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Short Communication

Gelatinization of Rough Rice Using Far- Infrared (FIR) Radiation

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***ABSTRACT*:** *Gelatinization of rough rice is an important unit operation in the rice parboiling process. The possibility of applying far-infrared (FIR) radiation for gelatinization of rough rice was investigated in this study. The soaked rough rice was exposed to FIR radiation at 5 s intervals up to 30 s and moisture content, degree of gelatinization & color of rice were measured. The moisture content of rough rice immediately after exposing to FIR radiation was in the range of 27.8±0.1 - 21.4±0.6 % and it decreased with the increase of exposure time. The degree of gelatinization increased with exposure time and was in the range of 20.51% and 100%. The optimum degree of starch gelatinization of 40% was achieved in an exposure time of 20 s. The yellowness index was in the range of 21.95 – 34.54. The lightness (L*) of soaked rough rice exposed to FIR radiation was decreased with time from 60.30 to 52.72.*

Keywords: *Drying, infrared radiation, paddy, parboiling, rough rice*

INTRODUCTION

Parboiling is a hydrothermal treatment, performed either on rough rice (paddy). In the process, rice is soaked, steamed, and dried (Bhattacharya 2004; Delcour and Hoseney, 2010a; Buggenhout *et al.,* 2013). Soaking and steaming conditions during parboiling impact the degree of starch gelatinization (Himmelsbach *et al.,* 2008; Manful *et al.,* 2008).

Taechapairoj *et al.* (2004) observed that if paddy with an initial moisture content (41- 42.5%, db) is subject to superheated-steam fluidized bed drying at a temperature of 150-170 °C, the gelatinization of rice starch and evaporation of water occur simultaneously. Rordprapat *et al.* (2005) compared the conventional method and superheated-steam drying method to produce parboiled rice. They found that the head rice yield of a sample from the superheated steam drying method was significantly higher ($p<0.05$) than that of a sample produced conventionally.

According to Srinivas *et al.* (1981) dry heating of soaked paddy provides a better alternative for both gelatinization and drying. In dry heat parboiling the soaked rough rice, instead of being steamed, is subject to quick conduction heating at a high temperature. The paddy with

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high initial moisture content (>22%, wb) is found to be suitable for parboiling by this technique.

Infrared (IR) radiation is energy in the form of electromagnetic wave (Yang *et al.*, 2010). The infrared has a high rate of heat transfer, saves space, has superior product quality compared to conventional heated air drying, preserve vitamins in the food products, has lack of solute migration from the inner to the outer regions, saves energy, produces clean working environment and easy to automate (Tan *et al.*, 2001; Ranjan *et al.,* 2002; Mongpreneet *et al.*, 2002). The infrared radiation is divided into three classes; near-infrared radiation (0.78 -1.4 µm), mid infrared radiation (1.4 - 3 µm) and far-infrared radiation (3 - 1000 µm) (Shimazu *et al.*, 1991; Sakai and Mao, 2006). Infrared drying has been investigated as a potential method for obtaining high quality dried foodstuffs including fruits, vegetables and grains (Togrul, 2006).

Qualities of infrared dried parboiled rice have been evaluated by Das *et al.* (2004) in terms of head rice yield, color, percent-gelatinized kernel and specific energy consumption using five levels of radiation intensities and four levels of grain bed depths in a vibratory IR dryer. He reported that both radiation intensity and bed-depth significantly affected ($p<0.05$) the drying performance and rice qualities.

The objective of the research was to evaluate the possibility of applying FIR radiation for gelatinization of rough rice in the rice parboiling process.

METHODOLOGY

The experiments were conducted at the Institute of Postharvest Technology, Jayanthi Mawatha, Anuradhapura, Sri Lanka in 2014.

Sample preparation

The paddy (variety BG 358) samples procured from local market were cleaned by laboratory cleaning device (Model: Clipper Office Cleaner, Michigan, USA) to remove immature grains, undersize and oversize grains, stones, dust and chaff. The cleaned paddy was then soaked in cold water for 36 h. The water was changed at every 12 h and then the water was drained out. The experiment was carried out by 40±0.5 g of soaked rough rice with 30±0.8% (wb) moisture content. The moisture content of the sample was determined using oven drying method (ASAE, 1996).

The FIR radiation exposed paddy samples were dried in a convective oven (Model:Memmert-ULE 500, Schwabach,Germany) at 40 °C. Dried paddy samples of 35 g at 14 % (wb) moisture content were de-husked in a laboratory husker (Model: Satake THU-35 A, Hiroshima, Japan). The resulting brown rice was whitened in an abrasive polisher (Model: Satake TM-05, Hiroshima, Japan).The mild rice was ground into flour using mortar and pestle. The obtained flour was used to measure the degree of gelatinization and color values of FIR radiation exposed rough rice.

