Changes in the quality of some improved rice grain varieties during storage

Jumali, B Kusbiantoro, D D Handoko

Indonesian Center for Rice Research, Jalan Raya 9 Sukamandi, Subang 41256, West Java, Indonesia

E-mail: pakde_jum@yahoo.com

Abstract. This research aimed to investigate the changes in the quality of some improved rice grain varieties during storage. In the rainy season of 2014/2015, 10 improved rice varieties, namely, Inpari 10, 13, 16, 20, 30, Sintanur, Ciherang, Mekongga, Situ Bagendit, and Situ Patenggang, were planted at the Sukamandi Research Station, Indonesian Center for Rice Research. The rough rice grains were harvested at optimum maturity, machine threshed, and dried with a box dryer's aid at a temperature of 45°C for 10 hours until the water content was at 13-14%. Furthermore, they were packed in plastic sacks and stored at room temperature for six months (March - November 2015). At 0, 3, and 6 months of storage, the rice's physical, milling, and physicochemical qualities were analyzed. The results showed that the quality of all the rice grain varieties equally decreased during the six months of storage while the average grain moisture content slightly increased by 13.7% (13.30-14.16%). In addition, the yield of unpolished, polished, and head rice slightly decreased. While the percentage of broken rice, groats, green/chalky, and yellowing/damage grains slightly increased. Additionally, the gel consistency and alkali digestion remained constant, while the amylose content, water absorption ratio, and volume expansion ratio slightly increased.

1. Introduction

The Indonesian Center for Rice Research (ICRR) released various types of improved rice varieties for both irrigated (Inpari and Hipa varieties), upland (Inpago varieties), and swampy land (Inpara varieties). This contributed significantly to the national production of the grain. Examples of the improved irrigated rice varieties included the Ciherang, Mekongga, Situ Bagendit, Situ Patenggang, Sintanur, and Inpari 30 varieties.

The rice quality is a combination of its physical, physicochemical (eating and cooking), sensory and nutritional qualities. The physical quality includes its dimensions, mass, thermal, hygroscopic, mechanical, and moisture adsorption properties, including its weight-volume relationship [1]. Meanwhile, the physicochemical quality is determined by the amylose content, gelatinization temperature, and gel consistency [2].

The factors that affect the quality of rice include genetics (variety), environment, pre-harvest, and postharvest aspects (harvesting, threshing, drying, milling, and storage practices). Meanwhile, those
affecting the quality during storage are moisture content, storage temperature, duration[3], rice form (rough or milled rice), and packaging material [4].

It was discovered that rough rice likely had a longer shelf life than milled rice as it was protected from insects and deterioration of quality by its husk. The rough and milled rice either went through quality degradation or aging during storage. Rice aging involves changes in the physical and chemical properties of the main rice grain components. While the overall starch, protein, and lipid contents remain essentially unchanged during storage. However, structural changes occur, affecting the pasting and gel properties, flavor, and texture of cooked rice [5]. During the aging of milled rice, the cooked ones have a harder texture and are much fluffier compared to the fresh ones and less sticky [6]. Daniels et al. [7] reported that the temperature affected the cooking properties and peak viscosity during rough rice storage, while the storage duration affected the head rice yield and cooking properties. Therefore, this research aimed to investigate the effect of storage on some improved rice grain varieties.

2. Materials and Methods

In the rainy season of 2014/2015 at Sukamandi Research Station, ten seeds of improved rice varieties, namely, Inpari 10, 13, 16, 20, 30, Sintanur, Ciharang, Mekongga, Situ Bagendit, and Situ Patenggang, were planted at the Indonesian Center for Rice Research (ICRR). The rice crops were harvested upon optimum maturity, machine threshed and dried using a box dryer at a temperature of 45°C for 10 hours until the rough rice's moisture content was less than 14 %. The rice was subsequently dried using a box dryer (3.5m × 2.5m × 1.5m, diesel-fueled) at 40°C, and the speed of airflow through the pile of grain was 7.4 m / min for ± 10 hours.

