Physicochemical Properties of Some Improved Indonesian Red Rice Flour Varieties

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Abstract. Red rice is known to be rich in antioxidants due to the presence of bioactive compounds, such as phenolics and anthocyanins in the bran layers. Therefore, this study aims to characterise the physicochemical properties of some improved red rice varieties (Aek Sibundong, Inpari 24, Inpara 7, and Inpago 7) and to evaluate the cooking effect (Nagasari, Talam, and Apem cakes processing) on its phenolic content. The varieties were dehulled, with some being partially polished for 0, 30, and 60 secs, respectively. Furthermore, the rice flour was measured for its amylose, protein, fat, ash, water, and total phenolic content (TPC), as well as pasting properties. The results showed that polishing duration reduced the protein, fat, and ash components but increased the amylose content. Also, polishing duration decreased the initial gelatinisation temperature, while the influence on the breakdown and setback viscosities had no obvious patterns. Moreover, the TPC proportionally reduced to the polishing duration. The red rice flour of 30 secs was subsequently used to make Nagasari (boiling & steaming), Talam (steaming), and Apem (baking) cakes. Due to the processing of Nagasaki and Talam cakes, the TPC of 148-211 mg/100g, significantly decreased to approximately one-third, while the preparation of Apem reduced the total phenolic content in Inpago 7, Inpara 7, and Inpari 24, to almost half, except for Aek Sibundong.

1. Introduction
The Indonesian Centre for Rice Research (ICRR) released various varieties of improved types like Inpari (irrigated rice), Hipa (hybrid rice), Inpago (upland rice), and Inpara (swampy rice) into the society. Some improved varieties, such as Aek Sibundong, Inpari 24, Inpara 7, and Inpago 7, were also released by the ICRR. Unlike white or polished, red rice is usually marketed in an unpolished form in order to maintain the pigmentation present in the bran layers. Pigmented rice contains anthocyanins (antioxidants) and higher levels of nutrients such as protein and fibre in the bran layers compared to those being milled [1,2].

Generally, the Indonesian people are accustomed to eating cooked polished rice, which makes them dislike the properties of cooked unpolished grains. Therefore, the consumption of red rice is relatively low compared to that of the polished ones. However, to increase consumption, processing it into flour is a very promising strategy. The flour is an intermediate product with added value and raw material for a wide variety of food commodities, such as traditional wet cakes.

Also, the preparation processes affected both the changes of bioactive compounds and cooked rice's physical properties [3,4]. Thuengtung & Ogawa [5] reported that pigmented rice phenolic antioxidant was decreased after cooking, with the extent of the decline depending on the grain's cultivar and preparation method. This study aims to characterise the physicochemical properties of red rice flour
varieties while also evaluating the effect of cooking (traditional wet cakes processing) on their phenolic content.

2. Materials and Methods

2.1. Materials
The study materials were dried paddy of four improved red rice varieties, namely Aek Sibundong (irrigated rice), Inpari 24 (irrigated rice), Inpara 7 (swampy rice), and Inpago 7 (upland rice). All were obtained from the Sukamandi Research Station of ICRR. Meanwhile, the Ciherang and commercial white rice flour were both used as reference points, with eggs, margarine, sugar, coconut milk, and other cooking ingredients used in the preparation of Nagasari, Talam, and Apem cakes (traditional wet cakes).

2.2. Rice flour preparation
The dried paddy samples were peeled using a husker (Satake THU 35A) in order to produce the unpolished red rice. Some of the unpolished grains were partially polished using a polisher (Satake TM-05) for 0, 30, and 60 secs, respectively. Therefore, the red grains were subsequently grounded, using a laboratory grinder, in order to produce rice flour.

2.3. Implementation of rice flour in traditional cakes
In making traditional wet cakes, the use of red rice flour with the lowest degree of polishing was very much possible. A preliminary study conducted a simple experiment by preparing red rice porridge through the use of 0, 30, and 60 secs (polishing duration) unpolished grain flour, respectively. The porridge from the 0 secs flour was too runny, unlike the usual texture. Also, the porridge from the 30 secs rice flour had a less viscous texture than those of the 60 secs. Even at that, the 30 secs flour still had redder colour intensity than those of the 60 secs rice. Therefore, the wet cake processes used flour from the 30 secs partially polished red rice as raw material.

A trial activity to process the flour into wet cakes (Nagasari, Talam, and Apem) was conducted by considering the physicochemical properties and also the addition of some commonly used ingredients, such as eggs, margarine, and sugar.

