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Sensory Properties and Antioxidant Activity of Steamed Rice with Various of Black and White Rice Ratio

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Abstract

Black rice (BR) has higher content of fiber than white rice (WR). Furthermore, black rice contain anthocyanin which has numerous beneficial for health, including anti hyperglycemic effect and protection from cardiovascular disease. Unfortunately, it has firmer texture and distinguished flavor, which makes it not as preferable as WR. Adding white rice increased the acceptance of steamed black rice. The percentages of white rice which added in this study were 0% (S100); 25% (S75); 50% (S50); 75% (S25); and 100% (S0). Scoring preference test was used for sensory analysis, followed by proximate analysis for fiber and water content, total starch using Nelson-Somogyi method, total anthocyanin using pH differential method, total phenolic using Folin-Ciocalteu method, and antioxidant activity using 2,2-diphenyl-1-picrylhydrazyl (DPPH). S50 had the highest sensory preference while S25 was the lowest due to its pale color. S50 had higher fiber, anthocyanin, and phenolic content and higher antioxidant activity than S0, while it had higher total starch, water content, and tenderness than S100. Cooking process had reduced antioxidant activity on steamed BR, while the adding of WR had reduced it more. Based on the results, S50 was the best possible mix because it had the highest preference index and still had anthocyanin and phenolic content and antioxidant activity.

Keywords: Black rice; sensory preference; anthocyanin; phenolic; antioxidant.

Introduction

Rice (Oryza sativa) is consumed as staple for nearly half of the world’s population, especially in Asia. Even before the 1960s, Indonesia has become the largest rice consuming country per capita, followed by China and India (Mohanty, 2013). While Asia is provenas rice’s center of species origin, Indonesia is believed to become the secondary of species origin for it has a great diversity of rice genetics (Sitaresmi et al., 2013).

Two main subspecies of rice are japonica and indica, while Chang (1984) separated the third subspecies i.e. javanica or tropical japonica. Morphologically, it is closer to indica, thus some rice workers tend to classify it as its variant. But genetically, it is closer to japonica (Chakraborty, 2001; Chang, 1984; Haryanti et al., 2013). While Garris et al. (2005) further divided indica as indica and aus, and japonica as aromatic, temperate japonica, and tropical japonica; by genetic evidence they suggested that temperate japonica was derived from tropical japonica.

Historically, the evidence of rice cultivation in Bali and Java was only recorded from the ninth century AD which stated that rice had become a major subsistence crop at the time (Christie, 2007). Some rice cultivars which are widely known today, such as Mentik Wangi, was already recorded on Javanese literature from the 19th century, i.e. Serat Centhini (Ranggasutrasna et al., 2008). White rice is the cultivar
which is commonly consumed, while brown rice is usually consumed for health reasons. Black rice is unknown by most Javanese population up to the last decade, but still is often mistaken as black glutinous (waxy or sticky) rice. Black rice cultivar is mainly cultivated in Asia especially China, followed by Sri Lanka, Indonesia, India, etc. Some internationally well-known cultivars of black rice are Forbidden rice, Chinese black rice, and Indonesian black rice (Ujjawal, 2016) such as Cempo Ireng from Yogyakarta, Melik, Cibeusi, Toraja, and Jlihteng (Kristamtini, 2009; Pramitasari, 2012).

The dark purple color of black rice is derived from anthocyanin pigments (Indradewa, 2012). It contains high level of nutrients such as protein, minerals, and dietary fiber which are higher than brown and white rice (Ujjawal, 2016). Since ancient time, black rice has been believed as healthy food (Guo et al., 2007) and now is considered as functional food for its anthocyanin component (Indrasari et al., 2008). The anthocyanin of black rice is proven to have antihyperglycemic effect, increase insulin sensitivity, alleviate pancreatic and hepatic inflammation (Krisbianto et al., 2016; Pramitasari, 2014), and has higher antioxidant activity than α-tocopherol (Swasti, 2007).

Unlike white rice, black rice is not considered as a common staple for Indonesian population (Indradewa, 2012). Taste, aroma, texture, and health aspects, among others, are taken into consideration in selecting varieties of rice for consumption (Indrasari et al., 2008). Black rice has a harder texture than white rice (Pramitasari, 2012). Although it has stronger fragrant aroma than white rice (Kristamtini, 2009; Ujjawal, 2016), its aroma is resembles but milder than black glutinous rice and different from those of white rice. It may lead Indonesian people, especially in Java and Bali, to think that black rice is better to eat as snack just like black glutinous rice because its aroma is not suitable to go with most of Indonesian side dishes. The modification of steamed black rice as staple food is necessary to deal with its less desirable organoleptic properties.

