World Journal of Agricultural Sciences 4 (4): 409-415, 2008
ISSN 1817-3047

Effect of Soaking Temperature on Physical, Chemical and Cooking Properties of Parboiled Fragrant Rice

[1]K. Sareepuang, [1,2]S. Siriamornpun, [2]L. Wiset and [2]N. Meeso

[1]Department of Food Technology and Nutrition, Faculty of Technology,
Mahasarakham University, Mahasarakham, 44000, Thailand
[2]Research Unit of Drying Technology for Agricultural Products,
Faculty of Engineering Mahasarakham University, Khantharawichai, Mahasarakham 44150, Thailand

Abstract: KDML 105 is the most popular fragrant rice for export and consumption in Thailand but it has poor milling yield. To solve this problem, parboiling has been used for improving milling quality of damaged rice. Our present study investigated the effect of soaking temperature on physical, chemical and cooking properties of parboiled rice. The 12-month stored KDML 105 paddy samples were soaked at 40, 50 and 60°C for 3 h, then autoclaved with steam at 121°C 15 min and dried by cabinet tray dryer at 60°C to reach the moisture content of 23 g/100 g dry matter. Head milling yield was significantly increased from 51% in brown rice to 60-80% in parboiled rice. The results also showed that parboiling process significantly ($p<0.05$) increased protein, lipid and ash contents. Overall, soaking at 50°C for 3 h prior to steaming and drying was found to provide the most desirable quality of parboiled rice in our study in terms of nutritional quality and sensory properties.

Key words: Soaking temperature · Parboiled rice · Physical properties · Chemical properties · Cooking quality

INTRODUCTION

Khao Dawk Mali 105 (KDML 105) is the most popular aromatic rice variety in Thailand, in terms of production, consumption and export. Because of its famous reputation in appearance, cooking quality and high aroma level, the rice has gained an increasing popularity throughout the world food market. However it is sensitive to heat and fragile during handling, causing poor milling yield. Therefore, improvement of milling quality of damaged grain is needed.

Parboiling is a process developed for improving rice quality. It consists of soaking, steaming and drying of the rough rice. The major reasons for parboiling rice include higher milling yields, higher nutritional value and resistance to spoilage by insects and mold [1, 2]. The parboiling process is applied to rice with a preliminary objective of hardening the kernel in order to maximize head rice yield in milling. Besides milling yield, it was also the realization of the nutritional and health benefits of parboiled brown rice [3] compared to raw brown rice that created the awareness and importance of parboiling among consumers and manufacturers.

Several studies have reported on parboiling processes as reviewed by Luh and Mickus [4]. Traditionally, parboiling consists of steeping rough rice in water at room temperature followed by steaming or boiling at 100°C and sun-drying. Recently, more sophisticated procedures such as dry-heat parboiling and pressure parboiling have been applied [5]. Soaking at room temperature (traditional method of parboiling) is slow and that causes microbial contamination while hot soaking (CFTRI method) requires precise control and special care because a steep temperature and moisture gradient develops and may cause sloughing-off of the surfaces before hydration up to the core of the kernel is achieved. It has been suggested that starting soaking of paddy at 75°C and allowing the batch to cool naturally ensures the fastest possible hydration without complication [2]. However, such hot soaking requires precise control [6].

Therefore this study aimed to investigate the effect of soaking temperature on cooking quality physicals, chemicals and cooking properties of parboiled rice. We were especially interested in parboiling of fragrant rice which was quite fragile and kept for a long period of time.

Corresponding Author: S. Siriamornpun, Department of Food Technology and Nutrition, Faculty of Technology, Mahasarakham University, Mahasarakham, 44000, Thailand

MATERIALS AND METHODS

Materials: Khao Dawk Mali 105 (KDML 105) was used for the experiments. Paddy samples were harvested at from the largest rice production region; "Tung Kula Rong Hai", located in the northeast of Thailand. Before conducting the experiment, rough rice was stored in a chamber of room temperature for period of about 12 months.

