Varietal Effect on Engineering Properties and Proximate Composition of Organic Rice in Eastern Java Indonesia

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Abstract. Engineering properties and proximate composition of milled rice was determined for different organic rice varieties, i.e. Ciherang (CH), IR-64 (IR), Sintanur (ST), Pandanwangi (PW), Merah Bali (MB), Coklat Berlian (CB), Merah A2 (MA) and Hitam Melik (HM). The engineering properties parameters included the length (L), width (W), L/W ratio, 1000 kernels weight, bulk density (ρb), angle of repose (φ), thermal conductivity (k), volumetric specific heat (Cp), thermal diffusivity (α), and colour attributes (L*, a*, b*). The proximate compositions of rice were evaluated in terms of the protein, carbohydrate, fat, ash, moisture, and amylose contents. The results showed that organic rice kernels from eastern Java ranged from "medium" to "long" according to their L values and seemed to have slender to medium shape based on their L/W ratio. The weight of 1000 rice kernels were about 18.00-23.29 g depending on the variety, in which the varieties of IR and MA indicated the lowest and highest values, respectively. The ρb values of rice varied from 0.77 to 0.88 g/cm³, while the φ values were about 21.1-26.3°. The highest k, Cp, and α values were revealed by varieties of PW (0.115 W/m.K), MB (2.236 MJ/m³.K), and CB (0.099 mm²/s), respectively. It was found that non-white color organic rice varieties, including MB, CB, MA, and HM, showed higher protein and fat contents than white color rice samples such as CH, IR, ST, and PW. The present organic rice samples were categorized as "low" to "intermediate" amylose content with a variety of values from 16.6 to 21.8%.

Keywords: Engineering properties, Composition, Organic rice, Variety

1. Introduction

Improved consumer's awareness of healthy food in Indonesia increases the consumption and popularity of organic rice, making it the most consumed organic food after organic vegetables [1]. Such condition has encouraged the development of organic rice farming in eastern Java region, i.e. districts of Banyuwangi, Bondowoso, and Situbondo recently, resulting in mounted production of organic rice that leading to growing economic welfare for stakeholders. In line with this progressive development, the hard work of some farmers groups in Bondowoso has been appreciated by the Control Union Certification (EU) with the international organic certificates. This certificate is an institutional statement on the authenticity of rice cultivation organically in such a region, but not indicating the quality of organic rice products that vary, possibly due to differences in variety, planting system, and post-harvest handling and processing methods. Relevant studies on the effect of variations in rice variety and planting systems (organic or inorganic) on the quality of rice products have been reported previously by several authors [2,3]. However, there are no publications found informing the
quality attributes of milled organic rice from the eastern Java area. Therefore, the present study aimed to identify the quality of selected organic rice varieties grown in the East Java area in terms of their engineering properties and proximate composition. Comprehensive data of these organic rice quality is essential for designing and manufacturing the particular types of equipment used in rice processing and cooking operations. Moreover, these data may enrich the database of organic rice quality in Indonesia and are used for labeling organic rice products as well.

2. Methods
Eight different varieties of organic milled rice were used as material in this study, including Ciheraong (CH), IR64 (IR), Sintanur (ST), Pandanwangi (PW), Merah Bali (MB), Coklat Berlian (CB), Merah A2 (MA) and Hitam Melik (HM). The rice indicating white colour kernels such as CH, IR, ST and PW, were grouped as white rice, while the others (MB, CB, MA and HM), classified as non-white rice. These samples were purchased initially from various organic rice producers in the districts of Banyuwangi, Bondowoso and Situbondo, brought to the laboratory, then transferred into plastic bags and then stored at room temperature prior to analysis of its engineering properties and proximate composition.

