The Effect of Soaking Temperature and Cinnamon Extract Concentration on the Quality of Parboiled Rice

Nugrah Widiastuti Tistianingrum[1], *Wisnu Adi* Yulianto[2*]

[1]Agricultural Product Technology Study Program, Faculty of Agroindustry, University of Mercu Buana Yogyakarta, Indonesia
[2]Food Science Master Program, Faculty of Agroindustry, University of Mercu Buana Yogyakarta, Indonesia

Abstract. The temperature of the soaking of paddy in a solution of chromium and magnesium, as well as cinnamon extract affects the hydration of the paddy, the adsorption of chromium and magnesium, and the taste of parboiled rice. The purpose of this study was to produce parboiled rice which is favoured by panellists, has a low glycemic index (GI) and has a high content of resistant starch (RS), Cr and Mg. This research was carried out using a completely randomized design with two treatment factors, namely the paddy soaking temperatures (60, 65 and 70˚C) and the soaking concentrations of cinnamon extract (0, 5, 10 and 15%). The paddy was soaked for 2.5 h, boiled with temperature of 100˚C for 20 min, cooled at a temperature of 0˚C for 12 h, dried at 50˚C and undergone the process of hulling. The results showed that the paddy soaking temperature and the soaking concentrations of cinnamon extract influenced the levels of RS, fortificants, GI and the panellists' preference of the parboiled rice produced. The preferred rice was produced with soaking temperature of 65˚C and cinnamon extract of 10%. As the rice had a GI of 30.62, it is suitable for diabetics.

Keywords: soaking temperature, cinnamon extract, parboiled rice, glycemic index, resistant starch

1 Introduction

The number of diabetics in Indonesia is among the top 10 in the world, reaching 10.681 million people, which is 6.2% of the total population and is also estimated to reach 13.7 million in 2030 [1]. Meanwhile, most of the suffers are deficient in chromium (Cr) and magnesium (Mg) [2]. Lack of these micronutrients leads to an increase in blood sugar, therefore, the availability of food with adequate Cr and Mg content, as well as a low glycemic index (GI) is an important issue for the Indonesians that are fond of rice.

* Corresponding author: wisnuadi@mercubuana-yogya.ac.id

Rice generally has a high glycemic index of 64-93 [3], however, the grain is processed into parboiled form with a low value, namely < 55 [4-6]. In parboiled rice production, soaking is carried out for hydration or sufficient water absorption, which facilitates starch gelatinization in the next cooking stage [7]. The soaking treatment of rice variety PB1121 at 80°C reduces the grain's GI from 58.41 to 54.31 [8]. Sareepuang et al. [9] reported that soaking the grain of variety KDML 105 at 50 °C for 3 hours produced the most desirable parboiled rice in terms of nutritional quality and sensory properties, compared to carrying out the process at 40 °C and 60 °C.

To overcome nutritional deficiencies in diabetics, parboiled rice is enriched with Cr and Mg. The grains' Fe and Zn content can be increased by simultaneous fortification with these two nutrients during parboiling [10]. Chromium fortification has also been performed by Yulianto et al. [11], where the rice produced has a low GI (40), resistant starch of 11.88%, and a total Cr of 0.56 mg/kg. However, the sensory test results showed a level of preference between 'dislike' and 'like'.

Parboiled rice is less favored by consumers in Indonesia because it has an identical smell with husks and is a bit stale. Hence, during soaking, cinnamon extract can be added to enhance the aroma and taste. Furthermore, the supplements of this spice are known to control consumers' blood sugar levels and insulin sensitivity [12]. Ervina et al. [13] reported that cinnamon contains polyphenols (including flavonoids & tannins) and phenolic essential oils as the main antioxidants. The type-A procyanidin polymer compounds in cinnamon increase insulin receptor autophosphorylation and sensitivity [14], meaning an intake of 1, 3, or 6 grams per day reduces serum blood sugar levels, triglycerides, LDL cholesterol, and total cholesterol in people with type 2 diabetes [15]. Moreover, the component prevents the disease's signs and symptoms [16].

