As. J. Food Ag-Ind. **2009**, 2(04), 515-524

OPEN ACCESS

Asian Journal of Food and Agro-Industry
ISSN 1906-3040
Available online at www.ajofai.info

Research Article

Effect of pre-germination and parboiling on brown rice properties

Kanokkan Panchan and Onanong Naivikul*

Department of Food Science and Technology, Faculty of Agro-Industry,
Kasetsart University, Bangkok 10900, Thailand.

*Author to whom correspondence should be addressed, email: fagionn@ku.ac.th

This paper was originally presented at Food Innovation Asia 2009, Bangkok, Thailand.

Abstract

Rice is often modified by parboiling to improve its quality. Parboiling is the hydrothermal treatment applied to rough rice. As a result, the properties of the rice are changed which in turn improves the milling quality, nutritional value and storage stability of the grain. Rice quality may also be improved by germination. During germination, high molecular weight polymers are hydrolysed which decreases the molecular size and produces bio-functional substances. In order to determine changes in pre-germinated brown rice and parboiled pre-germinated brown rice, one variety of Thai rice (Suphan Buri 1) was selected for this research. Alkali digestibility, rice colour, reducing sugar content and pasting properties were measured to observe resultant changes in rice properties. The research suggested that the optimal soaking time for pre-germinated rough rice was 14 h at 30°C to obtain three levels of subsequent embryo growth lengths, 0.5 mm (minimum), 1 mm (optimum) and 2 mm (maximum) at respective incubation times of 14, 18 and 24 h. At these conditions the water content of pre-germinated rough rice was more than 30% (w/w) which was sufficient for the parboiling process. Gelatinization temperature of rice (GT) was recorded from the alkali spreading value of the brown rice. The results showed all pre-germinated brown rice had high GT (74.5-80°C) whereas all parboiled pre-germinated brown rice had lower GT (<70°C). The yellowness (b value) of all pre-germinated and all parboiled pre-germinated brown rice was significantly increased compared to normal brown rice ($P<0.05$). The reducing sugar contents of all pre-germinated and all parboiled pre-germinated brown rice were increased compared to brown rice upon prolonging incubation times ($P<0.05$). The pasting properties could be determined from viscosity values (peak viscosity, trough, breakdown and setback) of all pre-germinated and all parboiled pre-germinated brown rice and they were significantly decreased compared to brown rice as a result of starch hydrolysis.

Keywords: Pre-germinated brown rice, parboiled pre-germinated brown rice, incubating time, embryo growth length, viscosity, starch hydrolysis, Thailand

Introduction

Parboiled rice is produced from paddy rice through pre-treating it with heat energy and water before drying and milling. During parboiling, starch granules of rice are gelatinized. As a result of starch gelatinization, various property changes occur in the rice. The major objectives of parboiling are to increase the total and head yield of the paddy, prevent loss of nutrients during milling and prepare the rice according to the requirements of consumers [1].

During the germination process, saccharification softens the endosperm and dormant enzymes are activated. These enzymes decompose the high molecular weight polymers leading to the generation of bio-functional substances, which results in an increase of gamma-aminobutyric acid (GABA), free amino acids, dietary fibre, inositols, ferulic acid, phytic acid, tocotrienols, magnesium, potassium, zinc, γ-oryzanol and prolylendopeptidase inhibitor [2, 3, 4]. However, during the soaking process of the rice grains, microorganisms greatly multiply. By using high temperature and pressure in the parboiling process the number of potentially harmful microorganisms can be greatly reduced.

The objectives of this study was to select one variety of Thai rice (Suphan Buri 1) to (a), investigate the pre-germination conditions as a function of soaking times and incubating times at 30°C for producing three levels of embryo growth lengths from paddy rice grain, and (b), to determine the effect of pre-germinated and parboiling processes on physical, chemical and physicochemical properties such as moisture content, colour values, alkali digestibility, reducing sugar content and pasting properties.

Material and Methods

Materials

One cultivar Thai paddy rice (Suphan Buri 1) was used. This variety was obtained from the Bureau of Rice Research and Development, Rice Department, Thailand. The Suphan Buri 1 paddy rice was stored in self-sealing plastic bags under freezing at -18°C for 6 months before being used.