2.1 Measurement of engineering properties
The engineering properties of organic rice was measured in terms of physical, thermal, and color properties. Physical properties of rice were represented by the length (L), width (W), L/W ratio, the weight of 1000 kernels, bulk density (ρb), and angle of repose (φ). Both L and W values of 50 rice kernels from each variety, were measured using a digital Vernier caliper. Based on kernel length (L) values [4], organic milled rice were grouped as "extra-long" (>7.50 mm), "long" (6.61-7.50 mm), "medium" (5.51-6.60 mm), or "short" (<5.50 mm), whereas their shape were classified using L/W ratio values [5], i.e. "slender" (>3.0), "medium" (2.1-3.0), "bold" (1.1-2.0) and "round" (1.0 or less). The weight of 1000 rice kernels were determined using a Sartorius balance (model MSE2202S), by knowing the initial weight of 50 rice kernels and then weighed separately to determine 1000 kernels weight. The bulk density (ρb) of organic rice was determined using a modified method [6]. The angle of repose (φ) was determined by pouring rice samples into a standing funnel until the peak of the cone located precisely just below the outlet. When the height (H) and base diameter (D) of rice cone could be obtained, the value of φ was calculated using Equation 1.

\[ \phi = \tan^{-1}\left(\frac{2H}{D}\right) \]  

Thermal properties of organic rice, including volumetric specific heat (Cp), thermal conductivity (k), and thermal diffusivity (α) were determined using a thermal properties analyzer (KD2-Pro, Decagon). The measurement was carried out by inserting two types of needle sensors, such as TR-1 and SH-1, into a sealed plastic bag containing organic rice samples. The TR-1 was used to measure k value, while SH-1 was applied for determining the Cp and α values of organic rice. The results of thermal properties measurement were displayed on the apparatus when reading was completed [7].

Colour attributes of organic rice were expressed in terms of L*, a*, and b* values and were measured using a tristimulus colorimeter (Konica Minolta CR-10). The L* indicates lightness value ranging between 0 (black) and 100 (white). The a* value varies from green (-a*) and red (+a*), while the b* value ranges from blue (-b*) to yellow (+b*) [8]. Four readings of L*, a*, and b* values were recorded from three different positions on a sample surface.

2.2 Determination of proximate composition and amylose content
The protein, carbohydrate, fat, ash, and moisture content of rice samples were measured based on the AOAC Standard [9]. The results were reported on a dry basis and presented as mean values of triplicate experimental data. Amylose content was determined based on the colorimetric iodine assay method [10]. The organic milled rice was then grouped in the following categories based on their
amylose content, i.e. “waxy” (0-2%), “very low” (3-9%), “low” (10-19%), “intermediate” (20-25%) and “high” (>25%)

2.3 Data analysis
The data were analyzed statistically using SPSS software 14.00, and the means were distinguished using Duncan’s multiple range test (p ≤ 0.05) once subjected to the analysis of variance. All the data obtained in the present study were presented as mean values of duplicate or triplicate experimental data with the standard error of the mean.

3. Results and Discussion
A summary of the engineering properties and proximate composition of organic milled rice for different variety are presented in Table 1-2, and 3, respectively.

3.1 Engineering properties of organic rice
The length (L) of organic rice kernels varied between 6.1 and 7.2 mm depending significantly (p ≤ 0.05) on rice variety. It is shown in Table 1 that the longest and shortest L of rice kernels were revealed by MA (7.2 mm) and HM (6.1 mm) varieties, respectively. Based on the L of kernels, the majority of rice varieties presented in this study were categorized mostly as “long” kernel, except for PW, CB, and HM, which grouped as “medium” kernel [4]. The variety of organic rice affected significantly (p ≤ 0.05) the values of kernel width (W) that ranged between 1.9 (IR) and 2.6 mm (HM). The typical shape of organic rice kernel from the eastern Java region might be expressed by their L/W ratio that ranges from 2.4 to 3.5 according to rice variety. Table 1 shows that there are two groups of kernels shape [5] in relation to the organic rice varieties, namely “medium” (PW, CB, and HM) and “slender” (CH, IR, ST, MB and MA). These principal axial dimensions of the rice kernels are essential in designing and selecting sieve separators for the sortation process. Comparable results have also been reported in former work for the kernel dimensions while investigating inorganic rice of CH variety [11].