Therefore, this research aims to determine the effect of temperature and cinnamon extract concentration during the soaking process on resistant starch, fortificants, glycemic index, and preference of parboiled rice fortified with chromium and magnesium.

2 Material and method

2.1 Material

The Ciherang paddy with medium amylose content employed in this research was a certified rice seed obtained from an agricultural shop in Sleman, Yogyakarta, Indonesia was used. Cinnamon powder (*Cinnamomum burmannii*) was used as a natural herbal flavor enhancer. Chromium chloride and magnesium acetate (Sigma-Aldrich) were the is a source of Cr and Mg, respectively. Other chemicals and reagents were pro-analysts (Sigma-Aldrich).

2.2 Production of Cr and Mg Fortified - Parboiled Rice Enriched with Cinnamon Extract

The preparation of parboiled rice enriched with Cr and Mg as well as cinnamon extract was carried out with varying soaking temperatures and concentrations of the extract. The production steps are as follows:

Cinnamon Extract Preparation. In total, 400 grams of cinnamon powder was dissolved in 600 mL of water. This was followed by filtering with a cloth to obtain an extract concentration of 40%. A total of 468.75 mL, 937.5 mL, and 1406.25 mL of the extract were taken and diluted with distilled water to 3750 mL, respectively, therefore the

concentrations became 5%, 10%, and 15%, then the result was used as a grain soaking solution.

Production of Cr and Mg Fortified - Parboiled Rice Enriched with Cinnamon Extract. Up to 2.5 kg of Ciherang variety paddy was washed thrice and drained. Furthermore, each 2.5 kg of the rice was soaked in 5%, 10%, and 15% cinnamon extract solutions and at a temperature of 60, 65, and 70˚C for 2.5 hours. The fortification process was carried out by adding 20 mg and 6.56 g of chromium chloride and magnesium acetate, respectively, in 3750 mL of the aforementioned solution. After soaking, the rice was boiled in 3750 ml of distilled water at 100˚C for 20 minutes. The boiled grains were drained until they reached a temperature of 37˚C, then cooled at 0˚C for 12 hours. Moreover, they were dried using a cabinet dryer at a temperature of 50˚C until the water content reached 11-12%. In the final step, the dry grain was hulled to produce Cr and Mg fortified – parboiled rice enriched with cinnamon. Finally, the samples were analyzed for RS, fortificants, and GI, as well as tested to examine the panelists' preference level.

2.3 Chemical Analysis and Preference Level Test

The resistant starch content of Cr and Mg-fortified parboiled rice enriched with cinnamon extract was determined enzymatically by the gluco-oxidase method [17]. Chromium and magnesium levels were analyzed by the atomic absorption spectroscopy method [18]. Also, GI testing was carried out on healthy subjects, including 3 people for each rice sample tested [5].

To test consumer's preference level, 20 semi-trained panelists assessed the attributes of rice, namely color, aroma, taste, hardness, stickiness, and overall. The scale of preference level used was 1 = very like, 2 = like, 3 = slightly like, 4 = slightly dislike, 5 = dislike, and 6 = very dislike.

2.4 Experimental Design and Data Analysis

A completely randomized design was used with a factorial pattern of 2 factors, namely 1) soaking temperature: 60, 65 and 70°C; and 2) concentration of cinnamon extract treatment: 0, 5, 10 and 15%. The data obtained in form of resistant starch, fortificants, GI, and panelists' preferences were analyzed using the variance test (ANOVA) at the 95% confidence level. Once there was a significant difference in each treatment, the test was continued with Duncan's Multiple Distance Test.

3 Results and Discussion

3.1 Resistant Starch

The analysis results of resistant starch levels can be seen in Table 1. RS levels in Cr and Mg-fortified parboiled rice enriched with cinnamon extract ranged from 9.71-14.08%. Consequently, food is classified into several categories, namely low by 1 - 2.5%, moderate by 2.5 - 5%, high by 5.0 - 15%, and very high by > 15% [19], leading to the rice from this research being considered as containing high RS levels.