Methods

Brown rice preparation

Suphan Buri 1 paddy rice (250 g) was passed through a hulling device to remove the hulls from the kernels to produce brown rice. The brown rice sample was put into a plastic can and then stored in the refrigerator at 4°C for further analysis.

Pre-germinated brown rice production

- **Paddy rice preparation**
  The Suphan Buri 1 paddy grains were sorted to remove any foreign matter and to select the young grain from the mature grain by soaking 1.08 specific gravity of sodium chloride solution.

- **Determination suitable moisture content for soaking time and incubating time of paddy rice pre-germination**

In order to determine suitable moisture content for soaking time and incubating time of paddy rice pre-germination, the mature paddy rice grains (250 g per cotton bag) were soaked in tap water (average pH 6.9-7.5) at 30°C for 2, 4, 6, 8, 10, 12, 14, 16, 18, 24, 30 and 36 h. After each soaking, water was drained from each paddy rice bag. The paddy samples were placed on wet cotton cloth in a tray, covered with more wet cotton cloth and the tray closed with wrapping film. These samples trays were incubated at 30°C, 85% relative humidity (RH) for 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 and 36 hours.

- **Determination of pre-germination time at three levels of embryo growth length**
  Conditions such as suitable moisture content for soaking time and incubating time were used to select the suitable pre-germination time. By fixing soaking time but varying incubating time, pre-germinated paddy rice at 3 levels of embryo growth lengths; 0.5 mm. (minimum), 1 mm. (optimum), and 2 mm. (maximum) could be produced.

Parboiled pre-germinated brown rice production

The 3 types of sample prepared from the previous pre-germination method were then parboiled at 0.5 bar for 10 minutes by using steamer pot (Olla Innova 6L; Fagor, Spain) [5].

Brown rice and brown rice flour preparation

Supan Buri 1 paddy rice was de-hulled to produce brown rice, whereas all pre-germinated paddy rice, parboiled paddy rice and all parboiled pre-germinated paddy rice were dried at 45 ± 10°C until moisture content was less than 12% and then kept at room temperature (approximately 30°C) for 7 days before being de-hulled to produce pre-germinated brown rice, parboiled brown rice and parboiled pre-germinated brown rice.

Brown rice, pre-germinated brown rice, parboiled brown rice and parboiled pre-germinated brown rice were finely ground and passed through a 100-mesh sieve before analysis.

Moisture content

2- 3 g of flour was weighed and placed in dried tarred moisture cans and the containers placed in a well-ventilated hot air oven at 130°C for 14–16 hours. The covered cans were then weighed after cooling to room temperature to determine the loss in weight and record it as a percentage of moisture loss [6].

Colour measurement

A colour meter (Chroma Meter CR 310) was used to measure the colour values of whole kernel brown rice utilizing the L, a, b uniform colour space procedure [5]. The value of 'L' is a measure of the brightness from black (0) to white (100). The value of 'a' describes red (+a) and green (-a) colour and the value of 'b' describes yellow (+b) and blue (-b) colour. The instrument was calibrated with a standard white plate having L, a and b values of 94.2, 0.3157 and 0.3320, respectively.

Reducing sugar content

In order to extract the reducing sugar, flour (1.00 g) was placed in a 50 mL centrifuge tube. A solution of 50% ethanol (10 mL) was then added [7]. The sample was thoroughly stirred and centrifuged at 5,000 rpm for 15 min at 25°C [8]. The supernatant (1 mL) was added to an alkaline copper reagent (1 mL) before being placed in a screw-capped test tube. Each sample was heated in boiling water for 15 minutes. After heating, the tube was immediately cooled in

an ice bath. A Nelson reagent (1 mL) was added and mixed with a vortex mixer. The sample was kept at room temperature for 30 minutes. The sample was then diluted in 5 or 10 mL of distilled water before the amount of reducing sugar was measured by a spectrophotometer at the absorbance wavelength 520 nm. The standard used was D-glucose.