The thousand rice kernels’ weight ranged from 18.00-23.29 g depending on rice variety. There were significant differences (p ≤ 0.05) among the organic rice variety presented in this study, as shown in Table 1. Higher values of the 1000 kernels weight resulted in heavier single kernel weight of a respective variety of organic rice than those with lower values of 1000 kernels weight. This result was confirmed with the previous study for the inorganic rice of Merah variety [12].

| Rice Variety | L (mm) | W (mm) | L/W ratio | 1000 kernels weight (g) | Bulk density (g/cm³) | φ (°) |
|--------------|--------|--------|-----------|-------------------------|----------------------|-------|
| Ciherrang    | 6.9±0.1 de | 2.2±0.0 cd | 3.1±0.1 b | 20.84±0.17 bc | 0.87±0.00 d | 21.1±0.6 a |
| IR 64        | 6.7±0.1 c  | 1.9±0.0 a  | 3.5±0.1 c  | 18.00±0.29 a  | 0.85±0.00 c  | 24.8±1.1 bc |
| Sintanur     | 6.7±0.1 cd | 2.1±0.0 bc | 3.2±0.1 b  | 21.52±0.00 c  | 0.88±0.00 d  | 25.9±0.7 bc |
| Pandanwangi  | 6.2±0.1 ab | 2.5±0.0 c  | 2.5±0.1 a  | 20.82±0.17 bc | 0.84±0.01 c  | 23.9±1.7 abc |
| Merah bali   | 7.0±0.1 e  | 2.2±0.0 de | 3.2±0.1 b  | 20.35±0.44 bc | 0.77±0.01 a  | 23.4±0.3 abc |
| Coklat berlian | 6.4±0.1 b | 2.1±0.0 bcd | 3.0±0.1 b | 18.17±0.89 a | 0.79±0.00 b | 26.3±0.8 c |
| Merah A2     | 7.2±0.1 f  | 2.1±0.0 b  | 3.5±0.1 c  | 23.29±0.41 d  | 0.85±0.00 c  | 22.9±1.1 ab |
| Hitam melik  | 6.1±0.0 a  | 2.6±0.0 f  | 2.4±0.0 a  | 19.83±0.16 b  | 0.78±0.01 ab | 25.9±0.1 bc |

*Means not sharing a common alphabet within a column are significantly different at p ≤ 0.05*
Bulk density ($\rho_b$) of organic rice kernels for different varieties is shown in Table 1 and significantly different from each other ($p \leq 0.05$). The $\rho_b$ values varied between 0.77 and 0.88 g/cm$^3$ and showing the influence of rice variety on the $\rho_b$ values. The lowest and the highest $\rho_b$ values among the organic rice samples were indicated by MB (0.77 g/cm$^3$) and ST (0.88 g/cm$^3$) varieties, respectively. It was found that the group of non-white rice samples such as MB, CB, MA, and HM revealed lower $\rho_b$ values in comparison to the white rice group, i.e., CH, IR, ST and PW, suggesting the need for more packaging space to lodge the same weight of rice.

It can be seen in Table 1 that the mean values of the angle of repose ($\phi$) for organic rice samples ranged from 21.1 to 26.3° depending upon the rice variety. Two rice varieties indicated a significant difference ($p \leq 0.05$) each other in the $\phi$ values, i.e., varieties of CH (21.1°) and CB (26.3°). The CH variety could proclaim itself to be the best flowability rice kernels among the organic rice samples because it showed the lowest $\phi$ value. However, as the $\phi$ values obtained in this study were mostly less than or equal to 25°, all organic rice samples could be grouped into "very good" to "excellent" in flowability, with exception to the ST, CB, and HM variety [13].

Table 2 shows color attributes for different varieties of organic rice, including $L^*$, $a^*$, and $b^*$ values. Significant differences ($p \leq 0.05$) were observed between $L^*$ values among rice varieties, exhibiting dissimilarity of brightness properties for each rice variety. As expected, the white rice varieties, including CH, IR, ST, and PW, showed brighter color appearance than non-white rice varieties (MB, CB, MA, and HM). The $L^*$ values of the white rice group varied from 61.3 to 67.4, while for the non-white rice group ranged from 42.2 and 58.3. The brightest and the darkest rice color found in this work were shown by a variety of CH (67.4) and MA (42.2), respectively. It seemed that the rice brightness was influenced possibly by the values of $a^*$ and $b^*$. It is confirmed in Table 2 that the higher $L^*$ values show the lower $a^*$ and higher $b^*$ values simultaneously. Besides, all the non-white rice variety showed the highest value of $a^*$, proving as organic rice with redder color appearance among the organic rice samples.

