IOP Conf. Series: Earth and Environmental Science **102** (2018) 012101 doi:10.1088/1755-1315/102/1/012101

Evaluation of resistant starch, glycemic index and fortificants content of premix rice coated with various concentrations and types of edible coating materials

W A Yulianto*, A M Susiati and H A N Adhini

Faculty of Agro-industry, University of Mercu Buana Yogyakarta, Jl. Wates Km 10, Argomulyo, Bantul, Yogyakarta 55753

*E-mail: wisnuadi@mercubuana-yogya.ac.id

Abstract. The incidence of diabetes in Indonesia has been increasing year by year. Diets with a low glycemic index and high resistant starch foods can assist diabetics in controlling their blood glucose levels. Diabetics are known to have micro-nutrient deficiencies of chromium, magnesium and vitamin D that can be overcome by consuming parboiled rice fortified by use of a coating method. The fortification of parboiled rice (premix rice) can be achieved by coating with HPMC (hydroxypropyl methyl cellulose), MC (methyl cellulose), CMC (carboxyl methyl cellulose), gum arabic and rice starch. This research aimed to evaluate the levels of resistant starch, glycemic index and fortificants of premix rice coated with different concentrations and types of edible coating materials. This research used completely randomized design, with treatments to the concentrations and the types of edible coating (HPMC, CMC, MC, gum arabic and rice starch). The concentrations of edible coating were 0.15%, 0.2% and 0.25% for cellulose derivative coatings; 25%, 30%, 35% for gum arabic and 2%, 3.5% and 5% for rice starch. This research shows that fortified premix rice coated with various concentrations and types of edible coating materials is high in resistant starch and has a low glycemic index. The coating treatment affects the levels of magnesium and vitamin D, but does not affect the levels of chromium in parboiled rice. The premix rice with a low glycemic index and high nutrient content (chromium, magnesium and vitamin D) was premix rice coated by CMC 0.25% and HPMC 0.25% with glycemic indeces of 39.34 and 38.50, respectively.

***Keywords**: coating material, fortificant, glycemic, rice.*

1. Introduction

With 154.062 diabetes mellitus patients, Indonesia takes fourth place behind China (1,023,504 sufferers), India (760,429 sufferers) and the United States (223,937 patients) [1]. Based on the results of basic health research done in 2013, the prevalence of diabetics in Indonesia reached 6.9% of the population, the proportion with impaired glucose tolerance 29.9% and disturbed fasting blood sugar 36.6% [2].

Diabetics generally limit their consumption of rice based on the assumption that rice is a food that has a high glycemic response. However, not all rice is hyperglycemic [3]. Research done by [4] showed that traditional parboiled rice has a GI of 46 and can significantly lower the blood sugar profile in type 2 diabetes compared to eating non-parboiled rice (GI

55). Meanwhile, it has been reported that people with diabetes have a deficiency of chromium [5], a magnesium deficiency [6], and a vitamin D deficiency [7-8] as well. Such nutrient deficiencies can lead to an increase in blood sugar. Attempts to produce rice with a low GI and fortified with chromium have helped with success in developing the fortification process of parboiling rice with chromium [9] through the improvement of the process. Despite producing a low enough IG (36.33) and gastrointestinal starch of 11.88% (bk), the sensory test results by the panellists showed their favoured levels ranged from 'less preferred to preferred'. To improve consumer preferences a food aroma booster could be added to the rice.

Among the ingredients commonly used in food aroma boosters, pandan leaf extract is the most emphasized. The main compounds responsible for the fragrance or fragrant aroma of pandanus are: 2-acetyl-1-pyrolyine (2AP). These compounds are also found in scented rice (aromatic rice) [10-12]. Aside from being a food aroma booster, pandanus also has medical uses as a diuretic, cardio-tonic, and an anti-diabetic [13].