Parboiling: Parboiling processes was done followed by the methods of Saif *et al*. [7]. Samples of 100 g of rough rice were placed in an Erlenmeyer flask 500 ml. The samples were soaked in a water bath shaker with controlled temperature at 40, 50 and 60°C (±0.5°C). After that, the rice was taken out of the water bath, rid and excess water and the container with sample were put in an autoclave for steam (121°C 15 min). After steaming, the paddy was removed to cabinet tray dryer at 60°C to reach the moisture content of 23 g/100 g dry matter. Three parboiled rice products soaked at 40°C (PR40), 50°C (PR50) and 60°C (PR60) were determined for the following qualities.

Size Characteristics: Physical characteristics like 50 grain dimensions brown and parboiled rice were determined using normal suggested methods [8]. Linear dimensions of grains were measured with vernier calipers having a resolution of 0.05 mm (Mitutoyo Corporation, Japan).

Head Parboiled Rice Yield: Approximately one week after drying, the samples of parboiled rice were shelled and milled using a laboratory miller, which separates automatically whole and broken grains. The head rice yield (HRY%) was calculated as percentage of whole milled grains respect to the brown rice, the average value of duplicated was calculated [5].

Lightness and Color Value: A color meter (CR-300, Minolta Co., Ltd., Tokyo, Japan) was used to measure the lightness and color value of whole kernel milled rice utilizing the L^* a^* b^* uniform color space procedure. The value of L^* expresses the lightness value, a^* and b^* are the red/green and yellow/blue coordinates of the L^* a^* b^* color space system. The instrument was calibrated with a standard white plate having L^*, a^* and b^* values of 96.82, 0.04 and 2.23, respectively. Each measurement was replicated ten times and the average value was considered. The color value (B) of parboiled rice was calculated using the following formula [9, 10]:

$$B = \sqrt{(a^*)^2 + (b^*)^2} \quad (1)$$

Proximate Compositions: The moisture content of the brown rice flour was determined after drying at 105°C until a constant weight was attained. The Kjeldahl method was employed to determine the total nitrogen and the crude protein (N X 5.95) [11]. Ash contents (gravimetric) were determined based on methods outlined in AOAC [11]. Dietary fiber was estimated using the method of Deepa *et al*. [12].

Approximately 10 g of dehusked rice powder was used for lipid extraction with 20 ml of chloroform-methanol (2:1, v/v) containing 10 mg/L of butylated hydroxytoluene (BHT) and kept for 24 h. After that, filtered (NO. 4; Whatman, Clifton, New Jersey, USA) and separated with NaCl solution (1.5 v/v), kept for 12h and to open for lower phase. Moved to evaporated and dissolved with chloroform 10 ml and analyzed lipids content [13].

Cooking Properties

Cooking Time: Rice was cooked in excess water. Twenty grains rice was cooked with a colander in boiler placed on an electric heater (98°C) and timer for cooking time.

Water Uptake Ratio: Rice was cooked in excess water. Two grams rice was cooked with 20 ml water in a 100 ml beaker placed on an electric heater. Samples were removed at cooking time to weigh and calculated by equation:

$$\text{Water uptake (\%)} = \frac{\text{Weight of cooked rice}}{\text{Weight of raw rice}} \quad (2)$$

Elongation Ratio: Rice was cooked in excess water. Two grams rice was cooked with 20 ml water in a 100 ml beaker placed on an electric heater. Samples were removed at cooking time to measure with length and wide (before and after cooked) and calculated by equation:

$$\text{Elongation ratio} = \frac{\text{Length of cooked rice}}{\text{Length raw rice}} \quad (3)$$

Solid Loss: Rice was cooked in excess water. Two grams rice was cooked with 20 ml water in a 100 ml beaker placed on an electric heater. Twenty five-ml sample of the cooked rice water (previously well agitated) was placed in a pre-weighed flask and air-dried in an oven at 105°C for 1 h. After that, the sample was fully dried at the same temperature until a constant weight in the presence of P_2O_5 desiccant. The amount of solids leached was calculated as kilogram of solids per kilogram of dry grain [5].

Preparation of Cooked Rice: Dehusked rice (14% wet basis) was cooked in excess water. Twenty grains rice was cooked with a colander in boiler placed on an electric heater (98°C) at cooking time.

