Physical, Milling Quality and Physicochemical Properties of Several Local Glutinous Paddy Varieties in West Java, Indonesia

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Abstract. The objectives of this research was to study the physical quality of grain and rice, milling quality, and its physicochemical properties of several local glutinous rice. The research materials were obtained from local farmer in West Java. The analysis was conducted at the Rice Quality Laboratory at Indonesian Center for Rice Research (ICRR), Sukamandi, West Java. There are differences in physical quality of grain and rice, milled quality and rice protein content of several local glutinous rice. Based on the Indonesian National Standard quality of paddy (1993), the empty grain of the four types of local glutinous rice did not meet the quality of III (maximum 3%). Based on the components of immature+chalky grain quality, the four types of glutinous rice locally meet the quality of I (maximum 1%). The rice length and the shape of the five types of glutinous rice consecutively are medium (5.51 - 6.60 mm) and medium (2.1 - 3.0). The yield of brown rice of four types of glutinous rice ranged from 76.73% (Ketan Pulut) to 79.91% (Ketan Nangka). The rice yield of four types of glutinous rice ranged from 64.57% (Ketan Pecut) to 69.63% (Ketan Bilatung). The range of five sticky rice varieties ranged from 6.41 to 9.63%, which include very low amylose classification (2-19%). The gel consistency and gelatinizing temperature of five glutinous rice are soft and low consecutively.

1. Introduction
Indonesia has a wide genetic diversity of rice. Since ancient times the hereditary local rice varieties have been cultivated by the ancestors. In accordance with the development of the local rice varieties are adapted to the local environment. Local varieties generally have a good quality because every season farmers choose rice varieties with delicious taste of rice. In the field of rice breeding, Indonesian local rice is potential to be used as one of the elders of the crosses with regard to the specific advantages possessed by local varieties. It is expected to increase the benefits of rice varieties cultivated in specific localities [1].

Glutinous rice that is commonly found in the market generally comes from local varieties. Local varieties are generally long maturing varieties (5-6 months) with a yield potential of 40-50% lower than that of superior varieties [2]. Glutinous rice is one type of rice with very low amylose content. The amylose content is (1-2%) with a very fluffy rice texture [3]. Generally the content of glutinous rice amylose in Indonesia is 6-8%. The results of the characterization of management and utilization of germplasm in Indonesia [4] and catalog of plant germplasm passport data [5] showed many local...
varieties with low amylose levels equivalent to glutinous rice. Several new varieties of glutinous rice that have been released by the government through the Agency for Agricultural Research are Lusi (1989), Ketonggo (1999), Setail (2002) and Ciasem (2005) [6].

In addition to being consumed as rice, generally glutinous rice is also consumed as a snack or made into sticky rice flour as a raw material for snacks. Objectively, the quality of rice in the market is more determined by the physical properties and appearance of the rice grain. Good quality rice has a higher price than regular quality. The objectives of this study was to study the physical quality of grain and rice, milling quality, and its physicochemical properties of several local glutinous rice from West Java, Indonesia.

2. Materials and Methods
The research materials consist of four local rice samples from West Java, namely Ketan Nangka, Ketan Bilatung, Ketan Bodas and Ketan Pecut obtained from farmers in West Java. Each sample consisted of ± 1 kg of dry milled grain was sampled from each rice variety to be analysed. The research material was taken to the Rice Quality Laboratory, Indonesian Center for Rice Research at Sukamandi for quality analysis. Clean dried grain was peeled into brown rice using rice husker (Satake THU 35A). Then the brown rice is polished with rice polisher (Satake TM-05) into milled rice. Characterization of milled rice includes the physical quality of grain, physical quality and quality of milled rice and physicochemical properties of rice.

Identification of physical quality of grain includes moisture content, grain density, empty grain, immature grain + chalky grain, yellow grain + damaged grain, and 1000 grain weight. Identification of the physical character of rice includes the whiteness degree, clarity, milling degree (Satake Milling Meter scale), and the shape of rice. Rice milling quality analysis included the yield of brown rice, yield of milled rice, percentage of head rice, percentage of broken rice, and percentage of groats [7]. Analysis of the physicochemical properties of rice includes protein (Kjeldahl), amylose [8], gel consistency [9], gelatinization temperature [10], water absorption ratio (WAR) and volume expansion ratio (VER) [11] and amylographic properties [12]. The data were analysed using Anova and followed by DMRT test if there is a difference by using SPSS 14.0 software. The data were presented in average value.

