Application of two temperature hot water soaking for improving of paddy parboiling process

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Abstract: Soaking of paddy (rough rice) is the most time-consuming operation in the paddy parboiling process. A hot water soaking in two temperatures, paddy parboiling treatment has developed based on the gelatinization temperature of rice starch to achieve rapid completion of absorption of water into the rice kernel. As well, this treatment was aimed to eliminate the steaming process in paddy parboiling without changing milling qualities and improve parboiled rice palatability. BG 358 rice variety (short grain rice) was used for the experiment. Two soaking treatments of two hours soaking in hot water at 70°C and one hour soaking in hot water at 80°C were compared with modern and traditional parboiling treatments. Complete randomized design (CRD) was adopted to this experiment. Results revealed that the soaking two hours in hot water at 70°C in first stage caused to increase kernel moisture until an intermediate moisture content of 34.8% d.b. and one hour soaking in hot water at 80°C in second stage caused to increase kernel moisture until up to the saturation moisture content of 43.8% d.b. It was resulted in a 37.5% time reduction compared to modern hot water soaking and 87.5% time reduction compared to traditional parboiling. Further, treated rice by two temperatures hot water soaking showed significant improvement in terms of kernel color, and palatability characteristics such as taste, texture and odor compared to existing parboiled rice. However, there was no significant difference between treatments in terms of head rice yield, kernel hardness and broken grains percentage.

Keywords: paddy parboiling, hot water soaking, soaking duration, rice quality

1 Introduction

Parboiling of paddy (rough rice) is a traditional process in Southern Asia since ancient time, and it is still very popular in this region. Generally, parboiling process consists of three stages: soaking the cleaned raw rough rice to saturation moisture content, gelatinization of rice starch by adding heat to the moist kernels through steaming, and drying the product to suitable moisture content for milling or storage. Water and heat are the two main elements in the hydro-thermal process. Parboiling causes physical and chemical modifications in the grain, leading to favorable changes such as easier shelling, high head rice yield, less broken grains, increased resistance to insects, firmer cooked rice texture, less solids loss during cooking, better retention of nutrients (e.g. vitamins, and minerals), and higher oil content in the bran (Gariboldi, 1972; Bhattacharya, 1985; Pillaiyar, 1988). It has been pointed out that cracks, chalkiness, and incomplete grain filling were totally rectified and many of the previous defects were cured when paddy was parboiled properly (Bhattacharya, 1969). Although parboiling has been reported for lots of advantages, this process causes some drawbacks such as decreasing aroma and whiteness, changing taste, texture and palatability characteristics and its consequent effect on consumer acceptability (Luh et al., 1991). Paddy parboiling also constitutes an additional expenditure in rice processing. Parboiling of rough rice

can be achieved through a variety of methods that differ basically in the intensity of the hydrothermal treatment (Bhattacharya, 1985; Pillaiyar, 1988). Soaking is the most time-consuming operation in the parboiling process, followed by drying and steaming. In traditional parboiling, water at room temperature was used for soaking and it took one to two days. In modern method, using hot water soaking can be completed in a shorter time depending on the soaking water temperature. It takes approximately four hours in water at 70°C temperature (Igathinathane et al., 2005; Kwofie, and Ngadi, 2017). Long-duration ambient temperature water soaking leads to microbial growth and off-flavor development (Pillaiyar et al., 1980). Thus, the general objective of this study was to improve the parboiling process, shorten the soaking time by two temperatures hot water soaking, while eliminate steaming in paddy parboiling without changing the parboiled rice qualities such as less broken grain percentage, and high head rice yield percentage. Along with them, resulted treatments should improve kernel whiteness and palatability characteristics.

2   Methodology

BG 358 short grain (*samba*) rice variety (Length to breadth ratio = 2.15) was used for the experiment. The water temperature for hot soaking was determined according to the gelatinization temperature of rice (Igathinathane et al., 2005). Sri Lankan short grain rice varieties have intermediate amylose content therefore, their gelatinization temperature is 72°C-74°C (Silva and Swami, 1988). Accordingly, two temperatures hot water treatments were performed and these treatments were compared with modern and traditional parboiled treatments. Table 1 showed the treatments performed in this experiment.