The addition of pandan extract and micronutrients (Cr and Mg) to rice can be done by coating (coating). Edible coating materials which can be used for coating the rice are: methyl cellulose (MC) and hydroxypropyl methyl cellulose (HPMC). Such materials, and the combination of both, have been successfully used as an edible coating material in iron fortified rice [14]. As a result, panellists were found to favour iron fortified rice which had a combination of HPMC and MC (3: 1) by 2%. Similarly, it was reported by [15], that the maximum retention of micronutrients (vitamins and minerals) in premixed rice occurs when coated with HPMC and MC combinations (3: 1) with 100% iron retention. [12] applied a rice coating with 5% rice starch and 30% sorbitol used for enriching the aroma of pandan leaf extract. Choi et al. [16] coated the rice with resistant starch type 4 to decrease the digestibility and glucose response in experiments with mice. Meanwhile, gum arabic coating at a concentration of 40% and with 20% spice extract was the best treatment for fast rice coating [17].

This study aimed to evaluate the levels of resistant starch, glycemic and fortificants (chromium, magnesium and vitamin D) and to determine the best coating type and level of premix rice fortified with chromium, magnesium and vitamin D.

2. Materials and method.

2.1. Production of Parboiled Rice

A 10 kg of Ciherang variety rice was washed and disposed. It was then soaked in 15 litres of water at a temperature of 65 °C ± 2 °C for 2.5 hours, after which it was drained and steamed for 25 minutes, then cooled at 0 °C for 6 hours and finally dried. The drying process was done using a cabinet dryer until it had a moisture content of 13-14% (wet weight) at a temperature of 50 °C. The measurement of the water was conducted using a moisture tester.

2.2. Coating of Parboiled Rice

2.2.1. Preparation of pandanus extract. Pandan leaf extracts were prepared using the modified Al-Jamal and Rasheed [18] methods. A total of 500 g of pandan extract that had been previously destroyed was soaked in 1500 ml of hot water (88 °C) in a water bath for 6 hours. Furthermore, filtering, using Whatman paper no. 41, was carried out and finally a rotary vacuum concentration at a temperature of 60 °C to obtain 150 ml of the herbal extract.

2.2.2. Preparation of coating materials. The parboiled rice coating was made using a variety of edible coating materials, namely HPMC (hydroxypropyl methyl cellulose), MC (methyl cellulose), CMC (carboxyl methyl cellulose): 0.15%, 0.2% and 0.25%), gum arabic (25%, 30% and 35%) and rice starch (2%, 3.5% and 5%). A composition of the coating mixture of cellulose derivatives was used as in [15] with slight modification, consisting of 5% CMC / MC / HPMC, 28.5% ethanol (95%), and 66.7% water for 5% edible film content.

2.2.3. Coating of Parboiled Rice. 500 g of parboiled rice was coated with polymer-nutrients (Cr, Mg and vitamin D). The levels of daily upper limit of intake for adults were 50 mg for vitamin D and 350 mg for magnesium [19], while for Cr the daily limit of safe intake was 50-200 mg per day for adults [20]. This quantity was used as a reference in the parboiled rice fortification. To make 500 g of parboiled rice coating requires Cr solution: 5.6 ml or 112 μg of chromium, 13 ml or 780 mg of magnesium, and 4.5 ml or 900 IU of vitamin D (multi-nutrient solution).

The use of coatings from cellulose derivatives, multi-nutrient coating on parboiled rice was worked out with polymer solution gradually. Each finished coating was dried at a temperature of 40-50 ° C for 5-10 minutes to evaporate the solvent. While multi-nutrient coating with polymer solution (sorbitol 30%) in parboiled rice with gum arabic and rice starch was done in one stage, followed by a drying process.