3. Results and Discussion
3.1. Grain physical quality
The statistical analysis results showed that there were significant differences in the physical quality of grain such as moisture content, empty+dirty grain, grain density, 1000 grain weight, immature+chalky grain, yellow+damaged grains and red grains on four types of glutinous rice. The difference in moisture content of the four types of glutinous rice is due to differences in conditions during harvest and drying process. Grain moisture content of four glutinous rice varieties of local varieties analyzed ranged from 12.15 to 13.10% with an average of 12.55% (Table 1). This figure has fulfilled the requirements of three quality classes standards of grain quality SNI 0224-1987 / SPI-TAN / 01/01/1993 which is 14% (maximum) [13].

The yield of milled rice can be estimated by measuring the grain density. The grain density of the sample ranged from 459.0 (Ketan Pecut) - 515.0 (Ketan Bilatung). While the weight of 1000 grains of four types of local glutinous rice was consecutively ranged between 24.80 (Ketan Pecut) - 29.68 (Ketan Nangka). The result of statistical analysis showed that grain density value and weight of 1000 grains of four different types of local glutinous rice were different (Table 1). The difference between the two parameters is probably caused by differences in environmental conditions during the grain filling process. In general the high grain density and 1000 grain weight will result in a high yield of milled rice. Rice paddy density in Indonesia varied between 454.4-577.0 g / l [14].

There were a significant difference in the percentage of empty/dirty grain, green/chalky grain, yellow+damaged grains (Table 1). This is influenced by the environmental conditions of planting and
postharvest handling. Based on the quality standard of grain SNI 0224-1987/ SPI-TAN/01/01/1993, the empty grain of the four types of local glutinous rice did not meet the quality of class III (maximum 3%). Based on the components of immature chalky grain quality, the four types of local glutinous rice met the quality of class I (maximum 1%). Based on the yellow damaged grain quality component only met the quality of class I (maximum 2%), Ketan Bilatung and Ketan Nangka met the quality of class II (maximum 5%), and Ketan Bodas met the quality of class III (maximum 7%). Whereas based on the red grain quality component, only Ketan Bilatung fulfilled the quality of class II (maximum 2%) and the other three types of glutinous rice met the quality of class I (maximum 1%) (Table 1).

### Table 1. Grain physical quality of local glutinous rice

| Variety       | Moisture content (%) | Grain density (g/l) | Weight 1000 grain (g) | Empty+dirty (%) | Immature+chalky grain (%) | Yellow+damage grain (%) | Red grain (%) |
|---------------|----------------------|--------------------|-----------------------|------------------|--------------------------|-------------------------|---------------|
| Ketan Nangka  | 12.15 a              | 506.5 b            | 29.68 d               | 6.70 b           | 0.60 c                    | 2.47 c                  | 0.47 c        |
| Ketan Bilatung| 13.10 c              | 515.0 d            | 29.33 c               | 7.53 c           | 0.31 b                    | 2.05 b                  | 1.13 d        |
| Ketan Bodas   | 12.20 a              | 509.5 c            | 28.26 b               | 5.11 a           | 0.18 a                    | 6.24 d                  | 0.06 b        |
| Ketan Pecut   | 12.75 b              | 459.0 a            | 24.80 a               | 17.12 d          | 0.83 d                    | 0.00 a                  | 0.00 a        |

The number in one column followed by the same letter is not significantly different.

### 3.2. Physical quality of milled rice

The results of statistical analysis showed differences in the physical quality of rice, namely moisture content, length, shape of rice, whiteness degree, translucency and milling degree (Table 2). The International Rice Research Institute classifies the length of rice as follows: very long (> 7.5 mm), long (6.61-7.5 mm), medium (5.51-6.60 mm), and short (<5.50 mm). The ratio of length and width of the rice determines the classification of the grain shape. The International Rice Research Institute also classifies rice into 4 types: slender (> 3.0), medium (2.1-3.0), bold (1.1-2.0), and round (<= 1) [3]. The rice length and the shape of the five types of glutinous rice is medium (5.51 - 6.60 mm) and medium (2.1 - 3.0).

