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Evaluation of Cooking Quality of Chromium Fortified – Parboiled Rice

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Abstract. Parboiled rice was developed to produce rice that has low glycemic index, especially for diabetics. Yet, parboiled rice is not enough because diabetics also lack of chromium. The purpose of this experiment is to investigate the influence of paddy soaking time and chromium fortification on cooking quality of chromium fortified - parboiled rice (Cr -PR). The paddy was soaked for 2.5, 3.0, and 3.5 hours with chromium fortification at 0, 1.08, 3.42, 5.40 and 7.47 mg/L. The paddy soaked in different time and chromium fortification level did not affect the alkali spreading value and cooking time of CR-PR. The elongation of Cr-PR was from 1.39 to 1.48. Water uptake ratio increased due to addition of chromium, but the more addition of chromium (> 1.08 mg/L) the less water uptake ratio increase. The rice solid loss declined and it was influenced by the length of soaking time. The longer the soaking time and the higher the chromium addition, the harder the rice texture generated.

1. Introduction

The prevalence and incidence of diabetes mellitus has increased drastically in the new industrial countries and developing countries, including Indonesia. The prevalence of diabetes for all age-group worldwide was estimated to be 2.8% in 2000 and 4.4% in 2030. The number of people with diabetes is projected to rise from 171 million in 2000 to 366 million in 2030. In that year, the number of diabetics in Indonesia is predicted to reach 21.3 million, an increase of 150 percent from 8.43 million people in 2000 [1]. Globally, at least one in 10 deaths among adults aged 35-64 years is attributable to diabetes, rising to a quarter of all deaths in some parts of the world [2]. International Diabetes Federation (IDF) states that two individuals develop diabetes every 10 seconds and two individuals die of diabetes related conditions every 10 second worldwide [3]. One strategy that can be applied to manage diabetes is to consume foods that raise blood sugar slowly, but can provide the satisfaction of satiety. The trick is to consume food products that have a low glycemic index (GI). The research showed that traditional parboiled rice has IG 46 and can significantly lower the blood sugar profile of type 2 diabetics compared with non-parboiled rice is consumed (GI 55) [4]. The low GI values can be caused by high levels of resistant starch.

Yet, parboiled rice is not enough because diabetics also lack of chromium [5]. The mineral deficiency cause high blood sugar levels. Signs of Cr deficiency had similar metabolic syndrome with high blood sugar, high triglycerides, low density lipoprotein, and hypertension. Supplemental Cr has been shown to improve all these signs in human subjects [6].

In producing parboiled rice, the first step is soaking process. This stage plays an important role in hydration and pre-gelatinization process, whereas gelatinization process itself will take place during steaming. With the fortification of chromium in the parboiled rice processing, it is expected to be a functional food for diabetics. Iron fortification during parboiling of paddy has reported by Prom-u-thai et al. [7-9]. The soaking stage and the addition of chromium can affect the quality of physical, chemical and cooking quality of parboiled rice. Therefore, the research needs to be done to find out the effect of soaking time and chromium concentration to cooking quality of Cr-PR.

2. Experimental

2.1. Production of Chromium Fortified- Parboiled Rice (Cr-PR)

Five kilograms of Ciherang variety rice was washed to remove its chaff and other impurities. After that, soaking was done in hot water with a temperature of 65 °C for 2.5; 3; and 3.5 hours with the addition of chromium 0; 1.08; 3.42; 5.40 and 7.47 mg / L, then it was drained and heated/steamed for 25 minutes, and cooled at 0°C for about 14 hours and later it was dried. Grain drying was repeated 2 times, first it was drained until the water content reached 15% - 16%, while the second drying was conducted until the moisture content was 13% - 14%. The drying was done by using a cabinet dryer at a temperature of 50°C and then it was continued to the hulling. The result of parboiled rice then was tested its cooking quality and preference level of Cr-PR.

2.2. Alkali Spreading Value

Alkali spreading value (ASV) was used for predicting gelatinization temperature (GT). The spreading degree of individual milled rice kernel in a weak alkali solution (1.7% KOH) at room temperature (32±2°C) was evaluated on a 7- point numerical scale [10]. Each test was conducted three times. Each time, 10 intact milled grains were placed on a Petri dish to which 15 ml of 1.7% KOH was added. The grains were carefully separated from each other and incubated at ambient temperature for 23 hours to allow spreading of the grains. Grains swollen to the extent of a cottony center. A cloudy collar was given an alkali spread value score 4. Grains that were unaffected were given ASV of 2, and grains that were dispersed and disappeared completely were given a score of 7. A low ASV corresponds to a high gelatinization temperature. Assessment results are evaluated with a scale of 2-7, which is 2 to high GT, 3-5 to intermediate GT and 6-7 to low GT [10].

