±0.11ab	2.81±0.09de
08015	20.95±1.02e	42.83±2.04c	32.33±1.97abc	2.51±0.07b	2.76±0.16cd
08020	21.52±0.27f	48.33±3.20e	32.67±1.03bcd	2.48±0.10ab	2.62±0.10ab
09010	20.25±0.85d	54.83±2.23fg	32.67±1.03bcd	2.48±0.06ab	2.65±0.24bc
09015	20.82±1.44e	47.83±8.04e	31.00±2.45a	2.43±0.04ab	2.67±0.08bc
09020	20.19±1.30d	43.67±5.72cd	34.33±1.51e	2.47±0.08ab	2.60±0.07ab
10010	19.65±0.20bc	35.83±2.71b	33.33±1.03cde	2.47±0.05ab	2.66±0.25bc
10015	19.63±0.20bc	45.67±3.88de	34.67±1.03e	2.41±0.02a	2.50±0.07a
10020	19.98±1.10cd	57.17±2.32g	34.00±1.79de	2.46±0.07ab	2.92±0.13e

a, b, c, d, e, f, g, and h, values (mean ± standard deviation) are significantly different among parboiled conditions. The statistical analysis was used with a significance level of 0.05

Nutritional analysis

The nutrient analysis indicated similar values between the Kam Bangpra rice and the parboiled rice for the amounts of carbohydrates, protein, fat, dietary fiber, moisture, gamma oryzanol, and zinc (Table 4). Notably, the amount of iron in the parboiled rice was higher than in the non-parboiled Kam Bangpra rice

(23.0 and 18.6 mg/kg, respectively), which may have been due to the process of soaking and steaming, causing iron nutrients from rice husk, bran layer, or seed coat to penetrate into rice grains.

Table 4. Nutrition of Kam Bangpra rice and Kam Bangpra parboiled rice

Nutrient	Kam Bangpra rice	Kam Bangpra Parboiled rice
Total carbohydrate (g/100g)	71.22	73.56
Protein (g/100g)	11.85	9.63
Fat (g/100g)	3.03	3.21
Total dietary fiber (g/100g)	1.79	1.70
Moisture (g/100g)	12.33	12.02
Ash (g/100g)	1.57	1.58
Gamma oryzanol (mg/kg)	396.01	384.14
Iron (Fe) (mg/kg)	18.608	23.044
Zinc (Zn) (mg/kg)	24.034	21.237
Vitamin E (mg/100g)	0.47	0.41
Vitamin B_1 (mg/100g)	0.30	0.25
Vitamin B_2 (mg/100g)	0.03	0.04
Vitamin B_6 (mg/100g)	0.16	0.16
Vitamin B_{12} (mg/100g)	0.14	0.14
Folate (mcg DFE)	71	44
Total polyphenol (mg eq GA)	395.67	206.27
Total Anthocyanin (mg/100g)	19.51	9.23
- Cyanidin (mg/100g)	18.61	9.23
- Peonidin (mg/100g)	0.90	Not detected

Discussion

The optimal conditions for HRY occurred at 90 °C and a steaming duration of 20 minutes, indicating that an elevated temperature and extended steaming duration substantially enriched the quality of the head rice by enhancing starch gelatinization and hence reducing the breakage of rice grains (Buggenhout *et al.*, 2014). It resulted in an HRY increased to 21.58%. Generally, a higher initial soaking temperature (90 °C) and longer steaming times (15–20 minutes) resulted in increased milling yield and HRY (Manful *et al.*, 2009). However, ripening temperatures above 28/20 °C resulted in a decline in cooking quality and palatability (Chun *et al.*, 2015). Adjusting the soaking temperature and steaming duration impacted the physical and chemical properties of the rice grains, since higher temperatures and extended steaming periods often enhance the production of head rice, which is found to be advantageous for both quality of rice and commercial value.

The color changes of parboiled rice were influenced by various factors, including soaking temperature, steaming conditions, and milling degree (Mir and

Bosco, 2013). Often, the increased soaking temperatures and extended steaming durations produced darker rice grains. The darker hue of rice grains resulted from the Maillard reaction and the migration of bran pigments into the endosperm during steaming. The steaming periods was extended to 10–20 minutes that produced a darker rice grains (Noori *et al*., 2024) and often enhanced gel consistency. For example, soaking at 100°C for 20 minutes produced the highest gel consistency (57.17), indicating a firmer grain that would sustain its post-cooking shape well.

He *et al*. (2018) reported that elevated soaking temperatures (80°C and above) and extended steaming durations enhanced starch gelatinization, influencing texture and digestibility. Gel consistency was utilized as an efficient measure for evaluating the texture of the cooked rice, where elevated values signified a firmer, less sticky product, which may be advantageous for some culinary preparations.