2.3. Analysis of product and data

The premix rice obtained was analysed for glycemic starch (RS) using a modified Englyst method [21], vitamin D content by HPLC method, the Cr and Mg concentration were measured by the AAS method [22], and glycemic index testing was done using 16 healthy and non-diabetic volunteers. The design of the experiment was a complete randomized design (RAL). The results obtained were analysed with the variance (ANOVA) at 95% confidence level. If the difference was wide - each treatment was continued by Duncan Multiple Range Test. The treatment used was 15 treatments with 2 replications. After an overnight fast (10 hours), every 2 volunteers were asked to consume 1 type of cooked rice sample from the 15 products produced and afterwards, 3 volunteers were asked to consume bread as standard. The number of samples eaten is equivalent to 50 grams of carbohydrates.

3. Results and Discussion

3.1. Resistant starch

The high resistant starch (RS) content of premix rice (not significantly different), in the range of 7.85 - 10.56%, occurred in coating treatments with MC at all concentrations, 0.25% CMC coating, HPMC 0.25 %, and starch coating at concentrations of 3.5% and 5% (Table 1). Meanwhile, coating with gum arabic produced relatively low levels of RS at all concentration levels. MC coating was considered good enough to coat the premix rice when considered for its RS levels, because a low concentration level was able to produce high levels of BP-resistant starch digestibility. Previous research suggests that the resistant starch content of parboiled rice fortified with Cr increased from 9.57% to 11.99% [9]. [23] reported RS levels in Ciherang rice varieties of 1.78%. Resistant starch content of instant rice with heat moisture treatment process ranged from 7.63% to 10.18%, an increase in resistant starch content of 8.86 to 54.65% [24].

The RS that is present in the premix rice is included in type RS 3. The RS 3 is the most commonly found and is a starch fraction generally as amylose retrogradation during the cooling process of starch gelatinization [25]. The additional cooling of the *parboiling* process in this study provided opportunities for starch retrogradation. In general, the higher the level of amylose starch, the higher the content of the reistant starch and slow to digest [9]. The degree of retrogradation depends on the length of time and temperature of storage, starch sources, and other molecules contained in the system. Retrogradation that occurs in amylose is irreversible at temperatures of less than 100 ° C [26], because amylose crystals melt at temperatures above 100 ° C. It was reported by Guraya et al. [25], that a cooling process at a temperature of 1 ° C for 12 hours without agitation against the non-waxy starch solution which had been cut with pullulanase ramifications brought the digestion ratio down 59%. RS has functions such as being a dietary fibre that has a hypoglycemic effect, acting as a pre-biotic, reducing the risk of gallstone formation, having a hypocholesterolemic effect, inhibiting fat accumulation acids, especially butyric acid [27-29].

Table 1. Resistant starch content of premix rice fortified with chromium, magnesium, vitamin D and pandani extract using various types and concentrations of coating materials.

Treatment		Resistant starch (%)
Coating Type	Concentration (%)	
MC	0.15	9.27 ^{d}
MC	0.20	10.56 ^{d}
MC	0.25	7.85 ^{bcd}
CMC	0.15	4.56 ^{a}
CMC	0.20	5.92 ^{abc}
CMC	0.25	9.86 ^{d}
HPMC	0.15	4.74 ^{a}
HPMC	0.20	5.58 ^{ab}
HPMC	0.25	10.51 ^{d}
Rice starch	2.00	3.75 ^{a}
Rice starch	3.50	8.43 ^{cd}
Rice starch	5.00	10,18 ^{d}
Arabic gum	25.00	5.80 ^{abc}
Arabic gum	30.00	5.03 ^{a}
Arabic gum	35.00	4.75 ^{a}

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

3.2. Glycemic index

The glycemic index values were calculated based on the area under the curve of each volunteer's blood sugar response in each of the premix rice treatments shown in Table 2.

Based on data analysis of blood sugar levels in Table 2, it can be seen that the IG value of rice produced premix includes rice with a low IG value, because the range of IG values of premix rice is 31-54. Food with an IG index of less than 55 includes low-IG foods. Previous research reported *parboiled* rice modified with a Cr fortification of 28.13 g per 100 g of $CrCl_3$ and Cr picolinate has GI of 25 and 26 respectively [30].