Table 1   Performed paddy parboiling treatments in experiment

Treatment No.	Soaking water temperature (^{o}C)	Soaking duration	Steaming pressure	Steaming duration
1 New treatment (Two temperature hot water soaking)	70±2 80±2	2 hours 1 hour	- -	- -
2 (Modern parboiling)	70±2	4 and half hours	Atmospheric pressure	5 minutes
3 (Traditional parboiling)	28±3	30 hours	Atmospheric pressure	5 minutes

Figure 1 showed the laboratory arrangement for soaking experiments. Perforated containers (fabricated by wire mesh) were used for this parboiling experiment. The 300 g of paddy was put into these perforated containers and containers were placed in the thermostatically controlled hot water bath (Serial No. 54, CPN Industries, India). The water temperature in the water bath was adjusted according to temperature requirement of treatments (70°C and 80°C). The temperature fluctuation in water bath was found ±2°C. Same perforated containers were placed in the water at ambient room temperature 28°C±3°C in order to perform traditional parboiling treatment. Soaked paddy samples as modern and traditional methods of parboiling were steamed at atmospheric pressure (Table 1). Soaked and steamed paddy samples were subjected to dry up to 14 % moisture content in wet basis (wb) for safe milling. Laboratory electric dryer (Model No SOM 45, Scientronic Industries, India) was used for drying of paddy samples. In this study, air temperature inside the dryer was maintained at 92°C ± 2°C. When paddy moisture content reached to 16%-17% (wb) during drying, paddy was tempered for three hours. After three hours of tempering, drying was started again at 72°C±2°C temperature until the paddy reached 14% (wb) moisture content (Gunathilake et al., 2018).

Figure 1   The laboratory arrangement for soaking experiments

The dried paddy up to 14% (wb) moisture content was de-hulled using the Satake laboratory de-husker and then brown (unpolished) rice was polished using the Satake laboratory abrasive polisher. All rice samples were polished for 75 seconds; hence average degree of polish (bran removal) was maintained around 8%. Important milling characteristics such as broken grain percentage and head rice yield percentage were calculated by the method outlined by Bal (1974). Broken grain percentage was calculated using representative working sample of milled rice of 50 g obtained by precision sample divider. Rice grains, which are smaller than the 3/4 of the grain, were considered as broken grains and they were separated by hand picking and broken grain percentage was calculated by Equation (1). Accordingly, head rice yield was also calculated by Equation (2).

Rice kernel whiteness was measured using Mini-scan XE plus Hunter Lab Colorimeter. L value (lightness value) was used as whiteness of rice kernel. L value varies from 100 for perfect white and zero (0) for perfect black. Compression test was carried out for determination of rice kernel hardness (yield stress). The Instron, TA-XT2 texture analyzer was used to perform a compression test. Force at rupture was considered as the hardness of rice kernel. Three replicates were considered for each treatment and the applied force were averaged.

$$\text{Broken Grain Percentage} = \frac{Wb2}{Wm} \times 100 \qquad (1)$$

where, $Wb2$ = Weight of the broken grains in grams; Wm = Weight of the polish rice in grams.

$$\text{Head rice yield percentage} = \frac{Wr}{W} \times 100 \qquad (2)$$

where, Wr = Weight of the head rice in grams; W = Weight of the sample in grams used to analysis milling qualities.

2.1 Sensory evaluation procedure

Selected samples were cooked according to the method adopted by Ali and Ojah (1975) that 30 g of rice immersed in 300 mL of water in glass tube in a boiling water bath for 22 minutes. After cooking, cooked rice were emptied into a perforated circular strainer and kept two minutes to move out excess water and use for sensory test. The rice samples were coded by random numbers and served to 15 trained sensory panelists. Sensory panel members were requested to comment on the taste, odor and texture and they were given structured questionnaire as a 07-point hedonic scale shown in Table 2. Selected hedonic scale had been adopted by many previous researchers for similar studies (Schutz and Oamrell, 1974; Meullenet et al., 1998; Sitakalin and Meullenet, 2000; Jindal and Limpisut, 2002). Data of sensory evaluation were examined by the Friedman test with the aid of Minitab® computer package. Sum of rank achieved by Friedman test for each treatment were compared by the Duncan's multiple range test (DMRT) multiple comparison technique at $\alpha = 0.05$.

Table 2   The 7-point hedonic scale

Response	Points
Dislike extremely	1
Dislike	2
Dislike moderately	3
Neither like nor dislike	4
Like moderately	5
Like	6
Like extremely	7

Each treatment was replicated three times. Analysis of variance (ANOVA) on complete randomized design (CRD) by general liner model (GLM) procedure was performed and also treatment means were separated by the DMRT at $\alpha = 0.05$ level of significance.