Experimental apparatus

The schematic diagram of the experimental apparatus for gelatinization of soaked paddy using FIR radiation is shown in Fig. 1. FIR was produced using three 15 cm x 5 cm ceramic electric IR modules (660 W each) mounted at the top of the apparatus. The FIR waves were guided to the paddy sample uniformly by the stainless steel reflective waveguide (267 mm x 267 mm). A single layer of soaked paddy (40±0.5 g) was exposed to FIR radiation by placing the sample on a ceramic plate. The distance between FIR heaters and rough rice sample was 125 mm.

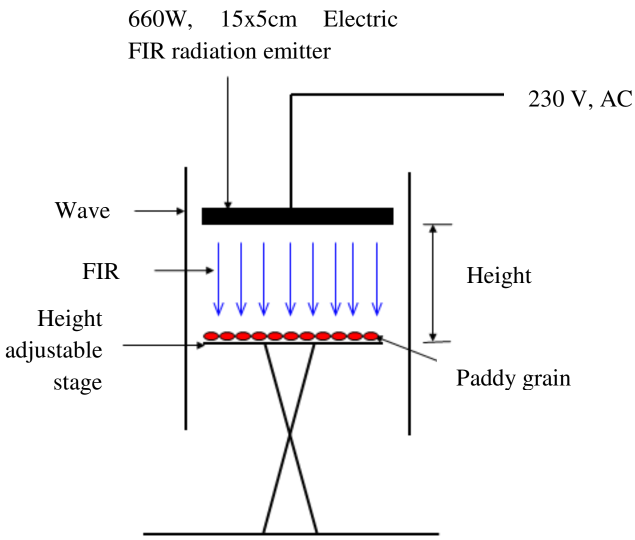

Fig. 1. Schematic diagram of the experimental apparatus for gelatinization of rough rice using FIR radiation

To achieve similar heating for all the samples, the ceramic electrical FIR radiation emitters turned on for 30 s before the testing of sample and then turned off for 150 s after the testing. Again these emitters turned on for 30 s before the testing of next sample. This was done to maintain similar temperature inside the apparatus before placing the soaked paddy samples throughout the experiment.

Moisture variation with FIR radiation

Weight of the samples before exposure to FIR radiation and the weights after exposing to 5, 10, 15, 20, 25, 30 s were measured using a digital balance (Model: Precisa 1620 C, Dietikon, Switzerland) for determining the moisture loss. The moisture contents were calculated by using Equation 1 and the rate of drying was calculated by dividing percentage of moisture removal from time.

$$Mc = Ww/Sw \times 100 \quad \text{.....01}$$

Where,
Mc - Moisture content % (w.b.), Ww - Water weight (g), Sw -Sample weight (g)

The degree of gelatinization of FIR radiation exposed rough rice

The Iodomatric value was used to measure the degree of gelatinization of soaked paddy (Wootton and Kensington, 1989).One gram of FIR radiation exposed rice flour was dissolved in water to the final volume of 100 ml in a volumetric flask. The sample was stirred (700 rpm) with magnetic stirrer (Model: AREX, Milano, Italy) for 60 s and filtered using filter paper (No 44). Duplicate aliquots (1 ml) were diluted to 10 ml and treated with 0.1 ml of iodine solution (1 g I_2, 4 g KI in 100 ml H_2O). Absorbance at 600 nm in 10 mm cells was then measured against a reagent black (0.1 ml iodine in 10 ml of water) by spectrophotometer (Model:Thermo-Spectronic Helios Gamma, England). A same reading of fully gelatinized rice produced by steaming was also measured. The equation 2 was used to calculate the degree of gelatinization.

$$DG = S_1 r / S_1 fg \ (100\ \% \qquad .....02$$

Where,
DG - Degree of Gelatinization, S_r- Spectrometer reading of sample, S_{fg} - Spectrometer reading of fully gelatinized sample

Color values of rough rice samples

Randomly obtained three milled rice samples (5 g) were used to measure the color. The flashing gun was pointed on the watch glass and color was measured by Hunter lab colorimeter (Hunter Lab, USA) in L*(lightness), a* (Redness), b* (Yellowness) color scale. The color of the product was expressed in terms of Yellowness Index that indicates the degree of departure of an object color from colorless or from a preferred white, toward yellow. The Yellowness Index was calculated by using following equation given by Hunter (1958).

$$YI = 100(1.28X - 1.06Z)/Y \qquad .....03$$

Where,
YI- Yellowness Index, *X, Y*, and *Z* - CIE tristimulus values

RESULTS AND DISCUSSION

Effect of FIR radiation exposed time on moisture removal

Table 1 shows the moisture content and rate of drying at different FIR radiation exposure time periods**.** The moisture content of each sample decreased with the increase of exposure time. Therefore, the moisture content had reduced at higher exposure times which simultaneously had higher temperatures. The rate of drying was gradually decreased and then showed constant rate with increase of exposure time.