Alkali digestibility

Ten grains of brown rice samples were incubated in 27 mL of 1.7% KOH at room temperature for 23 hours. A 7-point scale was used to determine the degree of spreading. The scales 1-7 correspond to the degree of degradation by alkali [9]. Alkali digestibility value using 1.7% KOH is inversely related to gelatinization temperature of starch, i.e. 74.5-80.0°C (high gelatinization temperature), 74.1-74.4°C (moderately high gelatinization temperature), 70.5-74.0°C (moderate gelatinization temperature) and 55.0-69.0°C (low gelatinization temperature).

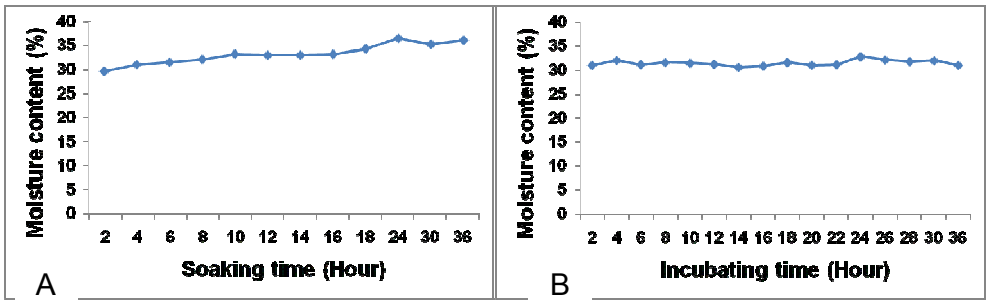
Pasting properties

Pasting properties of each brown rice flour sample were determined by the Rapid Visco Analyzer (RVA 4, Newport Scientific, Australia) following the approved method [6]. Each sample (3 g, 12% moisture basis) was dispersed in 25 mL of distilled water and standard 1 measurement profile was applied.

Results and Discussion

Moisture content for soaking time and incubating time of paddy rice pre-germination

The moisture content of paddy rice during soaking and incubating for 2-36 hours was more than 30% (Figure 1A, 1B). The initial 70% pre-germination of grains occurred when soaking paddy for at least 14 hours and incubating for at least 14 hours. At these conditions it can be concluded it was also the minimum level of pre-germinated paddy rice.



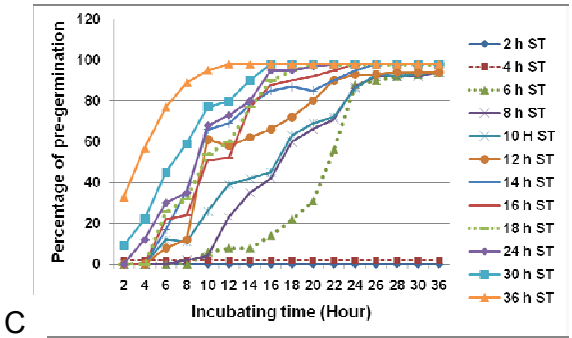


Figure 1. Moisture content of Suphan Buri 1 paddy rice.

After soaking at 30°C for 2-36 hours (A), moisture content of paddy rice after soaking at 30°C for 14 hours then incubating at 30°C, 85% RH for 2-36 hours (B) and percentage of pre-germination

when soaking at 30°C for 2-36 hours (soaking time; ST) then incubating at 30°C, 85% RH for 2-36 hours (C).

Conditions for pre-germination process of paddy rice

Duringthe process of producing pre-germinated brown rice at different embryo growth lengths, the paddy was soaked at 30°C for 14 hours and incubated at 30°C, 85%RH for 2-36 hours, the moisture content of paddy at all incubating times being more than 30% (Figure 1C). The respective incubation times of 14 (28 h of pre-germination time), 18 (32 h of pre-germination time) and 24 (38 h of pre-germination time) hours, gave three levels of subsequent embryo growth lengths, 0.5 mm (minimum), 1 mm (optimum) and 2 mm (maximum) (Figure 1C).