Texture Profile Analysis of Cooled Rice: A texture analyzer, TA-XT2 (Texture Technologies Corp., Scardale, NY) was used to perform the TPA of cooked rice. The tests were performed using a 5 kg load cell and two-cycle compression tests [14]. When the sample preparation is finished four grains of cooked rice were selected from the centre of the saucepan. These grains were carefully placed, with the aid of a spatula, under the rod-type probe (10.0 cm diameter) and then the sample was compressed to 60% at 0.5 mm/s (5). The time between chews was 3 s. Textural parameters recorded from the test curves were hardness (H), adhesiveness (A), springiness (S), cohesiveness (C), gumminess and (G) and chewiness (Chew) which is a measurement of the elastic recovery of the sample, in terms of speed and forces derived. All these parameters were determined from the two cycle curves using Texture Export for Window (Stable Micro Systems, Godalming, UK). The texture profile analysis was repeated ten times per replicate.

Sensory Evaluation: The parboiled brown rice were cooked and served to a discriminatory and communicative panel of 50 people to compare with cooked brown rice (6). An evaluation card (15) for multiple sample difference tests for quality attributes such as color, aroma, texture, taste and overall acceptability was prepared and given to each panelist. At least one sample (not necessarily a control) was duplicated for judging the efficacy of the panelist also. The scores were statistically analyzed.

RESULTS AND DISCUSSION

Effect of Soaking Temperature on Physicals Properties: KDML 105 is a long, slender, clear translucent grain with good cooking quality. Observations on length and Width of brown rice kernel are given in Table 1. The length and Width of parboiled rice were ranged from 7.0-9.0 mm and 2.02-2.06 mm, respectively, which were greater and shorter than those of brown rice.

Parboiling process provided higher head rice yield as compared to unparboiled rice. Head milling rice yield was significantly increased from 51% in brown rice to 59, 83 and 84% in PR 40, PR 50 and PR60, respectively. Saif *et al.* [7] reported that the increase in length, width and thickness due to parboiling process, leading to some advantages over the unparboiled one such as the strengthening of kernel integrity, increase of milling recovery and decrease of cooking losses (2).

This improvement was caused by stronger structure of rice starch as a result of gelatinization process [16].

Table 2 shows the effect of soaking temperature on the lightness value. The lightness value of parboiled rice decreased while the color value increased with increasing soaking temperature. PR60 had significant greater color value than PR50 and PR40 but there were not significant differences between PR40 and PR50. This also indicates that lower soaking temperature could provide a less colored product. This finding was in agreement with the data reported by Islam *et al*. 2003 [10]. Due to parboiling treatment, discoloration of grain occurs which decreases the lightness value. The lightness (or whiteness) of parboiled rice was mainly affected by the temperature and

Table 1: Physical properties and head rice yield of brown and parboiled rice

		Soaking temperature of parboiled rice		
Parameters	Brown rice	PR40	PR50	PR60
Length (/grain, mm)	7.44±0.13[d]	7.76±0.02[c]	8.10±0.21[b]	8.53±0.15[a]
Width (/grain, mm)	2.12±0.09[a]	2.06±0.01[b]	2.02±0.02[c]	2.04±0.5[bc]
Head rice yield (HY%)	50.92±0.03[d]	59.22±0.19[c]	82.98±0.59[b]	84.46±0.12[a]

Values within a row followed by the same letter are not significantly different at 5% probability level according to DNMRT

PR40 = Parboiled rice soaked at 40°C, PR50 = Parboiled rice soaked at 50°C, PR60 = Parboiled rice soaked at 60°C

Table 2: Lightness and color value

		Soaking temperature of parboiled rice		
Parameters	Brown rice	PR40	PR50	PR60
Lightness	58.63±1.15[a]	53.80±1.15[b]	52.65±1.12[b]	51.30±1.00[c]
Color value	16.51±0.63[c]	19.36±0.99[b]	19.63±0.78[b]	20.14±0.63[a]

Values within a row followed by the same letter are not significantly different at 5% probability level according to DNMRT