Correct adjustments of the cooking time and water absorption rate were essential for attaining the desired texture in cooked rice. The cooking time was in the range 31–38 minutes. Notably, rice soaked at higher temperatures and for longer periods had shorter cooking times and resulted to enhance water absorption and starch leaching, which influenced the final texture of the cooked rice (Saeed *et al*., 2011), suggesting soaking during the parboiling process may enhance cooking efficiency.

In addition, Promsomboon and Promsomboon (2019) found that the husk and bran layers of Kam Bangpra rice were dark purple, with the rice having a slender body. Based on the current results, the Kam Bangpra rice had higher levels of gamma oryzanol (241.22 mg/kg) and antioxidant content (106.23 mg/100 g) than riceberry (46.20 mg/kg and 47.50 mg/100 g, respectively). Although the iron content in the Kam Bangpra rice (11.43 mg/kg) was less than that of riceberry (13.80 kg/kg), based on the current results, the production process of parboiled rice from Kam Bangpra increased the amount of iron in the Kam Bangpra parboiled rice to 23.0 mg/kg.

It showed the combimnation results which affecred the parboiled rice on the contents of antioxidants and vitamins in brown rice. Although the steaming of rice can reduce total phenolic compounds and antioxidants (Balbinoti *et al*., 2020), parboiled rice still had the highest total phenolic content and antioxidant activity compared to other types of rice (Sripum *et al*., 2017). In addition, parboiling rice affected the rice quality by improving the nutritional value through the retention of vitamins and micronutrients (Bhattacharya, 2013). Overall, the effects of steaming on the antioxidants and vitamins of rice depended on the specific processing conditions and rice variety.

Furthermore, parboiled rice had a medium glycemic index (GI) range (48–93) and a longer shelf life than non-parboiled rice (Boers *et al*., 2015), with one study reporting that parboiling reduced the glycemic response in healthy individuals, reporting a 10% reduction in the GI (Pathiraje *et al*., 2011). These findings suggested that parboiled rice is a healthier alternative to conventional white rice, as well as having a longer shelf life.

Varying the soaking temperature and steaming time of the rice significantly affected the milling properties (BRY and HRY) and cooking properties (amylose content, gel consistency, cooking time, water absorption rate, and volume expansion). These factors should facilitate for adopting to improve cooking methods that tailored to specific rice varieties and desired textures. Finally, the findings were consistent with established research in food science, providing insights for both consumers and culinary professionals.

Acknowledgements

This research project was supported by a research grant from the Thailand Science Research and Innovation (TSRI), National Science, Research and Innovation Fund (NSRF), Basic Research Fund: fiscal year 2020 (Project no.1669). We would like to thank the Faculty of Science and Technology, and the Faculty of Agriculture and Natural Resources, Rajamangala University of Technology Tawan-ok, Chonburi Province, Thailand, for their participation and facility support.

Conflicts of interest

The authors declare no conflict of interest.

References

AACC. (2010). AACC Method 44-19.01: Moisture—Air-Oven Method, Drying at 135°. In Approved Methods of the American Association of Cereal Chemists 11th Ed. American Association of Cereal Chemists.

AOAC. (2019). Official Methods of Analysis of the Association of Official Analytical Chemists: Official Methods of Analysis of AOAC International. 21st Edition, AOAC, Washington DC.

Balbinoti, T. C. V., Stafussa, A. P., Haminiuk, C. W. I., Maciel, G. M., Sassaki, G. L., Jorge, L. M. de M. and Jorge, R. M. M. (2020). Addition of grape pomace in the hydration step of parboiling increases the antioxidant properties of rice. International Journal of Food Science & Technology, 55:2370-2380.

Bhattacharya, K. R. (2004). Chapter 13: Parboiling of rice. In: *RICE: Chemistry and Technology*. American Association of Cereal Chemists, Inc. pp.329-404.

Bhattacharya, K. R. (2013). Effect of parboiling on rice quality. In: *Rice Quality*. Elsevier. pp.247-297.

Billiris, M. A., Siebenmorgen, T. J., Meullenet, J. F. and Mauromoustakos, A. (2012). Rice degree of milling effects on hydration, texture, sensory and energy characteristics. Part 1. Cooking using excess water. Journal of Food Engineering, 113:559-568.

Boers, H. M., Seijen ten Hoorn, J. and Mela, D. J. (2015). A systematic review of the influence of rice characteristics and processing methods on postprandial glycaemic and insulinaemic responses. British Journal of Nutrition, 114:1035-1045.

Buggenhout, J., Brijs, K. and Delcour, J. A. (2014). Soaking conditions during brown rice parboiling impact the level of breakage-Susceptible Rice Kernels. Cereal Chemistry, 91:554-559.

Cagampang, G. B., Perez, C. M. and Juliano, B. O. (1973). A gel consistency test for eating quality of rice. Journal of the Science of Food and Agriculture, 24:1589-1594.