2.4. Traditional cakes preparation
The preparation of the Nagasari cake (without banana) from the flour involved boiling and steaming. During this process, 250g flour, one tablespoon of tapioca, 100 g of granulated sugar, 500 ml coconut milk, and salt were used. The coconut milk was divided into two parts, with half of it being mixed with rice flour, tapioca, salt, and sugar, while the other remaining portion was boiled. Also, the dough was mixed with the boiled coconut milk and heated over low flame. Additionally, the dough was stirred until smooth, removed, and wrapped in banana leaves while being steamed till its cooked (about 1 hour).

Furthermore, Talam cake (salted) processing involved steaming, as 200g flour, 2 tablespoons of tapioca, salt, and 700 ml of coconut milk were used. All ingredients were mixed with coconut milk, then steamed until finally cooked.

Also, Apem cake processing involved baking, as 125 g of red rice flour, 125 g of wheat flour, 175 g of sugar, four eggs, 250 ml of thick coconut milk, and 5g of Fermipan (instant yeast) were used. The coconut milk was salted and boiled, then left to cool. The eggs and sugar were made fluffy, as the Fermipan, rice, and wheat flour, with coconut milk, were added. The mixture was stirred until smoothness was achieved and left for about 1 hour. Afterward, the mold was heated, with the mixture being poured sufficiently and baked until finally cooked.

2.5. Chemical analysis
The rice grain was analysed according to the physicochemical properties, which included water (AOAC 2016; 925.10), fat (AOAC 2016; 920.85), ash (AOAC 2016; 923.03), protein (AOAC 2016; 960.52A), and amylose (Rice National Standard) contents [6]. Furthermore, the amylograph properties
were analysed with the aid of a viscometer (Brookfield DV-II + Pro Programmable Viscometer, 2005), while the total phenolic compound (TPC) analysis was performed using a spectrophotometer. Besides, the wet cakes (Nagasari, Talam, and Apem) were analysed the TPC. All these analyses were conducted in three replicates.

2.6. Data analysis
This study was conducted by a factorial randomised plan with the treatment of rice variety. The data were analysed using Analysis of variance (ANOVA), accompanied by Duncan's multiple range test (DMRT), just in case there is a difference. Also, the statistical analysis was performed using XLSTAT 2014.5 software.

3. Result and Discussion

3.1. Proximate composition of red rice flour
Inpago 7 (21.50%) had the highest amylose content among the unpolished red rice, while the Inpari 24 had the lowest (17.36%). As a comparison to the red rice samples, unpolished Ciherang and commercial white bran flour had amylose content of 21.0% and 25.2%, respectively (Table 1).

The rice milling process, especially the polishing duration, greatly affected the amylose content and proximate composition of the red bran. The polishing duration at 0, 30, and 60 secs, tends to reduce the levels of protein, fat, and ash significantly while also increasing the amylose content of milled rice relevantly (Table 1). Furthermore, these results were in line with that of Park et al. [7] research. On all unpolished rice varieties, it was observed that the red colour intensity faded with every effort of polishing. Lamberts et al. [8] stated that yellow and red pigment levels decreased from the surface of the brown rice to the middle endosperm. Milled rice whiteness and lightness linearly increased during milling, while the yellow colour decreased with the polishing degree increment [9].

Rice milling technology improves the acceptance of bran. Generally, Indonesian people consume polished rice 2–3 times daily, triggering the Rice National Standard [6] to require that milled varieties should have 80-100% polishing (or milling) degrees. Nowadays, the demands for unpolished and pigmented rice are increasing. More people are starting to become aware of the beneficial aspects of consuming pigmented types. In fact, unpolished rice is considered good for health because it contains various minerals (Fe, Zn, and more) and vitamins (B, and more), which are essential to the body [10]. Also, the consumption of unpolished rice reduces the risk of type 2 diabetes [11].

Table 1. Effects of polishing duration (0, 30, and 60 seconds) on the proximate composition of red rice (dry basis)