PR40 = Parboiled rice soaked at 40°C, PR50 = Parboiled rice soaked at 50°C, PR60 = Parboiled rice soaked at 60°C

Table 3: Proximate composition of brown and parboiled brown rice (% dry basis)

		Soaking temperature of brown parboiled rice		
Component	Brown rice	PR40	PR50	PR60
Moisture (%)	23.08±0.13	23.14±0.65	23.34±0.26	23.24±0.22
Total protein (%)	7.74±0.34[b]	7.84±0.32[b]	8.19±0.12[a]	7.86±0.18[b]
Lipids content (%)	1.99±0.08[c]	2.39±0.09[a]	2.19±0.05[b]	2.08±0.01[c]
Ash (%)	1.21±0.3[b]	1.25±0.02[b]	1.34±0.02[a]	1.30±0.03[a]
Crude fiber (%)	1.79±0.04	1.75±0.02	1.71±0.11	1.72±0.12
Total carbohydrate (%)	64.52±1.67	63.88±1.59	63.58±2.59	64.13±1.88

Values within a row followed by the same letter are not significantly different at 5% probability level according to DNMRT

PR40 = Parboiled rice soaked at 40°C, PR50 = Parboiled rice soaked at 50°C, PR60 = Parboiled rice soaked at 60°C

Table 4: Cooking quality of brown and parboiled brown rice

		Soaking temperature of brown parboiled rice		
Parameters	Brown rice	PR40	PR50	PR60
Cooking time (min)	18.03±0.35[a]	14.60±0.27[b]	14.53±0.01[c]	14.33±0.03[d]
Water uptake ratio	2.29±0.05[a]	1.64±0.00[b]	1.67±0.01[b]	1.68±0.00[b]
Elongation ratio	1.19±0.07[a]	1.06±0.02[c]	1.07±0.06[b]	1.08±0.03[b]
Solid loss (%)	1.49±0.09[a]	0.87±0.03[b]	0.36±0.03[c]	0.31±0.02[d]

Values within a row followed by the same letter are not significantly different at 5% probability level according to DNMRT

PR40 = Parboiled rice soaked at 40°C, PR50 = Parboiled rice soaked at 50°C, PR60 = Parboiled rice soaked at 60°C

time of steaming [17, 18, 19]. The sample size did not significantly effect on the lightness value. Discoloration of rice due to parboiling treatment is another important quality indicator. It is a negative effect of parboiling, because dark colored parboiled rice losses market value and consumer acceptability in most countries [2]. Many researchers measured the color value due to parboiling treatments [17, 18, 19, 20]. They reported that discoloration was mainly caused by Maillard type non-enzymatic browning and the processing conditions determine the intensity of color during parboiling. The husk pigment also contributes by diffusing into the endosperm during soaking [21].

Effect of Soaking Temperature on Chemical Properties: Cereals are the major source of carbohydrates, proteins, fats and bioactive compounds to the vegetarian population worldwide. The proximate compositions of brown rice and parboiled brown rice are presented in Table 3. In this study, one-year-old paddy samples were stored at room temperature and used for proximate composition study. The moisture contents were approximately 23-24%, which were not significantly different among studied samples. Significant differences were observed in proteins, lipids and ash content among the rice samples. PR50 had significant higher protein content ($p<0.05$) than the brown rice. PR40 and PR50 had significant higher lipid contents compared with brown rice. The total crude fiber contents in all treatments including brown rice were found to be not significantly different. The crude protein and crude fat contents increased significantly after germination, probably because of biosynthesis of new compounds during germination [22, 23]. The total dietary fiber content of the rough rice significantly increased. This tendency for an increase in dietary fiber after germination agrees with reports for buckwheat [23, 24]. Increases in dietary fiber could be resulted from the formation of primary cell walls, through an increase in pectic substance in a middle lamella [25, 26].