2.3. Cooking Time

Rice samples (10 g) were individually taken and cooked around 97 - 99°C with 70 ml distilled water in a 100 ml beaker glass which placed in a boiling water bath. Sampling was done 20 minutes after cooking. Cooking time was determined by parallel plates method in which cooked rice was pressed between 2 glass plates every 1 minute until at least 90% no longer has opaque centre or till no white core was left [11].

2.4. Elongation Ratio

Rice was cooked in excess water. Two grams rice was cooked around 97 - 99°C with 20 ml distilled water in a 100 ml beaker placed in a boiling water bath [12]. Samples were removed at the cooking time to measure the length and width (before and after cooking) and calculated by equation:

$$\text{Elongation ratio}=\frac{\text{length of cooked rice (mm)}}{\text{length of raw rice (mm)}} \qquad (1)$$

2.5. Water Uptake Ratio

Rice was cooked in excess water. Two grams rice was cooked around 97 - 99°C with 20 ml distilled water in a 100 ml beaker placed in a boiling water bath [12]. Samples were removed at the cooking time to weigh and calculated by equation:

$$\text{Water uptake ratio}=\frac{\text{weight of cooked rice (g)}}{\text{weight of raw rice (g)}} \qquad (2)$$

2.6. Solid Loss and Texture

Rice was cooked in excess water. Two grams rice was cooked around 97 - 99°C with 20 ml distilled water in a 100 ml beaker placed in a boiling water bath [12]. Five-ml sample of the cooked rice water (previously well agitated) was taken at the cooking time and 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. The amount of solids leached was calculated as kilogram of solids per kilogram of dry grain [12]. Measurement of texture of the cooked chromium fortified – parboiled rice was used Zwick (Type DO-FBO. 5TS).

2.7. Statistical Analysis

The research used completely randomized design (CRD) with 2 factorial patterns; hydration time (2.5, 3 and 3.5 hours) as the first factor and the addition of $CrCl_3$ (0; 1.08; 3.42; 5.40 and 7.47 mg/L) as the second factor. Analysis of variance (ANOVA) and test of significance were performed using SPSS (Statistical Analysis System Software) version-19 with confidence level of 95 % (significance level $P < 0.05$). The samples were randomized for all the analyses describe above.

3. Results and Discussion

3.1. Alkali Spreading Value

Different soaking time and chromium concentration do not affect the alkali spreading value (ASV) of the Cr-PR as exhibited in table 1. Cr-PR has alkali spreading value of 3 - 5. According to Bergmen et al. [13], the data indicated that the rice is at the medium / intermediate level of GT (Gelatinization Temperature) which means the Cr-PR can undergo gelatinization of starch at the temperature of 70 – 74°C. It is the temperature at which 90% of rice starch granules swell irreversibly in hot water with loss crystalline structure and birefringence [13]. Dipti et al. [14] reported ASV of six fine grain rice varieties (Superfast, Basmati 4488, Khaszar, Basmati PNR, Badshabhog, and BRRI dhan 28) range from 3.0 – 3.9. GT was indexed by alkali spreading test. ASV corresponds to the following GT range: low = < 70°C (ASV = 6-7), intermediate = 70 - 74°C (ASV = 3 – 5), and high = > 74°C (ASV = 2) [10]. A low ASV corresponds to high GT, conversely, a high ASV indicates a low GT.

Table 1. Alkali spreading value of Cr-PR during soaking.

Soaking Time (hours)	$CrCl_3$ (mg/L) Concentration				
	0	1.08	3.42	5.40	7.47
2.5	3	4	4	5	5
3.0	4	5	5	5	5
3.5	3	4	4	4	4

Note: Not significant

3.2. Cooking Time

Cooking time for the rice is until 90% of the starch in the grain no longer shows opaque center when it is pressed between two glass plates. Rice differs in optimum cooking time in excess water between 15 – 25 minutes without pre-soaking [15]. The treatment with various lengths of soaking time and concentrations of chromium do not affect cooking time of Cr-PR as shown in table 2. This result is in line with the value of ASV as shown in table 1. The present study indicated that ASV of Cr-PR cooked in excess water range from 23 to 25 minutes and on the average 23.80 ± 1.16 minutes. This length is faster than the cooking time of rice without parboiling process (28 minutes) because of pre-gelatinization process (hot soaking) during the manufacturing of parboiled rice.

Table 2. Cooking time (minutes) of Cr-PR during soaking.