| Rice variety     | Amylose (%) | Protein (%) | Lipid (%) | Ash (%) | Water (%) |
|------------------|-------------|-------------|-----------|---------|-----------|
| **Aek Sibundong**|             |             |           |         |           |
| Unpolished       | 21.36 ± 0.16 ± 0.08 | 9.38 ± 0.16 ± 0.08 | 2.26 ± 0.03 ± 0.00 | 1.00 ± 0.01 ± 0.00 | 9.75 ± 0.15 ± 0.00 |
| 30s polished     | 22.25 ± 0.10 ± 0.05 | 9.07 ± 0.14 ± 0.03 | 1.71 ± 0.03 ± 0.06 | 1.05 ± 0.04 ± 0.04 | 10.31 ± 0.11 ± 0.03 |
| 60s polished     | 23.11 ± 0.09 ± 0.02 | 8.87 ± 0.17 ± 0.00 | 1.37 ± 0.03 ± 0.00 | 0.76 ± 0.05 ± 0.00 | 10.15 ± 0.25 ± 0.06 |
| **Inpari 24**    |             |             |           |         |           |
| Unpolished       | 17.36 ± 0.16 ± 0.07 | 9.74 ± 0.13 ± 0.00 | 2.77 ± 0.07 ± 0.00 | 1.34 ± 0.04 ± 0.00 | 11.18 ± 0.10 ± 0.05 |
| 30s polished     | 18.77 ± 0.10 ± 0.00 | 9.36 ± 0.22 ± 0.00 | 2.01 ± 0.03 ± 0.00 | 0.95 ± 0.02 ± 0.00 | 11.07 ± 0.28 ± 0.00 |
| 60s polished     | 19.71 ± 0.10 ± 0.00 | 9.31 ± 0.08 ± 0.00 | 1.41 ± 0.09 ± 0.00 | 0.62 ± 0.01 ± 0.00 | 11.49 ± 0.05 ± 0.05 |
| **Inpara 7**     |             |             |           |         |           |
| Unpolished       | 20.95 ± 0.14 ± 0.00 | 11.27 ± 0.15 ± 0.00 | 2.14 ± 0.09 ± 0.00 | 1.17 ± 0.01 ± 0.00 | 9.68 ± 0.08 ± 0.00 |
3.2. Pasting properties of red rice flour
The polishing duration seemed to decrease the initial gelatinisation temperature, while the effect on viscosity, when the starch granules rupture, had no obvious patterns (Table 2). The viscosity value when the granules break down differs from each degree of milling (0, 30, and 60s polishing duration) while also indicating the different constituent materials' composition. Park et al. [7] stated that, although not significant, the initial temperature of gelatinisation decreased with increasing polishing degrees while the viscosity of ruptured starch increases. Furthermore, Hasjim et al. [12] stated that starch gelatinisation and paste properties were determined and related to differences in the level of carbohydrate structure in rice flour, such as particle size, sugar granule level, and molecular branching construction.

3.3. Total phenolic content of red rice flour
The polishing duration reduced the total phenolic content (TPC) in all red rice grains (Table 2). In addition, the Ciherang and the commercial bran flour contained total phenolics, even though the value was relatively lower compared to the powdered red grains. Furthermore, the TPC includes all compounds possessing phenol groups, such as phenolic acids, flavonoids, anthocyanins, and proanthocyanidins [1].

Antioxidants in rice are classified into six groups: phenolic acids, anthocyanins & proanthocyanins, tocopherols, and tocotrienols (vitamin E) γ-oryzanol, and phytic acids [1]. Goffman and Bergman [13] stated that among rice varieties with different colours (brown, purple, and red), the highest concentrations of phenolic content were discovered in the bran of red and purple.

3.4. Total phenolic content of traditional cakes prepared from red rice flour
The traditional wet cakes made were Nagasari, ApeM, and Talam cakes. The cooking was intended to explore phenolic compounds' resistance in red rice flour samples during boiling, steaming, or baking. The cooking of Nagasari and Talam cakes involved boiling or steaming process, while ApeM was being baked. Moreover, these three types of cakes are examples of products derived from red rice flour.

The TPC value of red rice flour, 148-211 mg/100g, significantly decreased to a quarter or less due to the Nagasari (33-55 mg/100g) or Talam preparation (30-45 mg/100mg) (Table 3). Except for Aek Sibundong, the process of cooking ApeM cake, which involved baking (high temperature in a short time), decreased the TPC in Inpago 7, Inpara 7, and Inpari 24 to 85, 73, and 52 mg/100g, respectively. Furthermore, Rewthong et al. [3] stated that cooking processes affected the changes of bioactive compounds and physical properties of cooked rice. Also, Thuengtung & Ogawa [5] reported that pigmented rice phenolic antioxidant was decreased after cooking, with the extent of the decline depends on the bran cultivar and processing method.
### Table 2. Effects of polishing time on the pasting properties and total phenolic content (TPC) of red rice samples