Low GI value of *parboiled* rice is affected by processing factors. Cooking starch at high temperatures for extended periods of time, and re-cooling, can cause changes in the structure of the dissolved starch granules to form degraded starch. This starch is insoluble and difficult to digest *(resistant starch).* The amount of RS in most crude products is generally very low, but processing and storage can cause an increase [31].

Based on the value of IG, the premix rice with a coating treatment of gum arabic has a low GI, despite having relatively low levels of RS. This can be due to gum arabic being included in the 'soluble dietary fibre' type . The presence of dietary fibre can affect blood glucose levels. In general, high dietary fibre contents contribute to low IG values. Pectin and gum belong to the water soluble fibre type and determine the viscosity of dietary fibre. Therefore, the soluble function of dietary fibre is needed by diabetes mellitus patients because it can reduce the absorption of glucose in the small intestine [32].

Table 2. Glycemic index of premix rice fortified with chromium, magnesium, vitamin D and pandanus extract using various types and concentrations of coating materials.

Treatment		Glycemic Index
Coating Type	Concentration (%)	
MC	0.15	33.39 [a]
MC	0.20	31.22 [a]
MC	0.25	33.43 [a]
CMC	0.15	52.68 [b]
CMC	0.20	33.93 [a]
CMC	0.25	33.34 [a]
HPMC	0.15	54.46 [b]
HPMC	0.20	53.43 [b]
HPMC	0.25	38.50 [a]
Rice starch	2.00	53.44 [b]
Rice starch	3.50	40.17 [a]
Rice starch	5.00	37.29 [a]
Arabic gum	25.00	34,56 [a]
Arabic gum	30.00	36.60 [a]
Arabic gum	35.00	38.29 [a]

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

3.3. Fortificants

3.3.1. Chromium. Fortification is the process of adding vitamins, minerals and amino acids to food products so as to improve the nutritional quality of food intake and provide health benefits with minimal risk. Table 3 shows that premix rice with various types and concentrations of coating materials did not affect the chromium content of the resulting premix rice, which ranged from 0.07 to 0.26 mg / kg. Research conducted by Yulianto et al. [9] reported that the parboiled rice obtained from a paddy soaking process with $CrCl_3$ levels of 7.47 mg / l produced rice with a 36.33 glycemic index and a total Cr content of 0.56 mg / kg. From the results of this study, it can be seen that the fortification of the coating is good enough to embed the source of Cr in parboiled rice.

Chromium is important in the control of blood sugar. The action of chromium is demonstrated by the activation of small peptides and increases to the action of insulin in the binding of insulin receptors, which causes increases in glucose or blood sugar entering the cells [19]. Adequate daily intake of chromium for men is 25-26 µg per person per day, while for women it is 19-30 µg per person per day [33]. Based on this nutritional adequacy rate, the Cr content of premix rice is much more than the adequate amount, so for this premix rice, dilution needs to be performed to meet the needs for daily chromium intake. From the analysis, data can be taken to show chromium content levels of 0.07 - 0.26 mg/1000 kg of rice, or 12.6-46.8 µg/ 180 g of rice (180 g of rice being estimated daily consumption), so the premix rice can be mixed up to 9.36 times to meet the intake requirement level of 5 µg chromium (20% of daily chromium requirement) as a fortified food.

Table 3. Chromium (mg/kg), magnesium (mg/kg) and vitamin D (mg/100 g) grade of premix rice using various types and concentrations of coating materials.