The dried rough rice was packed in plastic sacks, weighed (it was discovered to be approximately 55 Kg), three sacks each were filled with the different varieties and then stored by stacking them on wooden pallets in a storage room at room temperature for six months (March - November 2015). At 0, 3, and 6 months of storage, one plastic sack of each rice variety was opened for analyzing both the physical, milling and physicochemical qualities. In addition, the analysis of the physical quality of the rice, which includes the moisture content, length (l), width (w), and grain shape (l/w ratio) was carried out following The Indonesian National Standard (SNI) 01-0224: 1987 [8], the analysis of the milling quality was conducted following SNI 6128: 2015 [9], the analysis of amylose, gel consistency and gelatinization temperature was conducted following Cruz & Khush [10] procedure, while the water absorption ratio (WAR) and volume expansion ratio (VER) was performed according to Suismono et al. [11].

3. Result and Discussions

Rice grain quality is a combination of the physical, physicochemical (eating and cooking), sensory and nutritional qualities. However, the preferences of rice quality may vary among countries, and although rice growers, millers, or industry, and consumers may have the same characteristics on the quality of rice, they might place different emphasis on them. The rice millers or industry may emphasize rice with high total recovery (or yield) and proportion of head rice; however, rice consumers emphasize rice with great grain appearance, size, and shape, pasting properties, texture, taste, and flavor [10].

The physical characteristics of the ten rough rice varieties during storage are presented in Table 1. Their average moisture content at 0, 3, and 6 months of storage were 13.60%, 13.68%, and 13.70%, respectively. All the rice varieties analyzed met the SNI of rough rice [8]. However, only fourteen percent moisture content of rough rice and milled rice was considered safe for storage. Furthermore, twelve - fourteen percent was considered to be the optimum paddy moisture content for rice milling [12,13]. The SNI requires the water content of rough rice [8] and polished rice [9] to be a maximum of 14%.
The rice grain retained its shape even after six months of storage, and it was expressed as a ratio of length to width. Based on its shape, the rice was classified into four groups, namely slender grain, medium grain, short, slightly oval rice (bold), and round rice with a length to width ratio of 3.0, 2.1-3.0, 1.1-2.0, and 1.0, respectively. This classification showed that the Sintanur, Situ Bagendit, and Situ Patenggang varieties had an oval grain shape, whereas the others had a slender grain shape. However, the rice size and shape were not affected by postharvest handling because it was a genetic factor [14].

The milling quality of the ten rough rice varieties during storage is presented in Table 2. The average yield of unpolished, milled (polished), and head rice were slightly decreased at 0 (78.21, 69.08, 88.27), 3 (78.03, 68.81, 87.69), and 6 (77.70, 68.44, 86.90) months of storage, respectively. Meanwhile, the average percentage of broken grain, groats, green/ chalky, and yellow/damaged grains were slightly increased at 0 (8.68, 1.02, 0.61, 1.03), 3 (9.30, 1.15, 0.69, 1.17), and 6 (9.53, 1.22, 0.74, 1.53) months of storage, respectively.