In general, during the parboiling process, in order to gelatinize the starch the paddy must absorb sufficient quantities of water. If the starch in the endosperm is not fully gelatinized, there will be white cores present in the parboiled product. The time of exposure to steam must therefore be long enough to gelatinize the whole kernel completely. The moisture content of soaked paddy before parboiling should be 30-35% moisture content [10].

Colour values

The colours of three pre-germinated brown rice samples, pre-germinated brown rice at minimum level (GBR-28; 68.02), pre-germinated brown rice at optimum level (GBR-32; 66.78) and pre-germinated brown rice at maximum level (GBR-38; 66.53) were significantly different, being less brighter (L) than brown rice (BR; 69.33). In addition, the yellow colour (b+) of all pre-germinated brown rice (GBR-28; 22.85, GBR-32; 22.35 and GBR-38; 22.43) was significantly different from brown rice (BR; 21.86).

Due to the parboiling process, the brightness values significantly decreased when the three pre-germinated brown rice samples, parboiled pre-germinated brown rice at minimum level (PGBR-28; 57.99), parboiled pre-germinated brown rice at optimum level (PGBR-32; 57.32) and parboiled pre-germinated brown rice at maximum level (PGBR-38; 58.62) were parboiling. The yellow colour of all parboiled pre- germinated brown rice (PGBR-28; 28.74, PGBR-32; 28.59 and PGBR-38; 28.45) was significantly different from brown rice (BR; 21.86) as shown in Table 1.

It has been hypothesized that the colour changes of rice occurring during parboiling are mainly caused by nonenzymic browning of the Maillard type. In addition, nonenzymic browning, husk and bran pigments also appear to contribute to parboiled rice colour. The contribution of pigments to colouration of parboiled rice is supported by the fact that some nutrients (minerals and vitamins) from the bran diffuse into the kernel and other bran compound (lipids) leach out during parboiling, resulting in an increase of yellow appearance when compared with brown rice [11, 12].

Table 1. Colour values of pre-germinated brown rice and parboiled pre-germinated brown rice at different embryo growth lengths when compared with brown rice and parboiled brown rice.

Rice samples[(1)]	Colour values[(2)]	
	L	b
BR	69.33^{a} ± 0.31	21.86^{d} ± 0.20
GBR-28	68.02^{b} ± 0.05	22.85^{b} ± 0.17
GBR-32	66.78^{c} ± 0.42	22.35^{c} ± 0.20
GBR-38	66.53^{c} ± 0.24	22.43^{bc} ± 0.18
PBR	63.05^{d} ± 0.05	28.30^{a} ± 0.57
PGBR-28	57.99^{e} ± 0.26	28.74^{a} ± 0.16
PGBR-32	57.32^{f} ± 0.35	28.59^{a} ± 0.01
PGBR-38	58.62^{e} ± 0.34	28.45^{a} ± 0.01

(1) BR = Brown rice, GBR-28 = Pre-germinated brown rice at minimum level, GBR-32 = Pre-germinated brown rice at optimum level, GBR-38 = Pre-germinated brown rice at maximum level, PBR = Parboiled brown rice soaked for 14 hours, PGBR-28 = Parboiled pre-germinated brown rice at minimum level, PGBR-32 = Parboiled pre-germinated brown rice at optimum level, and PGBR-38 = Parboiled pre-germinated brown rice at maximum level.

(2) Values are means of triplicate measurements ± standard deviations. Means for each characteristic followed by the different letter within the same column are significantly different determined by ANOVA and Duncan's test (p<0.05).

Reducing sugar

The reducing sugar content between brown rice (BR; 44.42 mg/100 g samples) and the three pre-germinated brown rice (GBR-28; 96.92 mg/100 g samples, GBR-32; 127.69 mg/100 g samples and GBR-38; 291.92 mg/100 g samples) was significantly increased when pre-germination times increased (28-38 h) (Table 2). During germination, α-amylase degraded starch into a complex mixture of sugars which provide the energy for the growth of roots and shoots [13]. These sugars included glucose, maltose, maltotriose and a wide range of dextrins [14]. The increasing level of reducing sugar resulting from parboiling can in part be explained by sucrose conversion during soaking and, in addition, degradation of starch occurs during steaming [15].