Treatment		Cr (mg/kg)	Mg (mg/kg)	Vitamin D (mg/100 g)
Type of coating	Concentration (%)			
MC	0.15	0.21	1326.32 abc	0.19 a
MC	0.20	0.18	1348.89 abc	0.26 a
MC	0.25	0.21	1436.47 c	0.28 a
CMC	0.15	0.15	1113.94 a	2.04 b
CMC	0.20	0.12	1451.99 c	1.89 b
CMC	0.25	0.17	1322.18 abc	3.63 d
HPMC	0.15	0.14	1373.48 bc	2.01 b
HPMC	0.20	0.14	1275.09 abc	2,48 c
HPMC	0.25	0.10	1304.83 abc	3.58 d
Rice starch	2.00	0.11	1286.67 abc	0.25 a
Rice starch	3.50	0.11	1285.23 abc	0.24 a
Rice starch	5.00	0.09	1168.87 ab	0.27 a
Arabic gum	25.00	0.07	1303.93 abc	0.21 a
Arabic gum	30.00	0.11	1265.25 abc	0.20 a
Arabic gum	35.00	0.26	1214.18 abc	0.25 a

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

3.2.2. Magnesium From Table 3 it can be seen that the use of different concentrations of the same type of coating material did not make any significant difference to the magnesium content of multi-nutrient fortified parboiled rice, except on the type of CMC coatings which showed significant differences at concentration levels of 0.15% and 0.2%. The results of this study showed that fortification coating is good enough to attach a source of magnesium to parboiled rice.

In the fortification of food, fortificant levels (Cr, Mg and vitamin D) are not allowed to surpass the limit of 20% RDA *(recommended daily dietary allowances)* per serving [34]. The intake for the mineral Mg for men = 148 mg / person / day and women 155 mg / person / day [33]. The magnesium content of parboiled rice produced, ranged from 1100-1450 mg/kg. From the analysis, data can be taken to show magnesium levels of 1100-1450 mg / kg of rice or 198-261 mg /180 g of rice, the premix rice can be mixed with ordinary rice at 1.32 to 1.74 times to meet the daily needs of 148-155 mg of magnesium, or 6.6 to 8.7 times to satisfy the requirement of 29.6-31 mg of magnesium as a fortified food.

The importance of sufficient magnesium intake, especially in individuals with diabetes mellitus, can be attributed to its role in the homeostatic maintenance of blood glucose along with the activation of factors involved in insulin sensitivity [19].

3.3.3. Vitamin D Table 3 shows that the use of different concentrations of the same type of coating material did not make any significant difference to the levels of vitamin D of the multi-nutrient fortified parboiled rice, except on the types of CMC and HPMC coatings which showed significant differences. Parboiled rice coating treatment with MC coating materials, starch and arabic gum containing vitamin D, were not significantly different. Vitamin D content in these three types of coatings ranged from 0.19 to 0.28 mg / 100 g or less than 3 mg/100g.

The requisite vitamin D intake, according to the RDA, is 5 mg / day for adults (1 mg of cholecalciferol = 40 IU of the vitamin), while the upper daily intake limit for adults is 50 mg or

200 IU for vitamin D [19]. In Indonesia, the adequacy of vitamin D in children / infants is 5 - 15 mg / person / day, men 15 - 20 mg / person / day, women 15 - 20 mg / person / day [33]. The highest vitamin D levels in premix rice were 3.6 mg / 100 g of rice or 6.48 mg / 180 g of rice (estimated daily rice intake). From these data, it can be seen that fortification coating is not good enough as an embedded source of vitamin D in parboiled rice. This can be due to several reasons, one of which is because vitamin D is insoluble in water, while the coating material used in this research is soluble in water. In addition, vitamin D tends to be sensitive to heat, while the premix - parboiled rice coating process uses heat to a temperature of 50^{o}C.

4. Conclusion

Based on the results of this research, it was concluded that fortified premix rice coated with various concentrations and types of edible coating materials has high resistant starch and low glycemic index. Coating treatment affects the levels of magnesium and vitamin D, but does not affect the levels of chromium in parboiled rice. The premix rice with a low glycemic index and high nutrients (chromium, magnesium and vitamin D) was premix rice coated with CMC 0.25% and HPMC 0.25% producing glycemic indeces of 39.34 and 38.50, and resistant starch contents of 9.86% and 10.51%, respectively.

Acknowledgements

The author would like to thank the Directorate General of Higher Education, Ministry of Education and Culture, Indonesia, which has provided research funding through the National Strategic Research Program.

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