Table 1. Moisture content and rate of drying at different FIR radiation exposed time periods

Time(s)	Moisture Content (% wb)	Rate of drying (%/s)
0	30.75 ±0.53	0 ± 00
5	27.78 ±0.12	0.59 ± 0.12
10	26.88 ±0.54	0.39 ± 0.11
15	25.55 ±0.36	0.35 ± 0.05
20	24.76 ±0.64	0.30 ± 0.03
25	23.03 ±0.11	0.31 ± 0.03
30	21.38 ±0.56	0.31 ± 0.00

Effect of FIR exposed time on degree of gelatinization

The degree of gelatinization of rice starch at different FIR radiation exposed time periods is shown in Table 2.The degree of gelatinization increased with FIR exposure time. Marshall *et al.* (1993) suggested that a degree of starch gelatinization of ≈40% is sufficient to obtain a maximal head rice yield for microwave parboiled rough rice. Similar results were obtained by Miah *et al.* (2002a; 2002b) for conventionally parboiled rough rice. The 40% of starch gelatinization was obtained in 20 s by FIR radiation heating of rough rice. With FIR radiation the required gelatinization was achieved in fairly a lower time period of 20 s compared to 99.1 s in continuous parboiling (Adhikarinayake and Noomhorm, 1997).

Table 2. The degree of gelatinization at different FIR radiation exposed time periods

Time(s)	Sample reading	Degree of gelatinization (%)
0	0.012± 0.001	18.45± 1.1
5	0.013± 0.005	20.51 ± 7.8
10	0.025 ± 0.004	39.91 ± 1.3
15	0.023 ± 0.010	36.95 ± 11.4
20	0.025 ± 0.003	41.09 ± 9.8
25	0.049 ± 0.021	77.67 ± 22.8
30	0.062 ± 0.011	100.00 ± 0.0

Effect of FIR exposure time on the color

Table 3 shows obtained L* a* b* values and Yellowness index of FIR exposed rough rice at different FIR radiation exposure times. According to the table, L* values were decreased with FIR radiation exposure time and hence, lightness of rice reduced. b* had positive values and it implied that color of FIR exposed rough rice had turned to yellowish color. Yellowness index was in the range of 21.95-34.54. This too indicated the degree of departure of FIR exposed rough rice towards yellow.

Table 3. L* a* b* values and Yellowness index (YI) of rice at different FIR exposure time

Time	L*	a*	b*	YI
0	72.11 ± 1.53	- 0.76 ± 0.22	9.02 ± 0.23	21.95 ± 0.75
5	60.30± 1.97	- 0.59 ± 0.1	11.76 ± 0.53	34.51 ± 0.98
10	54.35 ± 0.01	- 0.72 ± 0.09	10.37 ± 0.07	33.53 ± 0.04
15	52.27 ± 0.18	- 0.75 ± 0.08	10.06 ± 0.82	33.74 ± 0.40
20	53.77 ± 0.28	- 0.65 ± 0.13	10.54 ± 0.30	34.54 ± 0.10
25	52.36 ± 1.30	- 0.83 ± 0.17	9.97 ± 0.35	33.27 ± 0.61
30	52.72 ± 1.14	- 0.80 ± 0.01	10.28 ± 0.78	33.93 ± 0.57

CONCLUSION

The obtained results indicate that FIR radiation can be effectively applied to gelatinized rough rice in parboiling process. The optimum degree of starch gelatinization (40 %) was achieved time period of 20 s. The results revealed that gelatinization could be done within very short period compared to existing methods. The moisture content of each sample decreased with the increase of exposure time. This indicates that gelatinization of rice starch and evaporation of water occurs simultaneously. According to YI, It was shown that the degree of departure of FIR exposed rough rice towards yellow. Therefore, it can be concluded that the simultaneous gelatinization of rice and drying of gelatinized rice could be effectively carried out by FIR radiation with in very short period using FIR radiation.

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