| Rice variety | Initial gelatinisation | Granular starch breakdown | Viscosity | TPC |
|--------------|------------------------|---------------------------|-----------|-----|
|              | Time (min)             | Temp. (°C)                | Time (min)| Temp. (°C)| Visc (cP) | 50°C (cP) | Setback (cP) | (mg/100g) |
|              |                        |                           |           |           |           |           |              |          |
| Ack Sibundong| Unpolished             | 16.3 ± 0.6<sup>a</sup>   | 85.5 ± 2.1<sup>cd</sup>  | 19.3 ± 0.6<sup>ef</sup> | 93.5 ± 0.2<sup>cd</sup> | 1145.0 ± 155.2<sup>ef</sup> | 1653.3 ± 162.5<sup>f</sup> | 508.3 ± 10.4<sup>f</sup> | 485.42 ± 60.59<sup>a</sup> |
|              | 30s polished            | 18.3 ± 0.6<sup>cd</sup>   | 89.5 ± 0.8<sup>b</sup>   | 20.3 ± 0.6<sup>ef</sup> | 93.6 ± 0.2<sup>bc</sup> | 1096.7 ± 295.1<sup>f</sup> | 1826.7 ± 288.8<sup>f</sup> | 730.0 ± 22.9<sup>b</sup> | 233.17 ± 30.23<sup>cd</sup> |
|              | 60s polished            | 16.7 ± 1.5<sup>gf</sup>   | 84.2 ± 3.3<sup>cd</sup>  | 20.7 ± 0.6<sup>ef</sup> | 93.7 ± 0.2<sup>bc</sup> | 1766.7 ± 155.9<sup>g</sup> | 2478.3 ± 302.3<sup>g</sup> | 711.7 ± 249.7<sup>g</sup> | 151.44 ± 7.80<sup>ef</sup> |
| Inpari 24    | Unpolished             | 18.7 ± 0.6<sup>bc</sup>   | 89.0 ± 0.4<sup>b</sup>   | 21.7 ± 0.6<sup>bcde</sup> | 93.7 ± 0.1<sup>bc</sup> | 228.05 ± 325.0<sup>cd</sup> | 3528.3 ± 287.6<sup>cd</sup> | 1243.3 ± 38.2<sup>ef</sup> | 518.91 ± 7.71<sup>a</sup> |
|              | 30s polished            | 17.7 ± 0.6<sup>bcd</sup>  | 83.7 ± 2.4<sup>b</sup>   | 22.3 ± 0.6<sup>bc</sup> | 93.6 ± 0.1<sup>bc</sup> | 3391.7 ± 330.0<sup>b</sup> | 4525.0 ± 409.2<sup>b</sup> | 1133.3 ± 101.3<sup>cd</sup> | 214.14 ± 61.11<sup>cd</sup> |
|              | 60s polished            | 18.0 ± 0.0<sup>c</sup>    | 85.1 ± 3.2<sup>cd</sup>  | 22.0 ± 1.0<sup>bcd</sup> | 93.6 ± 0.3<sup>bc</sup> | 3201.7 ± 527.8<sup>ab</sup> | 4403.3 ± 270.0<sup>ab</sup> | 1201.7 ± 321.0<sup>ef</sup> | 109.70 ± 5.76<sup>b</sup> |
| Inpara 7     | Unpolished             | 19.3 ± 1.2<sup>bc</sup>   | 90.1 ± 1.3<sup>b</sup>   | 2.02 ± 1.0<sup>bc</sup> | 93.8 ± 0.1<sup>bc</sup> | 1880.0 ± 148.1<sup>cd</sup> | 4235 ± 376.1<sup>b</sup> | 2355.0 ± 246.9<sup>cd</sup> | 404.54 ± 13.4<sup>b</sup> |
|              | 30s polished            | 20.3 ± 0.6<sup>b</sup>    | 90.0 ± 2.0<sup>b</sup>   | 22.7 ± 0.6<sup>b</sup> | 93.6 ± 0.3<sup>bc</sup> | 1780.0 ± 411.2<sup>cd</sup> | 3426.7 ± 478.3<sup>d</sup> | 1646.7 ± 126.6<sup>d</sup> | 221.58 ± 31.15<sup>d</sup> |
|              | 60s polished            | 19.0 ± 1.0<sup>abcd</sup> | 85.6 ± 2.3<sup>cd</sup>  | 23.3 ± 0.6<sup>a</sup> | 93.7 ± 0.1<sup>bc</sup> | 2543.3 ± 366.7<sup>b</sup> | 4330 ± 603.2<sup>a</sup> | 1786.7 ± 430.2<sup>d</sup> | 167.14 ± 1.49<sup>abcd</sup> |
| Inpago 7     | Unpolished             | 17.0 ± 1.0<sup>bc</sup>   | 84.7 ± 2.5<sup>cd</sup>  | 20.3 ± 0.6<sup>ef</sup> | 93.2 ± 0.3<sup>a</sup> | 2270.0 ± 437.0<sup>bc</sup> | 4111.7 ± 540.5<sup>b</sup> | 1841.7 ± 281.1<sup>bc</sup> | 531.54 ± 72.59<sup>a</sup> |
|              | 30s polished            | 18.7 ± 0.6<sup>bcd</sup>  | 87.8 ± 1.2<sup>bc</sup>  | 21 ± 0.0<sup>abc</sup> | 93.0 ± 0.2<sup>bc</sup> | 1631.7 ± 356.4<sup>b</sup> | 3180.0 ± 473.9<sup>d</sup> | 1548.3 ± 138.8<sup>bc</sup> | 210.10 ± 16.15<sup>bc</sup> |
|              | 60s polished            | 16.3 ± 0.6<sup>ef</sup>   | 80.5 ± 1.3<sup>c</sup>   | 21 ± 0.0<sup>abc</sup> | 93.1 ± 0.2<sup>b</sup> | 2525.0 ± 175.0<sup>g</sup> | 3788.3 ± 215.1<sup>b</sup> | 1263.3 ± 176.1<sup>ef</sup> | 168.86 ± 12.07<sup>bc</sup> |
| Ciberang     | Unpolished             | 20.0 ± 1.0<sup>bc</sup>   | 91.3 ± 1.9<sup>b</sup>   | 23 ± 1.7<sup>bc</sup> | 94.0 ± 0.2<sup>a</sup> | 1910.0 ± 249.1<sup>bc</sup> | 4373 ± 395.0<sup>b</sup> | 2463.3 ± 289.4<sup>b</sup> | 170.04 ± 5.24<sup>bc</sup> |
|              | 30s polished            | 19.3 ± 0.6<sup>bc</sup>   | 91.6 ± 1.2<sup>a</sup>   | 22 ± 1.0<sup>bcd</sup> | 93.9 ± 0.2<sup>bc</sup> | 2026.7 ± 150.9<sup>b</sup> | 4703 ± 295.7<sup>d</sup> | 2676.7 ± 290.1<sup>bc</sup> | 115.88 ± 8.45<sup>d</sup> |
|              | 60s polished            | 20.0 ± 0.0<sup>b</sup>    | 91.6 ± 0.5<sup>a</sup>   | 22.3 ± 0.6<sup>bc</sup> | 93.8 ± 0.2<sup>bc</sup> | 1731.7 ± 308.6<sup>cd</sup> | 4621 ± 192.8<sup>cd</sup> | 2890.0 ± 116.9<sup>bc</sup> | 93.25 ± 11.39<sup>bc</sup> |
| Commercial  white rice flour | Unpolished          | 17.7 ± 0.6<sup>b</sup>    | 92.3 ± 1.1<sup>a</sup>   | 0<sup>d</sup> | 0<sup>d</sup> | 0<sup>d</sup> | 3203 ± 86.1<sup>a</sup> | 3203 ± 86.1<sup>a</sup> | 40.08 ± 12.6<sup>b</sup> |