Soaking time (hours)	$CrCl_3$ (mg/L) concentrations				
	0	1.08	3.42	5.40	7.47
2.5	24	25	24	23	24
3.0	24	24	24	24	24
3.5	24	24	23	23	23

Note: Not significant

3.3. Elongation Ratio

Different soaking time and chromium concentrations made a significant effect on Cr-PR elongation after cooking process. Results are shown in table 3. Elongation is one of the important factors for the cooking rice. If the elongation of the rice reaches the appropriate length, it means the better the rice appearance. Based on the data in table 3, it is noted that the elongation ratio of parboiled rice with fortification chromium was ranged from 1.39 to 1.48. It is likely that the longer the soaking time, the longer the elongation ratio of Cr-PR. On the other hand, Cr addition (1.08-7.47 mg/L) in the same cooking time did not affect the Cr-PR elongation ratio. Elongation of rice can be influenced by both the length (l) / breadth (b) ratio and the amylose contents. Grain elongation ratio of *Ofada* rice (*Oryza sativa* L.) ranged from 1.24 – 1.75 [17]. A positive correlation was also recorded by both amylose content and l/b ratio in relation to elongation of rice [16].

Table 3. Elongation ratio (mm/mm) of Cr-PR during soaking.

Soaking time (hour)	$CrCl_3$ (mg/L) Concentration				
	0	1.08	3.42	5.40	7.47
2.5	1.39^{a}	1.43^{bc}	1.44^{bcd}	1.41^{ab}	1.43^{bc}
3.0	1.42^{abc}	1.44^{bcd}	1.41^{ab}	1.41^{ab}	1.44^{bcd}
3.5	1.41^{ab}	1.48^{e}	1.45^{cde}	1.45^{cde}	1.48^{e}

Note: The number followed by different letter indicates significant different (P<0,05)

Table 4. Water uptake ratio (g/g) of Cr-PR during soaking

Soaking Time (hour)	$CrCl_3$ (mg/L) concentration				
	0	1.08	3.42	5.40	7.47
2.5	2.90^{g}	3.06^{i}	2.93^{h}	2.88^{g}	2.73^{cd}
3.0	2.81^{f}	2.87^{g}	2.77^{e}	2.77^{e}	2.75^{de}
3.5	$2,60^{a}$	$2,71^{c}$	$2,68^{b}$	$2,66^{b}$	$2,60^{a}$

Note: The number followed by different letter indicates significant different (P<0,05)

3.4. Water Uptake Ratio

Water uptake ratio is important parameter in cooking rice. If the bulk density is higher, then correspondingly water uptake ratio will also be high. This has been attributed to the compact structure of a rice variety. Water uptake ratio shows a positive significant influence on grain elongation. Water uptake ratio of *Ofada* rice varied between of 1.74 – 2.11 [17]. The results of Cr-PR water uptake ratio measurement are presented in table 4. Based on the results of statistical analysis, it is known that the soaking time and the chromium concentration significantly affected water uptake ratio. The longer the soaking time and the greater the concentration of chromium (> 1.08 mg/L), the less the water absorption in the parboiled rice would be. In this study, it was observed water uptake ratio to be highest (3.06 g/g) for soaking time of 2.5 minutes and chromium concentration of 1.08 mg/L. The reduction of water absorption capacity in Cr-PR had caused changes in the structure of starch granules as the reaction of heat (hot soaking and steaming) during the proses of parboiling and retrogradation during cooling. Therefore, it can produce a sturdy structure. Disorganized cellular structure can enhance the probabilities for high water absorption during cooking and can contribute to longer cooking time [16].

3.5. Solid Loss

Solid in cooking water may be correlated with amylose content and may be related to stickiness of cooked rice. The data in table 5 shows that different soaking time and chromium concentration influenced the solid loss of Cr PR. Loss of solids in cooking water or the amount of solid released into cooking water was related to the amount of water that is absorbed. Low solid contents in the cooking gruel can be attributed to fact that the surface area in contact with water is smaller, resulting in a lower l/b ratio [16]. Rice varieties with higher amylose content are more prone to leaching out into the cooking water as starch grains expand during cooking [18]. This statement is contrary to results of this study that shown in table 5. It can be meant that the less amylose, the more solids separated at the cooking time, and the higher amylose content the less solids were separated.