This study was stressed on the organoleptic and nutritive changing on steamed black rice which was mixed with different ratio of white rice. It was expected that the mixing of black rice with white rice would increase panelists’ preference. On the other hand, it would reduce its nutritive value, as well as the capacity of black rice as functional food. All the rice varieties were from widely known local cultivars, i.e. Cempo Ireng for black rice and Mentik Wangi for white rice.

Materials and Methods

Materials

Polished white rice cultivar Mentik Wangi was purchased from farmland at Salam, Magelang, while black rice cultivar Cempo Ireng was from Lumpang Community, Yogyakarta. Ethanol 96%, citric acid, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich (St. Louis, MO, USA). L-(+)-ascorbic acid (vitamin C) was purchased from J.T. Baker (Selangor, Malaysia). Other chemicals were from Merck Millipore and kindly provided by Food Chemical and Biochemical Laboratory, Faculty of Agriculture Technology, Gadjah Mada University (UGM).
Sample preparation

Black rice and white rice were mixed with the concentration of black rice: 0% (S0), 25% (S25), 50% (S50), 75% (S75), and 100% (S100) w/w. Mixed rices were cooked in rice cooker (National SR-WO6N) with the addition of water at a ratio of 1:3 w/v for 30 minutes. Mixed steamed rice samples were used for sensory evaluation, crude fiber, water content, and total starch analyses.

For other analyses, mixed steamed rice samples were dried in cabinet dryer with a temperature of 50°C for 16 hours. Dried mixed rices, black rice grain (R100), and white rice grain (R0) were grounded by using dry grinder (BL-301 GS G/Y) to be less than 60 meshes. A total of 25 grams of each powder were macerated in 250 ml ethanol-citric 3% for 1 hour. It was then filtered with filter paper to separate its extract from the cake. The extracts were used as samples for total anthocyanin, total phenolic content, and antioxidant activity using DPPH analyses.

Sensory evaluation

A focus group consist of eight semi-trained panelists were asked to perform organoleptic test with a hedonic scale of 1 to 5. Each member did a closed assessment and followed by an open discussion (Meilgaard et al., 2000; Wong, 2008). Descriptive test was used for hardness assessment of the samples, while scoring preference test was for overall preference of the samples, i.e.: color, texture, and flavor.

Water content, crude fiber, and total starch

Water content of mixed steamed rice samples was analyzed by thermogravimetric method which was described on AOAC Official Method 934.01. Ceramic fiber filter method for crude fiber analysis was based on AOAC Official Method 962.09 by using 1.25% H₂SO₄ and 1.25% NaOH solution to digest the dried samples.

Nelson-Somogyi method was used to determine the total starch of mixed steamed rice samples (Nelson, 1944). Before the analysis, the starch component of the samples was hydrolyzed with HCl 30% and then neutralized with NaOH 40% (Poedjiadi, 1994).

Total anthocyanin, total phenolic content, and DPPH analyses

Total anthocyanin was determined by pH-differential method (Giusti and Wrolstad, 2001). Each 0.9 ml potassium chloride 0.025 M (pH 1) and sodium acetate 0.4 M (pH 4.5) buffers were mixed with 0.1 ml sample extract respectively. After 15 min incubation, absorbance was measured at 530 nm and 700 nm using spectrophotometer (Spectronic 200). Molecular weight (Mw = 449.2 g/mol) and molar absorptivity (ε = 26900 L/mol.cm) were regarded as cyanidin-3-glycoside.

The method for total phenolic content was based on Shui and Leong (2006) with gallic acid (0-1.0 mg/ml) as standard and the absorbance was measured at 765 nm. The data was served as mg Gallic Acid Equivalent (GAE)/g. Antioxidant activity by DPPH method was based on Krisbianto et al. (2016) with vitamin C (0-40 mg/L) was used as standard and the absorbance was measured at 515 nm. The data was served as mg Ascorbic acid Equivalent Antioxidant Capacity (AEAC)/g.
Statistical analysis

Completely Randomized Design was used for chemical analysis and organoleptic testing. The data were subjected to statistical analysis using one-way analysis of variance (ANOVA) followed by Duncan’s Multiple Range Test (DMRT) with SPSS 16.0 (SPSS, Inc., Chicago, IL, USA) at the 95% confidence level.