- The values with different superscript letters indicate significant differences (p < 0.05).
Table 3. Total phenolic content (mg/100g, dry basis) of 10s polished red rice and their traditional wet cakes (Nagasari, Apem, and Talam)

| Rice variety | Red rice flour | Nagasari | Apem | Talam |
|--------------|----------------|----------|------|-------|
| Aek Sibundong| 233.17 ± 30.23 a | 80.8 ± 6.5 cd | 209.2 ± 11.8 a | 88.5 ± 8.1 bcd |
| Inpari 24    | 214.14 ± 61.11 a | 80.1 ± 1.3 cd | 87.4 ± 6.9 bcd | 88.5 ± 6.1 bcd |
| Inpara 7     | 221.58 ± 31.15 a | 56.0 ± 12.8 d | 123.0 ± 9.1 bc | 82.5 ± 2.6 bcd |
| Inpago 7     | 210.10 ± 16.15 a | 84.3 ± 2.6 bcd | 143.4 ± 6.0 b | 58.6 ± 9.5 d |

4. Conclusions
The polishing duration (0s, 30s, and 60s) reduced the protein, fat, ash, and total phenolic content (TPC) of all red rice and increased all unpolished varieties' amylose content. Moreover, the processing of Apem cake retained more TPC, compared to that of Nagasari or Talam.

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