The retrograded starch produced is a type of resistant starch (RS) categorized as RS3. Starch retrogradation is affected by many factors, including water content, storage temperature, storage time, and additives in the system. The rate of retrogradation and RS formation is increased by a higher amylose-amylopectin ratio and storage at 1-25°C [20]. Furthermore, other research reported that cooling cooked white rice increased its resistant

starch [21]. Therefore, to produce high RS, Ciherang rice with 21-23% amylose content was used including cooling treatment at 0°C for 12 hours.

Table 1. Resistant starch content (%) of parboiled rice fortified with Cr and Mg at various soaking temperature and concentration of cinnamon extract

Soaking Temperature (˚C)	Concentration of Cinnamon Extract (%)			
	0	5	10	15
60	12.39^{cd}	9.71^{a}	13.05^{de}	14.08^{e}
65	12.50^{cd}	12.43^{cd}	13.82^{e}	19.84^{f}
70	13.19^{de}	13.79^{e}	11.57^{bc}	11.21^{b}

Numbers followed by different letter notations show significant differences at the 95% confidence level (P <0.05). The value of the average of 3 replications of the experiment.

In Table 1, it can be seen that the higher the concentration of cinnamon extract used in soaking paddy at 60˚C and 65˚C, the greater the increase in RS of parboiled rice. This indicates that soaking at that temperature is sufficient for water hydration, which then facilitates the cinnamon component to enter the starchy endosperm, and complete gelatinization occurs at the boiling stage, as well as the formed grain starch's retrogradation at the 0˚C cooling stage for 12 hours.

Furthermore, Table 1 shows the higher the concentration of cinnamon extract used in the soaking conducted at 70˚C, the lower the amount of RS in parboiled rice produced. This is because soaking at 70˚C allows starch gelatinization and loss of solidity. In fact, the gelatinization temperature of chromium-fortified parboiled rice has an alkaline spread value of 3-5 [22], meaning that rice tends to pass through this process at 70-74˚C or a medium temperature [23]. Therefore, Ciherang rice soaked at 70˚C has experienced gelatinization, thereby reducing the potential for interactions between starch and compounds contained in the cinnamon extract. Furthermore, the extract's phenolic components potentially bind to monosaccharides and polysaccharides in the starchy endosperm [24], hence forming RS type 4 which is a cross-link between starch and other compounds [25].

3.2 Chromium Level

The analysis results of the Cr content in the rice produced can be seen in Table 2. Chromium levels in Cr and Mg-parboiled fortified rice enriched with cinnamon extract ranged from 41 - 58 g Cr/kg or equivalent to 7.38 - 10.44 g Cr /180 g, where estimated rice consumption is 180 g per day.

Table 2. Chromium content (µg/kg) of parboiled rice fortified with Cr and Mg at various soaking temperature and concentration of cinnamon extract

Soaking Temperature (˚C)	Concentration of Cinnamon Extract (%)			
	0	5	10	15
60	47^{bc}	45^{bc}	42^{ab}	44^{ab}
65	42^{ab}	41^{a}	46^{abc}	46^{abc}
70	47^{bc}	58^{d}	51^{cd}	42^{ab}

Numbers followed by different letter notations show significant differences at the 95% confidence level (P <0.05). The value of the average of 3 replications of the experiment.

Based on Table 2, soaking in a solution of cinnamon extract greatly affects Cr penetration and absorption into the starchy endosperm. The higher concentration of extract used in soaking grain at temperatures of 60 and 65˚C inhibited the increase in the produced

rice's chromium content. The dissolved compounds in the soaking solution seemed to bind to Cr, therefore the Cr content in the produced rice did not increase. However, the use of 5 - 10% cinnamon extract in soaking rice at a higher temperature (70˚C) for 2.5 hours showed an elevation in Cr content in rice. Previous research reported that soaking rice with $CrCl_3$ of 1.08 mg/L (without herbal extract) at 65˚C for 2.5 hours yielded parboiled rice with a total Cr of 0.37 mg/kg or an increase of about 7.4 times [26].