Effect of Soaking Temperature on Cooking Properties: The effect of soaking temperature on cooking quality in terms of cooking time, water uptake elongation ratio and solid loss are shown in Table 4. Paddy samples were parboiled by soaking at different temperatures of 40, 50 and 60°C followed by steaming, drying and milling. The water uptake, elongation ratio and solid loss were calculated by equation 2 and 3, respectively. The cooking time was significantly decreased with increasing soaking temperature ($p<0.05$), from 14.59 to 14.53 and to14.33 min, respectively. Similar results were found in the water

Table 5: Texture profiles analysis of cooked brown and parboiled brown rice

		Soaking temperature of parboiled rice		
TPA Parameters	Brown rice	PR40	PR50	PR60
Hardness (g)	211.86±11.91[a]	167.12±11.24[b]	160.91±11.65[bc]	158.12±10.55[c]
Adhesiveness (g/s)	-0.027±0.004	-0.028±0.011	-0.032±0.003	-0.034±0.001
Cohesiveness	0.42±0.02	0.43±0.01	0.46±0.04	0.47±0.02
Gumminess (g)	89.49±2.30[a]	85.78±1.75[b]	81.50±5.11[bc]	80.07±1.08[c]
Springiness	0.70±0.039	0.70±0.01	0.69±0.04	0.68±0.02
Chewiness (g)	62.24±2.42[a]	60.16±1.55[a]	57.67±2.37[b]	56.17±1.55[b]

Values within a row followed by the same letter are not significantly different at 5% probability level according to DNMRT

PR40 = Parboiled rice soaked at 40°C, PR50 = Parboiled rice soaked at 50°C, PR60 = Parboiled rice soaked at 60°C

Table 6: Sensory evaluation of cooked brown rice and cooked brown parboiled rice (n=50)

		Soaking temperature of brown parboiled rice		
Parameters	Brown rice	PR40	PR50	PR60
Color	6.95±0.28[a]	5.63±0.16[c]	6.53±0.56[b]	5.82±0.61[c]
Odor	6.37±1.31[a]	5.69±0.02[b]	6.32±0.16[a]	4.37±0.09[b]
Texture	5.91±1.54[b]	5.66±0.22[b]	6.49±0.56[a]	6.47±0.45[ab]
Taste	6.17±0.39[c]	6.00±0.01[c]	6.58±0.01[a]	6.42±0.01[bc]
Overall	6.84±0.14[a]	5.69±0.05[d]	6.51±0.1[b]	5.95±0.03[c]

Values within a row followed by the same letter are not significantly different at 5% probability level according to DNMRT

PR40 = Parboiled rice soaked at 40°C, PR50 = Parboiled rice soaked at 50°C, PR60 = Parboiled rice soaked at 60°C

uptake and solid loss. It was observed that parboiled rice had lower solid loss at every soaking temperature compared with those of brown rice. This was caused by stronger structure of rice starch as a result of gelatinization process [16]. In contrast, the elongation ratio was significantly increased with temperature increased (p<0.05), however that of parboiled rice was less than brown rice. The present results demonstrated that the soaking temperature improved the cooking quality of parboiled brown rice by reducing cooking time and solid loss.

Effect of Soaking Temperature on Texture Profiles Analysis: The effect of soaking temperature on textural parameters is shown in the Table 5, where the texture behavior of unprocessed brown rice (raw) and parboiled brown rice is presented for the purposes of comparison. Brown and parboiled rice were cooked during 14.33 and 18.03 min respectively. The studied samples presented intermediate values of textural properties between raw and parboiled rice. Cooked parboiled rice had significant (p<0.05) smaller values of hardness and gumminess than cooked brown rice while other TPA parameters of all parboiled rice were found not significantly different compared with brown rice.

Parboiling has an obvious impact on the organoleptic properties of cooked rice. It has been reported that cooked parboiled rice is firmer and less sticky than non-parboiled cooked rice [6]. However, the results from this present study were found to be contrast. We found that cooked parboiled rice, at all soaked temperatures tested, were significantly softer than cooked brown rice, with significantly lower in chewiness. The possible explanation may be that the rough rice samples used in our study were harshly damaged during twelve month storage at ambient temperature. KDML 105 is a fragrant rice and with consideration of low milling head yield quality. Cracking and breaking grain kernels could in turn resulted in an increase of water uptake and consequently causing higher softness in parboiled rice. The hardness depends on the severity of the parboiling treatment. Many researchers reported that it is greatly affected by parboiling conditions, moisture content after drying, balance of starch, gelatinisation and retrogradation and other factors (2, 20, 27, 28, 29, 30).