Result and discussion

Steamed rice specification

Water content, crude fiber, and total starch of mixed steamed rices are shown in Table 1. S0 (100% of white rice) had the highest water content and total starch while S100 (100% black rice) was the lowest. Higher white rice ratio lead to higher water content and total starch of mixed steamed rices. The water content and total starch of S25 (75% white rice) was not significantly different with S0, while S50 and S75 were not significantly different to S100. This result was similar to Ayabe et al. (2014) who compared the physicochemical properties of nonsticky (japonica) Okunomurasaki black rice and polished Koshihikari white rice upon cooking. On the other hand, although the fiber contents were reduced along with the higher ratio of white rice, the results were not significantly different between the samples.

Table 1. Steamed rice specification

<table>
<thead>
<tr>
<th></th>
<th>Water content (%wb), mean (SD)</th>
<th>Crude fiber (%db), mean (SD)</th>
<th>Total starch (%db), mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S0</td>
<td>63.68 (1.84)</td>
<td>0.15 (0.11)</td>
<td>43.16 (0.44)</td>
</tr>
<tr>
<td>S25</td>
<td>61.72 (0.47)</td>
<td>0.17 (0.19)</td>
<td>35.80 (0.21)</td>
</tr>
<tr>
<td>S50</td>
<td>52.45 (0.13)</td>
<td>0.19 (0.00)</td>
<td>32.29 (6.69)</td>
</tr>
<tr>
<td>S75</td>
<td>52.34 (0.46)</td>
<td>0.21 (0.25)</td>
<td>28.71 (1.17)</td>
</tr>
<tr>
<td>S100</td>
<td>52.08 (1.03)</td>
<td>0.22 (0.14)</td>
<td>28.40 (5.15)</td>
</tr>
</tbody>
</table>

Description: different superscript on the same column show a significant different (p >0.05). SD = standard deviation; wb = wet basis; db = dry basis.

Mizuma (2014) proposed that polishing process would increase the starch content of polished rice by remove the outer layers which were high in protein and fat compared to the endosperm. While Haryadi (2006) stated that fat and protein inhibit water absorption of rice during cooking, Mizuma (2014) explained that starch absorbed more water than protein but fat inhibit water absorption.

Functional properties

Anthocyanin has a strong antioxidant activity, thus makes black rice as a functional food. Table 2 shows anthocyanin (TA) and phenolic contents (TPC) of mixed steamed black rices, black rice grain (R100), and white rice grain (R0), along with the antioxidant activity. The results show that both cooking process and the addition of white rice had significantly reduced TA, TPC, and antioxidant activity of the samples. The cooking process of black rice had reduced its TA around 68.55%, similar to Hiemori et al. (2009) that found the cooking process of black reduced its TA around 65-80%. The addition of white rice by 25% (S75), 50% (S50), and 75% (25%) lowered the TA by 7.69%, 20.50%, and 74.34% respectively. On the other hand, Kurilich et al. (2005) stated that cooking process might increase the bioavailability of anthocyanin because the destruction of cell walls had made anthocyanin more accessible by our digestive system.
Some researchers found that anthocyanin had a very low bioavailability and most of the anthocyanin that we consume would be excreted via urine and feces (Aguilar, dkk, 2013; Kurilich, dkk, 2005). However, it still showed a high systemic activity and gave an oxidative protection to the mucosa of our digestive system (Stintzing dan Carle, 2004).

### Table 2. Functional properties of rice

<table>
<thead>
<tr>
<th>Description</th>
<th>Total anthocyanin (mg/g), mean (SD)</th>
<th>Total phenolic content (mgGAE/g), mean (SD)</th>
<th>DPPH (mgAEAC/g), mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0</td>
<td>-</td>
<td>0.19 (0.11)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.44 (0.17)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>R100</td>
<td>69.02 (0.96)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.58 (0.23)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.41 (0.04)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>S0</td>
<td>-</td>
<td>0.01 (0.06)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.34 (0.11)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>S25</td>
<td>5.57 (0.96)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.16 (0.02)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.53 (0.14)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>S50</td>
<td>17.26 (0.96)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.38 (0.00)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.58 (0.10)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>S75</td>
<td>20.04 (0.00)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.67 (0.02)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.63 (0.01)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>S100</td>
<td>21.71 (1.67)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.22 (0.13)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.97 (0.11)&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Description: different superscript on the same column show a significant different (p>0.05). SD = standard deviation; GAE = gallic acid equivalent; AEAC = ascorbic acid equivalent antioxidant capacity.