3   Results and discussion

Figure 2 showed the variation in moisture content in rice kernel for these three different soaking treatments. The results indicated that positive linear relationship between kernel moisture content and soaking duration. Hot water soaking absorbed high amount of moisture in short period of time when compared to ambient water soaking. Initial moisture content of paddy samples subjected to three different treatments was kept at 15.1 dry basis (db). It was clear from the results that two temperatures hot water soaking at 70°C two hours and 80°C one hour soaking (treatment 1) absorbed water rapidly and rice kernel was saturated within three hours up to saturated moisture content of 43.8 db. Modern hot water soaking parboiling treatment (treatment 2) took four and half hours for saturation. Traditional ambient temperature

water soaking parboiling treatment (treatment 3) took 30 hours for saturation. Treatment 2 and 3 were undergone 5 min steaming treatment to facilitate starch gelatinization. However, it was observed that saturation moisture content of 43.8 db after soaking remained mostly same after steaming treatment in these two treatments (treatment 2 & 3). Igathinathane et al. (2005) pointed out that paddy soaking was the most time-consuming operation in paddy parboiling, therefore, they introduced combination soaking procedure in order to reduce soaking time in paddy parboiling.
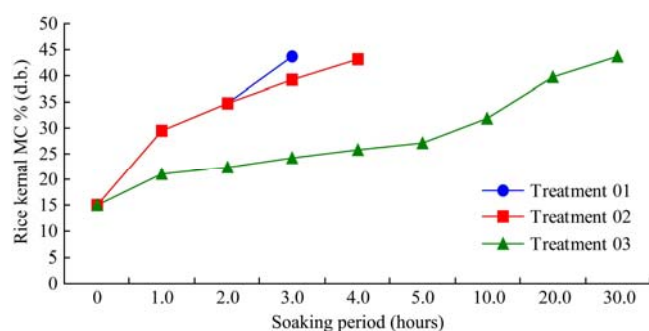

Figure 2   Variation of moisture content inside rice kernel with soaking treatments

The results showed that all three treatments were not shown any significant difference in terms of broken grain percentage, kernel hardness and head rice yield (Table 3). However, kernel whiteness was significantly different between the three treatments. The highest kernel whiteness has appeared in treatment-1 and lowest was observed in traditional parboiling treatment-3 (ambient water soaking treatment). Accordingly, it can be concluded that treatment-1 triggered high rice kernel whiteness compared to existing parboiling treatment (modern and traditional). Gariboldi (1974) explained that changing of rice kernel

whiteness was probably due to gelatinization of the starch and disintegration of the protein bodies in the endosperm with the increase in severity of the hydrothermal treatment of soaking and steaming. Miah et al. (2002) observed that parboiling with increasing soaking and steaming time caused the relative darkness to gradually increase.

Further, treatment-1 was also capable to maintain similar head rice yield as the existing parboiling treatments, even though steaming was eliminated from this treatment. This result indicated that rice kernel was gelatinized properly by treatment-1. Soaking of paddy in hot water at 80°C (above the gelatinization temperature 72°C-74°C) one hour facilitated proper rice kernel gelatinization. Igathinathane et al. (2005) showed soaking of paddy above the gelatinization temperature facilitated irreversible starch granule swelling of rice kernel. Accordingly, previous defects of the rice kernel such as cracks, chalkiness, and grain fissures were totally rectified by proper gelatinization of rice kernel and it caused high head rice yield.

Results of the sensory test were shown that palatability characteristics such as odour and taste significantly were improved by treatment-1 compare to the other two treatments (Table 3). Further, treatment-1 also caused to improve rice texture in comparison to the other two treatments, it was shown significant difference from treatment-3 (traditional parboiling). The results of DMRT (Table 3) clearly indicated that the treatment-1 improved all required qualities of rice in comparison to the existing parboiling treatments while reducing soaking time and eliminating of steaming in paddy parboiling

Table 3   The result of DMRT multiple mean comparisons of responses by treatments

Treatment No.	Mean broken grain %	Mean head rice yield %	Mean kernel hardness	Mean kernel whiteness	Taste mean sum of rank	Odor mean sum of rank	Texture mean sum of rank
Treat. 1	2.68[a]	71.6[a]	3.4[a]	60.42[a]	79.0[a]	80.0[a]	77.0[a]
Treat. 2	3.14[a]	71.4[a]	3.3[a]	57.96[a]	75.0[a]	70.0[b]	72.5[a]
Treat. 3	2.34[a]	71.7[a]	3.6[a]	53.43[b]	60.5[b]	58.5[c]	57.5[b]

Note: [a] Columns having same letter are not significantly difference at $\alpha = 0.05$ by DMRT.