Thermal conductivity ($k$) of different rice variety is presented in Table 2. It shows the ranged values in comparison to the white rice group, i.e., CH, IR, ST and PW, suggesting the need for more packaging space to lodge the same weight of rice.

**Table 2.** Color attributes and thermal properties of selected organic rice varieties

| Rice Variety   | $L^*$ (ab) | $a^*$ (ab) | $b^*$ (ab) | $k$ (W/m.K) | $Cp$ (MJ/m$^3$.K) | $\alpha$ (mm$^2$/s) |
|----------------|-----------|-----------|-----------|-------------|-----------------|-------------------|
| Cihering       | 67.4±0.1 | 1.0±0.0  | 13.5±0.1  | 0.105±0.001 | 1.625±0.014     | 0.096±0.000       |
| IR 64          | 65.5±0.2 | 2.3±0.1  | 15.7±0.2  | 0.108±0.001 | 1.845±0.075     | 0.093±0.002       |
| Sintanur       | 67.3±0.4 | 1.2±0.1  | 14.7±0.3  | 0.108±0.001 | 1.799±0.041     | 0.091±0.001       |
| Pandanwangi    | 61.3±0.3 | 1.3±0.1  | 13.2±0.1  | 0.115±0.001 | 1.581±0.014     | 0.097±0.001       |
| Merah bali     | 48.1±0.3 | 7.9±0.3  | 12.7±0.3  | 0.093±0.001 | 2.236±0.007     | 0.094±0.000       |
| Coklat berlian | 58.3±0.6 | 4.0±0.2  | 18.2±0.3  | 0.113±0.001 | 1.519±0.033     | 0.099±0.003       |
| Merah A2       | 42.2±0.3 | 7.9±0.3  | 9.5±0.3   | 0.104±0.001 | 1.437±0.017     | 0.093±0.000       |
| Hitam melik    | 43.2±0.1 | 5.9±0.2  | 9.5±0.2   | 0.103±0.001 | 1.433±0.007     | 0.099±0.001       |

Means not sharing a common alphabet within a column are significantly different at $p \leq 0.05$.
variety of the present organic rice (0.091-0.099 mm²/s). It was apparent that the thermal diffusivity was significantly different (p ≤ 0.05) each other depending on the variety. The ST and CB varieties have been named as the lowest and the highest thermal diffusivity, respectively, among the rice samples. The present result was similar to an earlier study, which indicated an opposite relationship between thermal diffusivity and bulk density [15].

3.2 Proximate composition and amylose content of organic rice

Proximate composition of organic milled rice varieties from the eastern Java area is listed in Table 3. The non-white organic rice varieties (MB, CB, MA, and HM) exhibited relatively higher protein content from 7.842 to 9.781% in comparison to the white rice group consisting of CH, IR, ST, and PW varieties (6.282-8.738%). There were significant differences (p ≤ 0.05) of protein content among the present organic rice because of different rice variety. The HM variety showed the highest protein content (9.781%) of the organic rice samples evaluated in this study. However, some protein data in Table 2 was slightly lower than that observed in the inorganic rice for similar varieties [11, 17]. The carbohydrate was a major component of the present organic rice. It is shown in Table 3 that the carbohydrate content of selected organic rice varieties ranged from 75.438 and 89.230% depending on the rice variety. Similar carbohydrate content was observed among the white organic rice varieties (CH, IR, ST, and PW), which was significantly higher (p ≤ 0.05) than non-white organic rice group such as MB, CB, MA, and HM. The fat content of organic rice was expectedly very low and showed various values between 0.241 and 2.715% relying on the variety. A comparison between fat content of white and non-white organic rice groups showed the opposite characteristic comparing to carbohydrate content, in which the white rice group revealed lower fat values than non-white rice. The highest and lowest fat content of rice samples were presented by the MA (2.715%) and IR (0.241%) varieties, respectively. Although the fat content in such rice samples showed low values, it is an essential factor determining the physicochemical and sensory properties of organic rice [17]. The ash component presented in organic milled rice was varied from 0.013 to 1.310% according to the rice variety. There was no significant different ash content (p ≤ 0.05) among the non-white organic rice except for the MB variety. Similar characteristic was also indicated by white organic rice varieties as the PW variety differ significantly (p ≤ 0.05) from this group of rice varieties. Since the ash content of rice is an inorganic residue resulted from the oxidation of rice through a heating process, it is then measured as the mineral content in rice [18]. The ash content of organic rice obtained during the experiment was relatively higher than those exhibited by former studies for similar varieties (CH and ST) of inorganic rice [11,19].