Based on the data of this research, for adults about 60 kg who eat 100 gram of mixed rices three times a day, we can estimate the anthocyanin intake for S100, S75, S50, and S25 are 109 ppm, 100 ppm, 86 ppm, and 28 ppm respectively. These calculations are higher than Krisbianto et al. (2016) who used 40 ppm and 80 ppm anthocyanin on rats. The results showed that 40 ppm and 80 ppm of anthocyanin had antihyperglycemic effect, increased insulin sensitivity, and alleviate pancreatic and hepatic inflammation on hyperglycemic rats. But a further research on human needs to be conducted to prove the functional properties of mixed steamed rices.

The antioxidant activity was also found on S0 and R0. These results might be due to the phenolic component of white rice cultivar Mentik Wangi. Pearson correlation test (data not shown) showed that TA and TPC had very strong and positive correlation to DPPH scavenging activity of mixed black rice extracts.

**Sensory evaluation**

Singh et al. (2013) found a significant linear correlation between the hardness of date fruits with water content and crude fiber. Figure 1 shows the hardness of mixed steamed rices on the scale of 1 to 5. Compared to Table 1, the hardness level of mixed steamed rices is positive correlated to the water content, while crude fiber content might not have much distribution.

![Figure 1. Hardness of mixed steamed rices on the scale of 1 (very tender) to 5 (very hard).](image)
The hardness of steamed rice is highly affected with its amylose-amylopectin contents. High amylose rices (25-33%) are dry and hard upon cooling, low amylose rices (2-9%) are moist and sticky, and waxy rices contain about 1-2% of amylose (Mutters and Thompson, 2009). Kristamtini et al. (2011) found that Mentik Wangi contained about 15-16% amylose and 35-42% amyllopectin so that this cultivar belong to the low amylose rices (10-20%). Amylose has a high rate of retrogradation thus the steamed rices with high content of amylose will have a hard texture. On the other hand, amyllopectin is better to holding water content which result in a tender texture of steamed rice (Pramitasari, 2012).

Juliano and Perez (1983) found that the hardness of steamed rice was positive correlated with its amylose content. By the rice cooker method, the same water: rice ratio for cooking led to a higher degree of hardness to high amylose rices and lower degree of hardness to low amylose rices.

Figure 2 shows the preference index of mixed steamed rices, comprised the texture, color, and flavor, on the scale of 1 to 5. The mean (SD) preference index of S0 was 3.38 (1.31) and was not significantly different to S75 and S100. Although the three of it were in neutral-like category, after the discussion it appeared only S0 was considered as neutral by the panelists because it had a tender texture and a delicate, pandan-like aroma. White rice cultivar Mentik Wangi is a local cultivar from Yogyakarta and for centuries has been known for its fragrance aroma (Kristamtini et al., 2011; Ranggasutrasna et al., 2008). The fragrant aroma of aromatic rice like Mentik Wangi is derived from active component 2-acetyl-1-pyrroline (Indrasari et al., 2008).

On the other hand, black rice cultivar Cempo Ireng was considered to have a soft, caramel-like aroma. After a further discussion, it appeared that S75 and S100 were considered to have similar properties, i.e. the hardest texture just like half-cooked white rice, unappealing darkest color (Figure 3), and detected bitterness. Bett-Garber et al. (2012) identified the taste of black rice as oily, meaty, medicinal, sweet aromatic, smoky, astringency, and bitterness. The bitterness and astringency were caused by the high phenolic content of pigmented rice grains. Table 2 shows that black rice had a higher concentration of phenolic components than white rice.

![Figure 2](image_url)  
**Figure 2.** Preference index of mixed steamed rices on the scale of 1 (very dislike) to 5 (very like).
Figure 3. Colors of mixed steamed rices.

S25 had the lowest preference index, i.e. 2.38 (0.74), mostly because of its uniformity and faded purple color with dark spots (Fig. 3). The concentration of black rice that was only 25% unable to dye the rest of white steamed rice and the texture was also harder than the white part, led to an unpleasant gritty texture of mixed steamed rice.

The highest preference index, i.e. 3.75 (1.04), was S50. It had a uniform dark purple color and texture, while the aroma of black rice was not very dominant.

Conclusion
The most preferred ratio of black rice: white rice was 1:1 (S50). The addition of 50% white rice cultivar Mentik Wangi enabled to alleviate the less desirable organoleptic properties of black rice cultivar Cempo Ireng comprised the texture, color, and flavor. On this ratio, the mixed steamed rice still had antioxidant activity.

References