Comparing experimental data of this work with those reported in literature. More recent papers pointed out the effects of drying conditions, rice variety, amylose content, gelatinization temperature, degree of milling and storage conditions on textural properties of cooked rice [5].

Effect of Soaking Temperature on Sensory Evaluation: Fifty panelists evaluated the cooked parboiled brow rice of three treatments and normal brown rice (control). Summary of the data obtained from these 50 panelists is given in Table 6. The mean scores of color, odor, texture taste and overall acceptance of parboiled rice were between 4.4 to 6.6, while those of brown rice were between 6.2 to 7.0. The results showed that PR50 gave the highest scores (6.51 out of 9) among all treatments but slightly lower than brown rice. Although, other attributes including texture and taste of PR50 were given higher preference scores than brown rice, the negative value for color of parboiled rice affected the overall acceptance by the panelists as compared to brown rice.

CONCLUSIONS

Soaking temperature is one of the most important processes of rice parboiling. Our present findings have demonstrated that significant differences were found in physical, chemical and cooking properties of parboiled rice compared to brown rice. Soaking temperature also resulted in nutrient changes such as protein, lipid and ash contents. However, optimum soaking temperature is to be considered to achieve consumer acceptability. According to present data, we specially recommend the parboiling process for damaged fragrant rice for improvement of head rice yield and cooking quality. Besides, greater nutritional values of parboiled rice is to be considered as a functional food.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Thailand Research Fund (TRF) with Office of Small and Medium Enterprises Promotion (OSMEP) for their financial support to this work. We also thank Commission on Higher Education and Mahasarakham University for financial support.

REFERENCES

1. Elbert, G.M., P. Tolaba and C. Suárez, 2000. Effects of Drying Conditions on Head Rice Yield and Browning Index of Parboiled Rice. J. Food Eng., 47: 37-41.
2. Bhattacharya, K.R., 1985. Parboiling of rice. In rice chemistry and technology, Juliano, B.O. (Ed.). American Association of Cereal Chemists, Inc., Minnesota, pp: 289-348.
3. Larsen, H.N., 2000. Glycaemic Index of Parboiled Rice Depends on the Severity of Processing: Study in Type 2 Diabetic Subjects. European J. Clin. Nutr., 54(5): 380-385.
4. Luh, B.S. and R.R. Mickus, 1980. Parboiled rice. In Rice: products and utilization, Luh, B.S. (Ed.), Westport, Connecticut: AVI Publishing Company Inc, pp: 501-542.
5. Bello, M., R. Baeza and M.P. Tolaba, 2004. Quality Characteristics of Milled and Cooked Rice Affected by Hydrothermal Treatment. J. Food Eng., 72: 124-133.
6. Kar, N., R.K. Jain and P.P. Srivastav, 1998. Parboiling of Dehusked Rice. J. Food Eng., 39: 17-22.
7. Saif, S.M.H., D.A. Suter and Y. Lan, 2004. Effects of Processing Conditions and Environmental Exposure on the Tensile Properties of Parboiled Rice Biosystems Engineering, 89 (3): 321-330.
8. AACC., 1976. Approved methods of analysis. American Association of Cereal Chemists. St. Paul, Minnesota, USA.
9. Kimura, T., J. Matsuda, Y. Ikeuchi and T. Yoshida, 1976. Basic Studies on Parboiled Rice (3): Effect of Processing Conditions on Properties of Parboiled Rice. J. Japanese Soc. Agril. Mach., 38(3): 379-383.
10. Islam, M.R., N. Shimizu and T. Kimura, 2003. Energy Requirement in Parboiling and Its Relationship to some Important Quality Indicators. J. Food Engin., 63: 433-439.
11. AOAC., 2002. Official Method of Analysis. A.O.A.C. Inc., Washington, D.C.
12. Deepa, G. Vasudeva Singh and K. Akhilender Naidu, 2007. Nutrient Composition and Physicochemical Properties of Indian Medicinal Rice-Njavara. Food Chem., 106: 165-171.
13. Siriamornpun, S., D. Li, L. Yang, W. Kanchanamayoon and M. Suttajit, 2005. Thai Jute Seed Oil: A Potential Polyunsaturated Fatty Acid Source. Songklanakarin J. Sci. Technol., 28: 11-15.
14. Suzuki, H., 1979. Use of texturometer for measuring the texture of cooked rice. In International Rice Research Institute. Chemical Aspects of rice quality, Los Bannos, Laguna, Philippines, pp: 327-341.
15. Indian Standard, 1971. Guide for Sensory Evaluation of Foods, IS: 6273 (Part-I), Indian Standards Institution Manak Bhawan, New Delhi.
16. Soponronnarit, S., A. Nathakaranakule, A. Jirajindalert and C. Taechapairoj, 2005. Parboiling Brown Rice using Super Heated Steam Fluidization Technique. J. Food Eng., 75: 423-432.