The whiteness degree of five glutinous rice ranged from 25.35 (Ketan Gadok) to 67.45 (Ketan Nangka) with the percentage of translucency ranged between 0.24 (Ketan Gadok) to 0.85 (Ketan Bilatung) (Table 2). The difference in the color of rice is caused by genetic factors. The level of translucency rice did not always affect the degree of white rice [14]. The translucency of rice is influenced by genetic factors and milling processes. The combination of whiteness degrees and rice translucency affect the milling degree of rice. White crystal BaSO4 with milling degrees up to scale 199 is used as a comparison in this measurement. Measurement of the milling degree of rice using Satake Milling Meter shows the range of 51.5 (Ketan Pecut) to 199 (Ketan Nangka) (Table 2).

### Table 2. Physical quality of local glutinous rice

| Variety       | Moisture content (%) | Length (mm) | Width (mm) | Rice shape (L/W) | Whiteness Degree (%) | Translucency (%) | Milling Degree |
|---------------|----------------------|-------------|------------|------------------|----------------------|------------------|----------------|
| Ketan Gadok   | 11.10 a              | 5.87 c      | 2.44 b     | 2.41 b           | 25.35 a              | 0.24 a           | -              |
| Ketan Nangka  | 12.21 b              | 5.81 b      | 2.64 d     | 2.20 a           | 67.45 e              | 0.71 c           | 199.00 d       |
| Ketan Bilatung| 13.10 d              | 6.15 e      | 2.53 c     | 2.43 c           | 63.25 d              | 0.85 e           | 194.00 c       |
| Ketan Bodas   | 12.20 b              | 5.95 d      | 2.46 b     | 2.42 c           | 59.80 c              | 0.79 d           | 177.00 b       |
| Ketan Pecut   | 12.70 c              | 5.77 a      | 2.41 a     | 2.40 b           | 31.85 b              | 0.48 b           | 51.5 a         |

The number in one column followed by the same letter is not significantly different.
Table 3. Milling quality of local glutinous rice

| Variety      | Yield       | Percentage                       |
|--------------|-------------|----------------------------------|
|              | Brown Rice (%) | Milled Rice (%) | Head Rice (%) | Broken Rice (%) | Groats (%) | Immature+ Chalky Grain (%) | Yellow+ Damaged Grain (%) |
| Ketan Gadok  | - c         | - e                        | 81.92 c       | 17.58 c         | 0.51 c     | 0.22 d                     | 2.39 e                    |
| Ketan Nangka | 79.91 c      | 69.10 c                    | 92.67 d       | 7.19 b          | 0.15 a     | 0.06 b                     | 1.09 c                    |
| Ketan Bilatung | 79.85 b     | 69.63 d                     | 95.29 e       | 4.51 a          | 0.20 b     | 0.14 c                     | 0.96 b                    |
| Ketan Bodas  | 80.22 d      | 68.60 b                    | 60.58 a       | 34.16 e         | 5.26 e     | 0.06 b                     | 1.39 d                    |
| Ketan Pecut  | 76.73 a      | 64.57 a                    | 78.93 b       | 19.31 d         | 1.77 d     | 0.03 a                     | 0.15 a                    |

The number in one column followed by the same letter is not significantly different

In Table 3 it can be seen that the quality of rice milling which consists of the yield of broken rice, percentage of head rice, percentage of broken rice, percentage of groats, percentage of immature chalky grain, and percentage of yellow damaged grain and based on the statistical analysis there is a difference of those indicator in five types of local glutinous rice. The yield of the four brown glutinous rice types ranged from 76.73% (Ketan Pecut) to 79.91% (Ketan Nangka). The yield of milled rice in the four types of glutinous rice ranged from 64.57% (Ketan Pecut) to 69.63% (Ketan Bilatung) (Table 3). The yield of milled rice in Indonesia ranged from 65-66% [14].

Based on the quality standard of rice SNI 6128: 2015 for the component of head rice and broken rice quality, Ketan Bilatung met the Premium quality class (minimum 95% and maximum 5%), Ketan Gadok, Ketan Nangka and Ketan Pecut met the Medium 1 quality class (minimum 78% and maximum 20%), and Ketan Bodas met Medium 3 quality class (minimum 60% and maximum 35%) [15].