Chromium is an essential mineral for controlling blood sugar. The control effect is indicated by Cr ability to activate small peptides and increase insulin's action in binding to the receptors, therefore helping blood sugar enter the body cells [27]. According to the Indonesian Ministry of Health, 2013, the need for chromium intake is 25-26 g/person/day for men and 19-30 g/person/day for women. These needs are provided from fortified food, as up to 20% of the daily Cr requirement or 5 g Cr per day. Based on the result, the produced rice contains 7.38-10.44 g Cr/180 g, meaning the required adequacy level has been exceeded.

3.3 Magnesium Level

The analysis results of the Mg levels in the produced rice can be seen in Table 3. Magnesium levels in parboiled rice enriched with cinnamon extract ranged from 381 to 441 mg Mg/kg, which is equivalent to 68.58 - 79.38 mg Mg/180 g of rice.

Table 3. Magnesium content (µg/kg) of parboiled rice fortified with Cr and Mg at various soaking temperature and concentration of cinnamon extract

Soaking Temperature (˚C)	Concentration of Cinnamon Extract (%)			
	0	5	10	15
60	393^{c}	441^{j}	419^{f}	382^{a}
65	412^{e}	437^{i}	381^{a}	381^{a}
70	406^{d}	429^{h}	424^{g}	388^{b}

Numbers followed by different letter notations show significant differences at the 95% confidence level ($P < 0.05$). The value of the average of 3 replications of the experiment.

After the paddy was soaked at 60, 65, and 70˚C, the Mg content increased when 5% cinnamon extract was used but decreased gradually with the addition of 10 and 15%. Decreased levels of Mg and Cr, occur due to the formation of complex compounds from phenol in cinnamon with Mg, as well as reduces the bioavailability of essential minerals e.g. chromium and magnesium present in food [24].

Magnesium intake is very important, especially for people with diabetes mellitus as its role is associated with maintaining homeostatic blood glucose and activating insulin sensitivity [27]. The mineral adequacy requirement for Mg is 148 mg/person/day for men and 155 mg/person/day for women [28]. These needs are provided from fortified food, as up to 20% of the daily Mg requirement or 9.6 - 31 mg/day. Based on the results, the produced rice contains 68.58 - 79.38 mg Mg/180 g, meaning the required adequacy level has been exceeded.

3.4 Glycemic Index

The glycemic index determination results of parboiled rice can be seen in Table 4. Overall, the GI of the produced rice was less than 55 with an average of 40.2, which is lower than the value reported by the previous research that produced parboiled Ciherang rice with a GI of 44.22 [29].

Table 4. Glycemic index of parboiled rice fortified with Cr and Mg at various soaking temperature and concentration of cinnamon extract

Soaking Temperature (˚C)	Concentration of Cinnamon Extract (%)			
	0	5	10	15
60	38.00^{c}	40.00^{e}	43.50^{f}	43.95^{f}
65	38.96^{d}	35.10^{b}	30.62^{a}	38.74^{cd}
70	43.51^{f}	44.00^{f}	38.60^{cd}	47.50^{g}

Numbers followed by different letter notations show significant differences at the 95% confidence level (P <0.05). The value of the average of 3 replications of the experiment.

The GI of rice soaked in 5, 10, and 15% cinnamon extract solutions at 65˚C were lower than the counterpart at 60˚C. However, the GI of rice soaked at 70˚C with the cinnamon solution was still higher than the counterpart at 65˚C. This is caused by RS and other factors such as phenol content in rice, the severity of soaking, higher temperature (shorter duration) or lower temperature (longer duration), amylose content, amylose/amylopectin ratio, and the crystallinity rate. Based on the result, the GI with cooling is lower than without cooling which is also in line with the report by Darandakumbura et al. [30]. The produced Bg 300 and Bg 358 rice varieties had an average GI of 67 and 68, respectively, which were lower ($p < 0.05$) compared to the raw form. On the other hand, cooling white rice increases its resistant starch content, hence the RS (2.03-2.91%) was negatively correlated with the glycemic index ($r = -0.674$) while contributing to 45.5% GI variability [31].