17. Bhattacharya, S., 1996. Kinetics on Color Changes in Rice due to Parboiling. J. Food Eng., 29: 99-106.
18. Bhattacharya, K.R. and P.V. Subba Rao, 1966. Processing Conditions and Milling Yield in Parboiling of Rice. J. Agril. Food Chem., 14(5): 473-475.
19. Kimura, T., K.R. Bhattacharya and S.Z. Ali, 1993. Discoloration Characteristics of Rice during Parboiling (I): Effect of Processing Conditions on the Color Intensity of Parboiled Rice. J. Soc. Agril. Structures, Japan, 24 (3): 23-30.
20. Pillaaiyar, P. and R. Mohandass, 1981. Hardness and Colour in Parboiled Rice Produced at Low and High Temperature. J. Food Sc. Technol., 18 : 7-9.
21. Subrahmanyan, V., A. Sreenivasan and H.P. Das Gupta, 1938. Studies on Quality of Rice (I). Effect of Milling on the Chemical Composition and Commercial Qualities of Raw and Parboiled Rice. Indian J. Agril. Sci., 8: 459-486.
22. Jung, G.H., N.Y. Park, S.M. Jang, J.B. Lee and Y.J. Jeong, 2005. Effects of Germination in Brown Rice by Addition Chitosan/Glutamic Acid. Korean J. Food Preservative, 4: 538-543.
23. Lee, Youn Ri, Ja Young Kim, Koan Sik Woo, In Guk Hwang, Kyong Ho Kim, Kee Jong Kim, Jae Hyun Kim and Heon Sang Jeong, 2007. Changes in the Chemical and Functional Components of Korean Rough Rice Before and After Germination. Food Sci. Biotechnol., 6: 1006-1010.
24. Lee, M.H., S.J. Woo, S.K. Oh and T.B. Kwon, 1994. Changes in Content and Composition of Dietary Fiber during Buckwheat Germination. Korean J. Food Nutr., 7: 274-283.
25. Ang, J.F. and G.A. Crosby, 2005. Formulating Reduced-Calorie Foods with Powered Cellulose. Food Technology. Chicago, 59: 35-38.
26. Ang, J.F. and W.B. Miller, 1991. Multiple Functions of Powdered Cellulose as Food Ingredient. Cereal Food World, 36: 558-562.
27. Ali, S.Z. and K.R. Bhattacharya, 1976. Starch Retrogradation and Starch Damage in Parboiled Rice and Flaked Rice. Die Stärke, 28: 233-240.
28. Itoh, K. and S. Kawamura, 1985. Processing Conditions of Parboiled Rice and Its Qualities (Studies on parboiled rice, part I). Nippon Shokuhin Kogyo Gakkaishi, 32: 471-479.
29. Kimura, T., 1991. Effects of Processing Conditions on the Hardening Characteristics of Parboiled Grain. J. Japanese Soc. Agril. Structure., 22: 111-116.
30. Islam, Md. Rabiul, Naoto Shimizu and Toshinori Kimura, 2000. Quality Evaluation of Parboiled Rice with Physical Properties. Food Sci. Technol. Res., 7 (1) : 57-63.