Treat – 1: Two Temperature hot water soaking, Treat – 2: Modern parboiling, Treat – 3: Traditional parboiling

4   Conclusion

It can be concluded that hot water soaking in two temperature, the first stage soaking at 70°C rice kernel absorbed water until an intermediate moisture content of

34.8% db (approx. 2 hours), followed second stage by soaking at 80°C (approx. 1 hour) absorbed water up to the saturation moisture content of 43.8% db, resulted in a 37.5% time reduction with compared to modern single-stage hot water soaking at 70°C and 87.5% time

reduction compared with conventional ambient water soaking of paddy at 25°C-30°C. Further, steaming process can be eliminated completely in paddy parboiling by two temperatures hot water treatment. Under the same treatment, a significant improvement was shown in terms of kernel color, and palatability characteristics such as odour, texture and taste. However, there were no significant difference among treatments in terms of head rice yield, kernel hardness, broken grains produced.

References

Ali, M. H., and R. P. Ojah. 1975. Physical components in steaming of paddy. *Journal of Food Science and Technology*, 25(1): 82–84.

Bal, S. 1974. Measurement of rice quality. No.72. New Delhi, India: REPC Publication.

Bhattacharya, K. R. 1969. Breakage of rice during milling and effect of parboiling. *Journal of Cereal Chemistry*, 46(5): 478–485.

Bhattacharya, K. R. 1985. Parboiling of rice. In *Rice Chemistry and Technology*, ed. B. O. Juliano, ch. 2, 82–112. St Paul, Minn, USA: American Association of Cereal Chemists.

Gariboldi, F. 1972. Parboiled rice. In *Rice Chemistry and Technology*, ed. D. F. Houston, ch. 3, 358–380. St Paul, Minn, USA: American Association of Cereal Chemists.

Gariboldi, F. 1974. Rice processing. FAO agricultural development paper No 97. Rome Italy: Food and Agricultural Organization of the United Nation.

Gunathilake, D. M. C. C., D. P. Senanayaka, P. Adiletta, and W. Senadeera. 2018. Drying of agricultural crops. In *Advances in Agricultural Machinery and Technologies*, ed. G. Chen, ch. 14, 331–365. Boca Raton Florida USA: CRC Press, Taylor & Francis Group.

Igathinathane, C., P. K. Chattopadhyay, and L. O. Pordesimo. 2005. Combination soaking procedure for rough rice parboiling.

Transaction of ASAE, 48(2): 665–671.

Jindal, V. K., and R. Limpisut. 2002. Back extrusion testing of cooked rice texture. ASAE Paper No. 026068. Chicago, Illinois, USA: ASAE Annual International Meeting, CIGR Hyatt Regency.

Kwofie, E. M., and M. Ngadi. 2017. A review of rice parboiling systems, energy supply, and consumption. *Renewable and Sustainable Energy Reviews*, 72: 465–472.

Luh, B. S., and R. R. Mickus. 1991. Parboiled rice. In *Rice Utilization*, ed. B. S. Luh, ch. 4, 51–88. Van Nostrand, Reinhold, New York, USA: Springer Science and Business Media.

Meullenet, J. F. C., J. Gross, B. P. Marks, and M. Danials. 1998. Sensory descriptive texture analyses of cooked rice and its correlation to instrumental parameters using an extrusion cell. *Cereal Chemistry*, 75(5): 714–720.

Miah, M. A. K., A. Haque, M. P. Douglass, and B. Clarke. 2002. Parboiling of rice. Part II: Effect of hot soaking time on the degree of starch gelatinization parboiling of rice. *International Journal of Food Science and Technology*, 37(5): 539–545.

Pillaiyar, P. 1988. Parboiling. In *Rice Postproduction Manual*, ch. 5, 166–229. New Delhi, India: Wiley Eastern Ltd.

Pillaiyar, P., B. S. Vasan, G. Rajendran, and V. Dhamarajan. 1980. Prevention of foul odour and minimizing soaking loss in conventional parboiling of paddy. *Journal of Food Science Technology*, 17(5): 228–231.

Schutz, H. G., and J. O. Oamrell. 1974. Prediction of hedonic rating of rice by sensory analysis. *Journal of Food Science*, 39(1): 203–206.

Silva, D. S., and T. Swami. 1988. Chemical compositions of local rice varieties and its aging conditions. *Journal of Agriculture and Food Chemistry*, 39(2): 420–422.1

Sitakalin, C., and J. F. C. Meullenet. 2000. Prediction of cooked rice texture using extrusion and compression tests in conjunction with spectral stress strain analysis. *Cereal Chemistry*, 77(4): 501–506.