Table 2. Reducing sugar of pre-germinated brown rice and parboiled pre-germinated brown rice at different embryo growth lengths when compared with brown rice and parboiled brown rice.

Rice samples[(1)]	Reducing sugar content (mg/ 100 g db samples)[(2)]
BR	44.42^{h} ± 0.38
GBR-28	96.92^{f} ± 3.26
GBR-32	127.69^{d} ± 8.70
GBR-38	291.92^{a} ± 0.54
PBR	58.08^{g} ± 0.54
PGBR-28	108.08^{e} ± 3.81
PGBR-32	145.38^{c} ± 5.44
PGBR-38	263.08^{b} ± 1.09

(1) BR = Brown rice, GBR-28 = Pre-germinated brown rice at minimum level, GBR-32 = Pre-germinated brown rice at optimum level, GBR-38 = Pre-germinated brown rice at maximum level, PBR = Parboiled brown rice after soaking for 14 hours, PGBR-28 = Parboiled pre-germinated brown rice at minimum level, PGBR-32 = Parboiled pre-germinated brown rice at optimum level, and PGBR-38 = Parboiled pre-germinated brown rice at maximum level.

(2) Values are means of triplicate measurements ± standard deviations. Means for each characteristic followed by the different letter within the same column are significantly different determined by ANOVA and Duncan's test (p<0.05).

Alkali digestibility

Gelatinization temperature (GT) was measured by the alkali spreading value of each brown rice soaked with 1.7% KOH for 23 hours. The scores of brown rice and three pre-germinated brown rice were rated in the range of 2.5-2.7 (74.5-80°C of GT) which indicated brown rice and all pre-germinated brown rice have high gelatinization temperature. The gelatinization temperature of parboiled brown rice and all parboiled pre-germinated brown rice were moderate and low, respectively (Table 3). The degree of gelatinization temperature relates to texture of cooked rice [16].

Table 3. Alkali digestibility of pre-germinated brown rice and parboiled pre-germinated brown rice at different embryo growth lengths when compared with brown rice and parboiled brown rice.

Rice samples(1)	Alkali digestible scores (1-7)	Degree of cooked grains temperature	Gelatinization temperature (°C)
BR	2.5	High	74.5-80.0
GBR-28	2.5	High	74.5-80.0
GBR-32	2.7	High	74.5-80.0
GBR-38	2.4	High	74.5-80.0
PBR	5.0	Moderate	70.5-74.0
PGBR-28	6.0	Low	55.0-69.0
PGBR-32	6.0	Low	55.0-69.0
PGBR-38	6.0	Low	55.0-69.0

(1) BR = Brown rice, GBR-28 = Pre-germinated brown rice at minimum level, GBR-32 = Pre-germinated brown rice at optimum level, GBR-38 = Pre-germinated brown rice at maximum level, PBR = Parboiled brown rice after soaking for 14 hours, PGBR-28 = Parboiled pre-germinated brown rice at minimum level, PGBR-32 = Parboiled pre-germinated brown rice at optimum level, and PGBR-38 = Parboiled pre-germinated brown rice at maximum level.

Pasting properties

The pasting properties of brown rice had the highest of all viscosity values (peak viscosity, trough, breakdown, final viscosity and setback). The pasting properties of pre-germinated brown rice decreased sharply when pre-germination time was increased (Table 4). During germination, amylolytic enzymes activate to break down starch producing more sugars and oligosaccharides, resulting in loss of viscosity [17].

The pasting properties of parboiled brown rice and three parboiled pre-germinated brown rice samples decreased significantly compared to brown rice (Table 4). The decrease in pasting properties occurred from the parboiling process that caused the starch to gelatinize which resulted in loss of viscosity. According to Sitachitta [5], the pasting properties of cooked white rice decreased when parboiled.