The amylose content of the present organic rice varied between 16.6 and 21.8%, depending on the rice variety. It is depicted in Figure 1 that the highest amylose content (21.8%) was observed to be CH variety, whereas the PW variety revealed the lowest one (16.57%). The present organic rice could be

| Rice Variety | Protein (%) | Carbohydrate (%) | Fat (%) | Ash (%) | Moisture (%) |
|--------------|-------------|------------------|---------|--------|--------------|
| Cibearang    | 6.28±0.150  | 89.05±0.043      | 0.726±0.012 | 0.55±0.027 | 10.66±0.029  |
| IR 64        | 7.12±0.001  | 89.08±0.086      | 0.241±0.009 | 0.57±0.005 | 10.10±0.089  |
| Sintanur     | 6.51±0.078  | 89.23±0.095      | 0.492±0.005 | 0.54±0.013 | 10.73±0.104  |
| Pandamwangi  | 8.73±0.072  | 86.96±0.039      | 0.838±0.012 | 0.49±0.016 | 11.70±0.011  |
| Merah bali   | 9.01±0.071  | 83.26±0.062      | 2.09±0.002  | 1.31±0.028 | 12.33±0.031  |
| Coklat berlian | 9.50±0.092 | 75.43±0.461     | 2.59±0.076  | 0.01±0.000  | 12.44±0.292  |
| Merah A2     | 7.84±0.179  | 78.12±0.047      | 2.71±0.025  | 0.01±0.000  | 11.30±0.108  |
| Hitam melik  | 9.78±0.091  | 75.67±0.207      | 2.04±0.057  | 0.01±0.000  | 12.48±0.173  |

Means not sharing a common alphabet within a column are significantly different at p ≤ 0.05.
classified into two groups based on their amylose content, i.e., intermediate amylose rice (CH, IR, and HM) and low amylose rice (ST, PW, MB, CB and MA). The organic rice containing intermediate amylose was higher volume expansion and degree of flakiness than low amylose. Hence, the rice with intermediate amylose content is preferred in several Asian countries such as Indonesia, Iran, Pakistan, Malaysia, Philippines, India, and some area of China and Vietnam [20].

![Figure 1. Amylose content of organic rice varieties in Eastern Java region](image)

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4. Conclusion
The organic rice kernels from eastern Java region was concluded to be "medium" to "long" based on L values, while appeared to show "slender to medium" shape kernels due to their L/W ratio. The thousand rice kernels' weight was about 18.0-23.3 g depending on the variety, while their bulk density ($\rho_b$) and angle of repose ($\varphi$) varied from 0.77 to 0.88 g/cm$^3$, and ranged between 21.1 and 26.3°, respectively. The highest volumetric specific heat (Cp), thermal conductivity (k), and thermal diffusivity ($\alpha$) were revealed by varieties of MB (2.236 MJ/m$^3$.K), PW (0.115 W/m.K) and CB (0.099 mm$^2$/s), respectively. Observations showed that non-white color organic rice varieties, including MB, CB, MA, and HM, exhibited higher protein and fat contents than white color rice samples such as CH, IR, ST, and PW. The amylose content of selected organic rice ranged between 16.6 and 21.8%, categorized as "low" to "intermediate" amylose rice.

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