### Table 1. The physical quality of all the rice varieties at 0, 3, and 6 months of storage

| Variety       | Moisture (%) | Length (l) (mm) | Wide (w) (mm) | Grain shape (w/l ratio) |
|---------------|--------------|----------------|--------------|-------------------------|
| Inpari 10     | 13.80±0.10   | 6.88±0.08      | 2.04±0.16    | 3.37±0.20               |
| Inpari 13     | 13.26±0.28   | 7.18±0.13      | 2.14±0.09    | 3.66±0.20               |
| Inpari 16     | 13.43±0.16   | 7.21±0.16      | 2.13±0.10    | 3.38±0.20               |
| Inpari 20     | 13.47±0.29   | 7.21±0.16      | 2.23±0.03    | 3.23±0.10               |
| Inpari 30     | 13.92±0.18   | 6.98±0.01      | 2.24±0.02    | 3.12±0.01               |
| Sintanur      | 13.66±0.00   | 6.30±0.39      | 2.67±0.28    | 2.36±0.52               |
| Cihergang     | 13.51±0.11   | 7.54±0.49      | 2.30±0.02    | 3.28±0.13               |
| Mekongga      | 14.12±0.54   | 6.93±0.04      | 2.25±0.01    | 3.08±0.01               |
| Situ Bagendit | 13.48±0.13   | 6.95±0.03      | 2.39±0.08    | 2.91±0.13               |
| Situ Patenggang | 13.35±0.22  | 6.81±0.13      | 2.31±0.03    | 2.95±0.11               |
| **Average**   | **13.60**    | **6.99**       | **2.27**     | **3.10**                |
| Inpari 10     | 13.77±0.06   | 6.89±0.06      | 2.08±0.11    | 3.31±0.12               |
| Inpari 13     | 13.31±0.26   | 7.15±0.12      | 2.15±0.08    | 3.33±0.13               |
| Inpari 16     | 13.43±0.18   | 7.21±0.16      | 2.12±0.06    | 3.40±0.18               |
| Inpari 20     | 14.11±0.30   | 7.19±0.15      | 2.23±0.00    | 3.22±0.06               |
| Inpari 30     | 13.93±0.18   | 6.88±0.07      | 2.11±0.08    | 3.26±0.08               |
| Sintanur      | 13.70±0.01   | 6.36±0.44      | 2.48±0.18    | 2.56±0.41               |
| Cihergang     | 13.55±0.09   | 7.53±0.39      | 2.30±0.05    | 3.27±0.09               |
| Mekongga      | 14.13±0.32   | 6.91±0.05      | 2.21±0.01    | 3.13±0.01               |
| Situ Bagendit | 13.48±0.14   | 6.95±0.02      | 2.37±0.10    | 2.93±0.15               |
| Situ Patenggang | 13.39±0.21  | 6.80±0.13      | 2.28±0.04    | 2.98±0.11               |
| **Average**   | **13.68**    | **6.98**       | **2.23**     | **3.14**                |
| Inpari 10     | 13.75±0.04   | 6.91±0.07      | 2.10±0.09    | 3.29±0.10               |
| Inpari 13     | 13.30±0.28   | 7.10±0.06      | 2.13±0.08    | 3.33±0.13               |
| Inpari 16     | 13.52±0.12   | 7.24±0.16      | 2.12±0.07    | 3.41±0.18               |
| Inpari 20     | 14.11±0.29   | 7.22±0.15      | 2.21±0.01    | 3.27±0.08               |
| Inpari 30     | 13.89±0.13   | 6.86±0.11      | 2.11±0.08    | 3.25±0.07               |
| Sintanur      | 13.71±0.01   | 6.36±0.46      | 2.48±0.18    | 2.56±0.42               |
| Cihergang     | 13.52±0.13   | 7.53±0.37      | 2.30±0.05    | 3.27±0.08               |
| Mekongga      | 14.16±0.33   | 7.14±0.09      | 2.24±0.01    | 3.18±0.02               |
| Situ Bagendit | 13.54±0.11   | 6.94±0.05      | 2.36±0.09    | 2.94±0.15               |
| Situ Patenggang | 13.34±0.25  | 6.85±0.11      | 2.29±0.04    | 2.99±0.11               |
| **Average**   | **13.70**    | **7.01**       | **2.23**     | **3.15**                |
At 0 months of storage, Inpari 30, Cihergan, Inpari 10, Mekongga, Situ Bagendit, and Situ Patenggang had a higher unpolished rice yield (78-79%) than the other rice varieties. They also had a higher number of broken grains (10%) than the others. Meanwhile, Inpari 30 and Cihergan also had a higher polished rice yield (68.63% and 71.82%), and head rice percentage (90.31% and 90.67%) compare to the others. However, at the third and sixth months of storage, their unpolished yield, polished yield, and head rice percentage became equally decreased, like the others.

Factors that affected the percentage of head rice during milling were drying techniques, moisture content, the milling processes. Improper drying techniques produced rice with a large number of broken grains. In addition, drying grains that were too thin on the cement drying floor caused the grains to quickly dry, which caused a large number of the grains to become cracked and break when crushed (milled) [15]. The optimum moisture content for rice milling was 12-14% or slightly above or below it. Therefore a moisture content greater than 20% resulted in broken rice/ groats [12,13].

Jumali et al. [16] reported that differences in drying methods between sun-drying and box drying only affected the physical quality of rice grain of Cihergan variety. In addition, the yield of unpolished and polished rice and the percentage of head rice of the Cihergan variety produced by drying with a box dryer was slightly higher than that of sun-drying. Therefore, the drying methods did not affect the physicochemical and organoleptic quality of the rice.