Parboiling generally reduces the GI value of most varieties. A lower glycemic response was shown in cooked white rice that was cooled for 24 hours at 4°C and then reheated than the freshly cooked counterpart [21]. A maximum of 10% decrease in GI value after parboiling was observed at Bg 352 [32]. Larsen et al. [4] reported a GI of 55.5 in non-parboiled rice (NP), 46.8 in traditional parboiled rice, and 39.6 in high pressure parboiled rice (PP), furthermore, the GI of PP is significantly lower than NP rice.

Based on Table 4, soaking at 60˚C with a concentration of 5-15% cinnamon extract increases the GI. Meanwhile, at 65˚C with 5-10% extract and 70˚C with 10% extract, there was a decrease in the GI of the rice produced. This was probably caused by the high levels of phenols that can be bound to the endosperm of rice starch. Type-A procyanidin polymers found in cinnamon have been reported to increase insulin receptor autophosphorylation and sensitivity [12, 14]. Non-covalent interactions between starch and phenolic compounds tend to occur as well as have an impact on the physicochemical and nutritional properties of foods. Zhou et al. [33] reported that starch and phenolic compounds interacted to form inclusion complexes in the form of single helical amylose, facilitated by hydrophobic effects, or complexes with weaker bonds through hydrogen bonds. The interaction effect on starch properties, including gelatinization and retrogradation, occurs depending on the chemical composition of phytochemical extracts, phenolic compounds, starch structure, and experimental conditions [33]. Besides, sorghum proanthocyanidins interacted strongly with starch to decrease its digestibility. This seemed to be specific for amylose, while the linear fragments of amylopectin indicated the hydrophobic interactions involved. In addition, cinnamon extract inhibits α-glucosidase activity and postprandial glucose excretion in diabetic rats [34].

3.5 Panelist's Preference Level

Sensory test results which include aroma, color, taste, hardness, stickiness, and overall attributes can be seen in Table 5.

Aroma. The preferred parboiled rice with a score of 1.90 - 2.30 (very like to slightly like), was mostly produced from the addition of 5% and 10% cinnamon extract. At this level, the cinnamon aroma is not too strong, therefore it is still acceptable to the panelists. Furthermore, the rice has a distinctive aroma caused by the content of cinnamaldehyde and eugenol compounds [16] which tend to reduce the husk's smell.

Color. The preferred color of parboiled rice with a score of 'like' to 'slightly like' was obtained from the treatment with cinnamon extract soaking of 0.5 and 10%. The panelists involved did not like the use of 15% extract that plays a role in the coloring of parboiled rice because cinnamon extract contains cinnamaldehyde which causes a yellowish appearance. Furthermore, bran, oxidative pigment, and Maillard reaction also affect the color. The parboiling including soaking and steaming, turns the color to brown [9] as well as increases the darkness, redness, and yellowness of brown and milled rice, while this change increases with the severity of the process. The changes in reducing sugars and free-amino nitrogen indicate the occurrence of Maillard reactions during steaming. The presence of furosine compounds in samples of brown rice and parboiled rice indicates the occurrence of Maillard reactions on the surface of brown rice and starchy endosperm [34]. In addition to the release of bran pigments during soaking, pigments diffusion into the endosperm during steaming also determines the color of parboiled rice [36].