The percentage of five types of glutinous rice met the Medium 1 quality class (maximum 2%), except for Ketan Bodas which did not met the quality class Medium 3 (maximum 5%) for groats. The five types of glutinous rice met the Medium 1 quality class (maximum 2%) for the percentage of immature chalky grain. The five types of glutinous rice met the quality class of Medium 1 (maximum of 2%), except Ketan Gadok which met the quality class of Medium 2 (maximum of 3%) for the percentage of yellow damaged grains (Table 3).

3.3. Physicochemical properties

In rice, protein is the second major component after starch. Protein content of brown rice is around 8%, and in milled rice is around 7%. The protein levels in rice are relatively low compared to other cereals, but the protein quality is relatively high especially in lysine amino acid content [16]. Increased rice protein content can directly increase protein supply in the diet, especially for low-income populations. The protein content of the five types of local glutinous rice ranged from 8.44 to 8.91%.

Amylose content is an important component in determining the physicochemical properties of rice. The physicochemical properties of rice affect the quality of the rice and the quality of cooked rice. The amylose content of starches in milled rice usually ranges from 15 to 35%. Based on amylose content, milled rice is classified as: waxy (1-2% amylose), non-waxy (>2% amylose), very low (2-19%), intermediate (20-25% amylose), and high (25-33% amylose) [3]. The range of amylose of the five types of glutinous rice between 6.41 to 9.63% so that it is classified as very low (2-19%). Although the amylose content does not include waxy or glutinous rice, the Indonesian people call it as glutinous rice based on the cooked rice texture.
Table 4. Protein content (dry basis) and cooking quality of local glutinous rice

| Variety       | Protein (%) | Amylose (%) | Gel Consistency (mm) | Cooking Quality | Alkali (Score) | Gelatinisation Temperature (°C) | WAR *) | VER **) |
|---------------|-------------|-------------|----------------------|----------------|---------------|-------------------------------|---------|---------|
| Ketan Gadok   | 8.6         | 9.3         | 100                  | Soft           | 7.0           | <70                           | 2.1     | 2.1     |
| Ketan Nangka  | 8.8         | 6.4         | 100                  | Soft           | 7.0           | <70                           | 2.1     | 2.1     |
| Ketan Bilatung| 8.9         | 8.3         | 100                  | Soft           | 7.0           | <70                           | 2.1     | 2.1     |
| Ketan Bodas   | 8.4         | 7.2         | 100                  | Soft           | 7.0           | <70                           | 2.2     | 2.1     |
| Ketan Pecut   | 8.9         | 9.6         | 100                  | Soft           | 7.0           | <70                           | 2.1     | 2.2     |

*) Water Absorption Ratio  
**) Volume Expansion Ratio

Rice is grouped into 3 groups based on the gel consistency, i.e., consistency of hard gel (very flaky rices) with gel length ≤ 40 mm, flaky rices with gel length 41-60 mm, and low gel consistency (soft rices) with gel length ≥ 61 mm [17]. Harder gel consistency gel is associated with harder cooked rice and this feature is particularly evident in high-amylose rice. Hard cooked rice also tend to be less sticky. The gel consistency of five glutinous rice are soft (Table 4).

Gelatinization temperature is the time required for cooking the milled rice. It is estimated by the extent of alkali spreading. The degree of spreading is measured using a seven-point scale. The corresponds of alkali spreading value to gelatinization temperature as follows: 1-2, high (74.5 – 80°C), 3 high intermediate, 4-5, intermediate (70-74°C), and 6-7, low (<70°C). In Asia there is a normally a preference for rice with intermediate gelatinization temperature. The gelatinization temperature characteristics of the five types of glutinous rice included low (Table 4). The measurement of the gelatinization temperature of the rice is one of the cooking quality tests related to cooking temperature, where water is absorbed and starch granules expand permanently in hot water. Rice with a high gelatinization temperature becomes very soft and tends to be sticky after cooking [18]. Rice that has a high gelatinization temperature requires more water and cooking time than those with moderate or low gelatinization temperatures. Thus the gelatinization temperature has a positive correlation with the time of rice cooking.