Table 5. Solid loss (g/100g) parboiled rice during soaking

Soaking Time (hour)	$CrCl_3$ (mg/L) Concentration				
	0	1.08	3.42	5.40	7.47
2.5	5.82^{k}	5.44^{ij}	5.46^{j}	5.36^{i}	4.88^{ef}
3.0	5.10^{h}	4.92^{fg}	4.76^{d}	4.62^{c}	4.36^{b}
3.5	5.12^{h}	4.98^{g}	4.94^{fg}	4.82^{de}	4.22^{a}

Note: The number followed by different letter indicates significant different (P<0,05)

3.6. Rice texture

Based on the results of statistical tests, it was obtained that the interaction between soaking time and the chromium concentration significantly affected the texture of CR-PR (table 6). The longer the soaking time, the harder the rice grain become. The hardness of the rice texture was caused by chromium fortified-parboiled rice amylose content which is in line with the analysis results of amylose content on a variety of soaking time and concentration of chromium (data not showed). The higher the amylose content of rice, the harder its texture was. The greater force (N) produced the harder texture of the rice. Such condition is in line with the higher level of amylose in the rice. There was a negative correlation between cooked rice firmness with moisture content of rice during cooking, that provides more evidence of the significant role moisture uptake plays in determining cooked rice firmness [19].

Table 6. Texture (Newton) of Cr-PR during soaking

Soaking time (hour)	$CrCl_3$ (mg/L) concentration				
	0	1.08	3.42	5.40	7.47
2.5	3.52^{b}	3.26^{a}	3.65^{c}	3.86^{d}	3.91^{e}
3.0	4.12^{f}	4.14^{f}	4.38^{h}	4.44^{i}	4.45^{i}
3.5	4.20^{g}	4.18^{g}	4.50^{j}	4.84^{k}	4.83^{k}

Note: The number followed by different letter indicates significant different (P<0.05)

4. Conclusion

From the research results of research and discussion, it can be concluded that treatment of soaking time and the chromium fortification did not affect the alkali spreading value and cooking time. The elongation of Cr-PR was from 1.39 to 1.48. The addition of chromium had increased water uptake ratio, but the greater concentration of chromium, the less water uptake ratio became. The longer soaking times, the lower its solid loss would be. The longer the soaking time and the addition of chromium, the harder the rice texture generated.

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References
[1] Wild S, Roglic G, Green A, Sicree R and King H 2004 *Diabetes Care* **27** 1047–53
[2] Roglic G and Unwin N 2005 *Diabetes Voice* **50** 33–4
[3] International Diabetes Federation 2007 *World diabetes media kit: every 10 seconds 1 person dies of diabetes* (Belgium: International Diabetes Federation Brussels)
[4] Larsen H N, Rasmusse O W, Rasmussen P H, Alstrup K K, Biswas S K, Tetens I, Thilsred S H and Hermansen K 2000 *EJCN* **54** 380–5
[5] Anderson R A 2008 *Proc. of Nutrition Society* **67** 48–53
[6] Cefalu W T and Hu F B 2004 *Diabetes Care* **27** 2742–51
[7] Prom-u-thai C, Fukai S, Godwin D I, Rerkasem B and Huang L 2008 *Food Chem*. **110** 390–8.
[8] Prom-u-thai C, Glahn R P, Cheng Z, Fukai S, Rerkasem B, and Huang L 2009 *Food Chem*. **112** 982–6
[9] Prom-u-thai C, Rerkasem B, Fukai S and Huang L 2010 *Food Chem.* **123** 628–34
[10] Khush G S, Paule C M and Delacruz M N 1979 *Proc. of the workshop on chemical aspect of rice quality* 21–31
[11] Juliano B O 1982 *An International survey of methods used for evaluation of cooking and eating qualities of milled rice* (Los Banos Laguna: Philippines IRRI)
[12] Sareepuan K, Siriamornpun S, Wiset L and Meeso N 2008 *WJAS* **4** 409–15
[13] Bergman C J, Bahattacharya K R and Ohtsubo K 2004 Rice end-use quality analysis *Rice: Chemistry and Technology* ed Champagne E T (Minnesota: America Association of Central Chemists Inc)
[14] Dipti S S, Hossain S T, Bari M N and Kabir K A 2002 *Pakistan J Nutr* **1** 188–90
[15] Raghavendra R S N and Juliano B O 1970 *J. Agric. Food Chem.* **18** 289–94
[16] Thomas R, Wan-Nadiah W A and Bhat R 2013 *IFRJ* **20** 1345–51
[17] Danbaba N, Anounye J C, Gana A S, Abo M E and Ukwungwu M N 2011 *IFRJ* **18** 629–34
[18] Juliano B O 1971 *Cereal Science Today* **16** 334–8
[19] Saleh M and Meullenet J F 2013 *IFRJ* **20** 1337–44