Table 5. Preference level of parboiled rice fortified with Cr and Mg at various soaking temperature and concentration of cinnamon extract

Treatment		Parameter					
Soaking Temperature (°C)	Concentration of Cinnamon Extract (%)	Aroma	Color	Taste	Hardness	Stickiness	Overall
60	0	3.10^{c}	2.40^{ab}	2.75^{bc}	3.50^{d}	2.70	2.85^{bc}
	5	2.15^{ab}	1.85^{a}	2.10^{a}	2.55^{a}	2.50	2.30^{ab}
	10	1.90^{a}	2.05^{ab}	2.15^{a}	2.45^{a}	2.25	2.05^{a}
	15	2.35^{ab}	2.45^{b}	2.35^{abc}	2.85^{abc}	2.30	2.45^{abc}
65	0	2.70^{bc}	2.20^{ab}	2.90^{c}	3.35^{cd}	280	2.75^{bc}
	5	2.30^{ab}	2.40^{ab}	2.40^{abc}	2.70^{a}	2.65	2.55^{abc}
	10	2.05^{ab}	2.30^{ab}	2.15^{a}	2.50^{a}	2.50	2.30^{ab}
	15	2.70^{bc}	3.25^{c}	2.75^{bc}	275^{ab}	2.70	2.90^{c}
70	0	2.70^{bc}	2.15^{ab}	2.55^{abc}	3.30^{bcd}	2.75	2.70^{bc}
	5	2.25^{ab}	1.85^{a}	2.30^{ab}	2.35^{a}	2.25	2.40^{abc}
	10	2.25^{ab}	2.20^{ab}	2.45^{abc}	265^{a}	2.50	2.40^{abc}
	15	2.65^{bc}	3.05^{c}	2.85^{bc}	2.90^{abc}	2.85	2.85^{bc}

The number followed by the same letter shows no significant difference at the 0.05 significance level ($P < 0.05$)

Taste. The panelists preferred the taste of parboiled rice soaked in 5% and 10% cinnamon extract solutions at three different temperatures (60, 65, and 70˚C), and the counterpart soaked in 0% at 70˚C. The level of taste is influenced by the content of cinnamaldehyde and eugenol which causes a distinctive taste plus a fragrant aroma [16]. However, rice soaked in 15% cinnamon extract solution at relatively high temperatures, namely 65 and 70˚C, was 'slightly disliked' by the panelists because its cinnamaldehyde and eugenol content was probably too high.

Hardness. Soaking temperature and concentration of cinnamon extract affected the panelists' preference for the hardness of the parboiled rice produced. The preferred rice was obtained by soaking in 5, 10, or 15% extract at 60, 65, and 70˚C. However, the counterpart without the addition of cinnamon extract tends to belong to the 'slightly like' to 'slightly dislike' category because its hardness is a little higher than non-parboiled rice. The interaction between phenolic compounds and starch forms complex compounds that affect the degree of retrogradation experienced [33], which in turn affects the produced rice's hardness.

Stickiness. Based on Table 5, the variation of soaking temperature and concentration had no significant effect on the produced rice's stickiness. Parboiling has a significant impact on the organoleptic properties of rice, hence the parboiled grain has been reported to be less sticky and harder than the non-parboiled counterpart [37]. This research is closely in line with Sareepuang et al. [9] which stated rice subjected to soaking treatments at temperatures of 40, 50, and 60˚C did not have a significantly different stickiness when compared to the parboiled rice produced.

Overall. Based on all the values in Table 5, the panelists' preferred parboiled rice was obtained from soaking rice with 5, 10, and 15% cinnamon extract at 60˚C, and soaking with 5% and 10% cinnamon extract at 65 or 70˚C.

4 CONCLUSION

The preferred parboiled rice with a value of 2.30 (like) and a low GI (30.62) was obtained from the soaking treatment with 10% cinnamon extract at 65˚C. This has RS, Cr, and Mg levels of 13.82%, 46 ug/kg, and 381 mg/kg, respectively while being suitable for diabetics due to having a low GI and capable of fulfilling the needs of these micronutrients in the sufferers. Soaking temperature of paddy and concentration of cinnamon extract affect the levels of Mg and Cr of parboiled rice, so it is necessary to study the interaction of these minerals with cinnamon extract and paddy.

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