Table 4. **Pasting properties of pre-germinated brown rice and parboiled pre-germinated brown rice at different embryo growth lengths when compared with brown rice and parboiled brown rice.**

Rice sample[(1)]	Pasting temp. (°C)	Peak time (min)	Viscosity[(2)] (cP)				
			Peak visco.	Trough	Breakdown	Final visco.	Setback
BR	62.9^{a} (0.6)	5.5^{bc} (0.0)	1,811^{a} (32.5)	1,158.5^{a} (41.7)	652.5^{a} (9.2)	2,471.5^{a} (6.4)	1,313.0^{a} (35.4)
GBR-28	62.9^{a} (0.5)	5.1^{bc} (0.0)	1,100.5^{b} (7.8)	513.5^{b} (4.9)	587.0^{b} (12.7)	1,205.5^{c} (3.5)	692.0^{b} (8.5)
GBR-32	62.9^{a} (0.5)	5.2^{bc} (0.0)	934.0^{c} (11.3)	517.5^{b} (2.1)	416.5^{c} (13.4)	1,240.0^{b} (15.6)	722.5^{b} (17.7)
GBR-38	64.1^{a} (1.1)	5.0^{c} (0.2)	401.5^{d} (6.4)	180.0^{cd} (4.2)	221.5^{d} (10.6)	552.0^{d} (0.0)	372.0^{c} (4.2)
PBR	62.9^{a} (0.5)	6.9^{a} (0.1)	205.0^{e} (4.2)	200.5^{c} (2.1)	4.5^{e} (2.1)	301.5^{e} (0.7)	101.0^{d} (1.4)
PGBR-28	62.9^{a} (0.5)	6.9^{a} (0.0)	96.5^{g} (2.1)	89.5^{e} (3.5)	7.0^{e} (5.7)	146.0^{g} (24.0)	56.5^{e} (27.6)
PGBR-32	63.3^{a} (1.1)	6.2^{ab} (1.0)	151.5^{f} (13.4)	145.5^{d} (4.9)	6.0^{e} (8.5)	251.0^{f} (9.9)	105.5^{d} (14.8)
PGBR-38	65.3^{a} (3.9)	6.3^{ab} (1.0)	183.5^{ef} (9.2)	176.5^{cd} (4.2)	7.0^{e} (4.2)	291.0^{e} (0.0)	114.5^{d} (4.9)

(1) BR = Brown rice, GBR-28 = Pre-germinated brown rice at minimum level, GBR-32 = Pre-germinated brown rice at optimum level, GBR-38 = Pre-germinated brown rice at maximum level, PBR = Parboiled brown rice after soaking for 14 hours, PGBR-28 = Parboiled pre-germinated brown rice at minimum level, PGBR-32 = Parboiled pre-germinated brown rice at optimum level, and PGBR-38 = Parboiled pre-germinated brown rice at maximum level.

(2) Values are means of duplicate measurements. Means for each characteristics followed by the different letter within the same column are significantly different determined by ANOVA and Duncan's test (p<0.05). Number in each parenthesis indicated standard derivative value.

Conclusions

Germination and parboiling processes can affect the properties of brown rice.

In order to determine the property changes in pre-germinated brown rice and parboiled pre-germinated brown rice, one Thai rice variety (Suphan Buri 1) was used. The optimal soaking time for pre-germinated paddy rice was 14 hours at 30°C to obtain three levels of embryo growth lengths, 0.5 mm (minimum), 1 mm (optimum) and 2 mm (maximum) at respective incubating times of 14 (28 h of pre-germination time), 18 (32 h of pre-germination time) and 24 (38 h of pre-germination time) hours. Under these conditions the water content of pre-germinated paddy rice was more than 30% (w/w).

During germination, α-amylase is activated and this decomposed starch into a complex mixture of sugars which provide the energy for the growth of roots and shoots. This can be observed from the increase in reducing sugar when brown rice was pre-germinated. As a result of starch degradation during pre-germination, the viscosity properties of brown rice were also changed.

During parboiling, starch granules of rice are gelatinized. The colour change of parboiled brown rice was caused mainly by Maillard reaction and pigments from husk and bran diffused into the kernel. The increased level of reducing sugar can be explained by sucrose conversion during soaking, in addition to the degradation of starch occurring during steaming. As the rice starch of parboiled brown rice was gelatinized, it also loses its viscosity properties.

Acknowledgement
This study was partially supported by the Agricultural Research Development Agency (Public Organization).

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