Each rice variety has the ability to absorb different water in the process of cooking rice. This is caused by the different amylose content which causes a difference in the number of active groups. The average of water absorption ratio (WAR) from rice in Indonesia is 2.5 times and the average of volume expansion ratio (VER) is 3.5 times compared to the volume of rice [14]. The WAR of five types of local glutinous rice range from 2.1 to 2.2, meaning that the water needed to cook of 100 g glutinous rice is 210 ml to 220 ml. The greater the level of water absorption, the greater the water needed to cook rice [19]. The level of volume expansion ratio (VER) of the five types of glutinous rice ranged from 2.1 to 2.2 compared to the volume of rice (Table 4).

3.4. Amylograph property

Observation of amylograph profile was carried out to determine the characteristics of starch in an ingredient when undergoing a heating and cooling process. Information on amylograph profiles can be used in determining sensory quality [20] and cooking quality [21] ingredients that are sources of starch. Heating on starch in excess water conditions with stirring will cause starch granules to expand irreversibly. Development of starch granules was followed by the release of amylose molecules, resulting in the formation of higher viscosity starch paste [22,23,24].

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Table 5. Amylographic profile of lokal glutinous rice

| Variety            | Initial Gelatinization | Granular starch breaks | Viscosity |
|--------------------|------------------------|------------------------|-----------|
|                    | Time (minute) | Temp. (°C) | Time (minute) | Temp. (°C) | Visco (cp) | 50°C (cp) | Setback (cp) |
| Ketan gadok        | 6          | 49.0      | 11          | 69.6      | 691.2     | 921.6     | 230.4       |
| Ketan nangka       | 6          | 47.4      | 11          | 68.4      | 1260.8    | 1068.8    | -192.0      |
| Ketan bilatung     | 6          | 48.8      | 11          | 69.1      | 1094.4    | 1318.4    | 224.0       |
| Ketan boda          | 6          | 47.8      | 11          | 69.2      | 1843.2    | 1299.2    | -544.0      |
| Ketan pecut         | 8          | 56.8      | 13          | 77.3      | 230.4     | 736       | 505.6       |

The initial temperature of gelatinization in Table 5 is the pasting temperature, i.e. the temperature at which the viscosity changes in the flour suspension significantly [25]. Pasting the glutinous rice sample temperature (Table 5) ranged from 47.4 to 56.8°C. This value is lower than the pasting temperature value of rice with low to high amylose content whose value ranges between 59.9 - 74.5°C [26]. Amylose molecules form complexes with fat which inhibit starch granule swelling, this inhibition has a lower pasting temperature [27]. The glutinous rice samples analyzed had a much lower amylose content than the samples of several new superior rice varieties [26]. The peak viscosity ranged of glutinous samples (230.4 - 1843.2 cP) is lower than that of several new superior rice varieties whose values reach 2585.6 - 4649.0 cP [26].

When the paste reaches peak viscosity, with heating and stirring continuing, the starch granule will be broken, so that the viscosity of the paste will decrease [22,23]. After the heating process has been replaced by cooling, several starch molecules will re-form to form a gel [22]. Amylose tendency to aggregate with others is greater than amylopectin. This gel formation causes the paste viscosity to increase [28]. The phenomenon of increasing starch paste viscosity due to the cooling process is called retrogradation or setback [22,23]. The setback value in Table 5 is the difference between viscosity at 50°C and peak viscosity [24]. The greater the setback value, the greater the tendency of a sample to retrograde when cooled. In Table 5 it can be seen that the Ketan Bodas sample (-544) has the lowest retrogradation tendency, and Ketan Pecut has the highest retrogradation tendency (505.6). The setback value of samples of glutinous rice with very low amylose levels is much smaller than the setback value of rice samples with low to high amylose content (2233.6 - 3788.8) in the research of physicochemical properties and cooking quality of several new superior rice varieties [26].

4. Conclusions
The rice length and shape of the five types of glutinous rice are medium. The yield of brown rice and milled rice of five local glutinous rice ranged from 76-80 % and 65-70% consecutively. Ketan Bilatung has the highest head rice percentage that fulfill the Premium quality class of rice Indonesian National Standard of 6128: 2015. The amylose content of five local glutinous rice ranged from 6.4 % to 9.3% with soft gel consistency and low gelatinization temperature. Ketan Bodas has the lowest retrogradation tendency and Ketan Pecut has the highest retrogradation tendency.

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