Table 2. The milling quality of all rice varieties at 0, 3, and 6 months of storage

| Variety | 0 month of storage (March 2015) | 3 months of storage (July 2015) | 6 months of storage (November 2015) |
|---------|---------------------------------|---------------------------------|------------------------------------|
|         | Unpolished rice yield | Polished rice yield | Head rice yield | Broken grain | Groats | Green/ Chalky | Yellow/ damaged |
| Inpari 10 | 78.3±0.23 | 70.46±0.98 | 87.65±0.44 | 10.04±0.96 | 0.51±0.36 | 0.07±0.38 | 1.45±0.3 |
| Inpari 13 | 76.6±3.18 | 67.81±0.90 | 88.72±0.32 | 7.09±1.12 | 1.72±0.49 | 0.62±0.01 | 0.97±0.04 |
| Inpari 16 | 76.4±1.79 | 67.96±0.79 | 87.45±0.58 | 10.45±1.25 | 0.92±1.07 | 1.28±0.47 | 0.68±0.25 |
| Inpari 20 | 78.2±6.65 | 67.73±0.95 | 86.27±0.00 | 6.14±1.18 | 1.12±0.07 | 0.66±0.04 | 1.19±0.11 |
| Inpari 30 | 78.3±1.59 | 68.63±0.32 | 90.31±1.44 | 7.55±0.8 | 0.36±0.47 | 1.42±0.57 | 1.56±0.37 |
| Situnur | 77.7±4.99 | 68.59±0.35 | 88.26±0.01 | 6.69±1.41 | 1.24±0.16 | 0.71±0.07 | 1.37±0.24 |
| Cihergan | 79.2±1.04 | 71.82±1.94 | 90.69±1.71 | 8.32±0.25 | 0.81±0.15 | 0.11±0.35 | 0.92±0.08 |
| Mekongga | 78.19±0.01 | 68.64±0.31 | 87.36±0.64 | 10.14±1.03 | 0.97±0.05 | 0.07±0.38 | 0.64±0.28 |
| Situ Bagendit | 79.35±0.81 | 69.86±0.55 | 87.65±0.44 | 10.23±1.14 | 1.26±1.14 | 0.15±0.33 | 0.73±0.21 |
| Situ Patenggang | 79.15±0.66 | 69.27±0.13 | 86.33±1.37 | 10.15±1.12 | 1.31±0.21 | 0.97±0.33 | 0.84±0.13 |
| Average | 78.21 | 69.08 | 85.27 | 8.68 | 1.02 | 0.61 | 1.03 |

At 0 months of storage, Inpari 30, Cihergan, Inpari 10, Mekongga, Situ Bagendit, and Situ Patenggang had a higher unpolished rice yield (78-79%) than the other rice varieties. They also had a higher number of broken grains (10%) than the others. Meanwhile, Inpari 30 and Cihergan also had a higher polished rice yield (68.63% and 71.82%), and head rice percentage (90.31% and 90.67%) compare to the others. However, at the third and sixth months of storage, their unpolished yield, polished yield, and head rice percentage became equally decreased, like the others.

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The presence of a high percentage of green/chalky grains in milled rice indicated that the rice crops particularly the panicles were not yet mature enough to be harvested, while physiological factors caused chalky grains (rice grains that were half as white or whiter than soft textured chalk).

The physicochemical quality of all rice varieties at 0, 3, and 6 months of storage is shown in Table 3. During six months of storage, the average gel consistency (65 mm, soft) and alkali digestion (high gelatinization temperature except for Sintanur) remained constant, while the amylose content, water absorption ratio, and volume swelling ratio were slightly increased at 0 (20.85, 2.8, 2.6), 3 (21.19, 2.9, 2.9) and 6 months (21.71, 3.0, 2.9) of storage, respectively.

Other cooking quality components were water absorption ration (WAR) and volume expansion ratio (VER). During cooking the rice, water was absorbed to fill the cavities of the starch molecules, which later formed a gel when heated. After the formation of the gel, excess cooking water emerged from the starch/rice structure. Therefore, it was discovered that a little or a large amount of water absorbed could be used to indicate the nature of low or high rice starch (amylose).