Chinaworn, S., Sennoi, R., Puthmee, T. and Pornsuriya, P. (2023). Responses of modern and local Thai rice varieties to the aerobic soil. Australian Journal of Crop Science, 17:233-239.

Chun, A., Lee, H.-J., Hamaker, B. R. and Janaswamy, S. (2015). Effects of ripening temperature on starch structure and gelatinization, pasting, and cooking properties in rice (*Oryza sativa*). Journal of Agricultural and Food Chemistry, 63:3085-3093.

He, M., Qiu, C., Liao, Z., Sui, Z. and Corke, H. (2018). Impact of cooking conditions on the properties of rice: Combined temperature and cooking time. International Journal of Biological Macromolecules, 117:87-94.

Hu, Z., Tang, X., Liu, J., Zhu, Z. and Shao, Y. (2017). Effect of parboiling on phytochemical content, antioxidant activity and physicochemical properties of germinated red rice. Food Chemistry, 214:285-292.

Igathinathane, C., Chattopadhyay, P. K. and Pordesimo, L. O. (2005). Combination soaking procedure for rough rice parboiling. Transactions of the ASAE, 48:665-671.

Juliano, B. O. and Villareal, C. P. (1993). *Grain quality evaluation of world rices*. International Rice Research Institute.

Kongseree, N. (2004). Quality of cooked rice. In: *Quality and Inspection of Thai Jasmine Rice*. Department of Agriculture and Office of Industrial Economics, pp.41-61.

Leethanapanich, K., Mauromoustakos, A. and Wang, Y. J. (2016). Impacts of parboiling conditions on quality characteristics of parboiled commingled rice. Journal of Cereal Science, 69:283-289.

Manful, J. T., Abbey, L. D. and Coker, R. D. (2009). Effect of artisanal parboiling methods on milling yield and cooked rice textural characteristics. Journal of Food Quality, 32:725-734.

Mir, S. A. and Bosco, S. J. D. (2013). Effect of soaking temperature on physical and functional properties of parboiled rice cultivars grown in temperate region of India. Food and Nutrition Sciences, 4:282-288.

Noori, Z., Furuichi, S., Kakar, K., Aryan, S., El-Sheikh, M. A., Elansary, H. O. and Mozafari, R. (2024). Elucidation of soaking and steaming duration in parboiling: effects on the physical quality and appearance of local rice cultivars. Cogent Food & Agriculture, 10.

Oli, P., Ward, R., Adhikari, B. and Torley, P. (2014). Parboiled rice: Understanding from a materials science approach. Journal of Food Engineering, 124:173-183.

Pathiraje, P. M. H. D., Madhujith, W. M. T., Chandrasekara, A. and Nissanka, S. P. (2011). The effect of rice variety and parboiling on in vivo glycemic response. Tropical Agricultural Research, 22:26.

Promsomboon, P. and Promsomboon, S. (2019). Environmental responsibility of rice var. Kum Bangpra and Riceberry in lowland and upland conditions. International Journal of Agricultural Technology, 15:747-752.

Ratanacoon, M., Jaisamut, O., Sudprasert, P. and Promsomboon, S. (2023). Chemical composition of Kum Bangpra rice bran, rice bran oil and their anthocyanin color powder production. International Journal of Agricultural Technology, 19:1243-1256.

Saeed, F., Pasha, I., Anjum, F. M., Suleria, H. A. R. and Farooq, M. (2011). Effect of parboiling on physico-chemical and cooking attributes of different rice cultivars. Internet Journal of Food Safety, 13:237-245.

Saleh, M. and Meullenet, J. F. (2015). Cooked rice texture and rice flour pasting properties; impacted by rice temperature during milling. Journal of Food Science and Technology, 52:1602-1609.

Sopanangkul, A., Promsomboon, S., Promsomboon, P. and Chinaworn, S. (2023). Substitution of wheat flour using Kum Bangpra rice flour in development of gluten-free cake. Rajamangala University of Technology Tawan-Ok Research Journal, 16:29-38.

Sripum, C., Kukreja, R. K., Charoenkiatkul, S., Kriengsinyos, W. and Suttisansanee, U. (2017). The effect of extraction conditions on antioxidant activities and total phenolic contents of different processed Thai Jasmine rice. International Food Research Journal, 24.

Tanghiranrat, J., Itsarasook, K., Prompamorn, P., Imsathian, N., Sriburin, N., Bangsiri, N. and Chantree, K. (2021). Antioxidant Efficiency of black glutinous rice (*Oryza sativa L.*(indica)) extracts: application in lipid-based food products. Burapha Science Journal, 26:1345-1363.

Zhang, W., Cheng, B., Zeng, X., Tang, Q., Shu, Z., and Wang, P. (2022). Physicochemical and digestible properties of parboiled black rice with different amylose contents. Frontiers in Nutrition, 9:934209.

(Received: 18 April 2025, Revised: 20 January 2026, Accepted: 10 March 2026)