### Table 3. The physicochemical quality of all rice varieties at 0, 3 and 6 months of storage

| No | Variety       | Gel Consistency (GC)* | Amylose | Scale (mm) | GC type           | Alkali Digestion* | WAR** | VER*** | Gelatinization temperature |
|----|---------------|-----------------------|---------|------------|-------------------|-------------------|--------|--------|-----------------------------|
|    |               |                       |         |            |                   |                   |        |        |                             |
| 0 month of storage (March 2015) |               |                       |         |            |                   |                   |        |        |                             |
| 1  | Inpari 10     | 22.30±1.03            | 67.2±1.48 | soft       | 2                  | high              | 2.9±0.07 | 2.8±0.14 |
| 2  | Inpari 13     | 18.89±1.39            | 62.1±2.12 | soft       | 2                  | high              | 2.7±0.14 | 2.7±0.07 |
| 3  | Inpari 16     | 20.42±0.30            | 65.7±0.42 | soft       | 2                  | high              | 3.1±0.21 | 3.0±0.28 |
| 4  | Inpari 20     | 20.67±0.13            | 66.8±1.20 | soft       | 2                  | high              | 2.8±0.07 | 2.7±0.07 |
| 5  | Inpari 30     | 21.46±0.43            | 65.3±0.14 | soft       | 2                  | high              | 3.0±0.14 | 2.9±0.21 |
| 6  | Sintanur      | 19.12±1.17            | 65.5±0.28 | soft       | 5                  | intermediate     | 2.7±0.07 | 3.0±0.28 |
| 7  | Ciherang      | 20.18±0.47            | 64.9±0.14 | soft       | 1                  | high              | 2.8±0.0 | 3.2±0.42 |
| 8  | Mekongga      | 22.13±0.91            | 67.1±1.41 | soft       | 2                  | high              | 2.7±0.07 | 3.1±0.35 |
| 9  | Situ Bagendit | 21.31±0.33            | 62.5±1.84 | soft       | 1                  | high              | 2.8±0.0 | 3.0±0.28 |
| 10 | Situ          | 22.04±0.84            | 63.4±1.20 | soft       | 1                  | high              | 2.8±0.0 | 2.8±0.14 |
|    | Patpenggang   |                       |         |            |                   |                   |        |        |                             |
|    | Average       |                       |         |            |                   |                   | 20.85  | 65.1   | 2.8              | 2.6              |
| 3 months of storage (July 2015) |               |                       |         |            |                   |                   |        |        |                             |
| 1  | Inpari 10     | 22.48±0.91            | 66.4±1.06 | soft       | 2                  | high              | 2.8±0.07 | 2.8±0.07 |
| 2  | Inpari 13     | 19.88±0.93            | 62.3±1.84 | soft       | 2                  | high              | 2.8±0.07 | 2.7±0.14 |
| 3  | Inpari 16     | 20.64±0.39            | 66.1±0.85 | soft       | 2                  | high              | 2.9±0.00 | 3.0±0.07 |
| 4  | Inpari 20     | 21.11±0.06            | 66.8±1.34 | soft       | 2                  | high              | 2.8±0.07 | 2.7±0.14 |
| 5  | Inpari 30     | 21.82±0.45            | 65.9±0.71 | soft       | 2                  | high              | 2.7±0.14 | 2.7±0.14 |
| 6  | Sintanur      | 19.16±1.44            | 64.8±0.07 | soft       | 5                  | intermediate     | 2.9±0.00 | 3.0±0.07 |
| 7  | Ciherang      | 20.56±0.37            | 65.0±0.07 | soft       | 1                  | high              | 2.9±0.00 | 2.8±0.07 |
| 8  | Mekongga      | 22.55±0.96            | 65.2±0.21 | soft       | 2                  | high              | 3.1±0.14 | 3.0±0.07 |
| 9  | Situ Bagendit | 21.88±0.49            | 62.3±1.84 | soft       | 1                  | high              | 2.9±0.00 | 3.0±0.07 |
| 10 | Situ          | 21.86±0.47            | 64.0±0.64 | soft       | 2                  | high              | 2.9±0.00 | 2.8±0.07 |
|    | Patpenggang   |                       |         |            |                   |                   | 21.19  | 64.9   | 2.9              | 2.9              |
|    | Average       |                       |         |            |                   |                   |         |        |                             |
| 6 months of storage (November 2015) |               |                       |         |            |                   |                   |        |        |                             |
| 1  | Inpari 10     | 22.89±0.83            | 67.1±1.7 | soft       | 2                  | high              | 2.8±0.14 | 2.8±0.07 |
| 2  | Inpari 13     | 20.23±1.05            | 63.2±1.06 | soft       | 2                  | high              | 3.1±0.07 | 2.7±0.14 |
| 3  | Inpari 16     | 21.56±0.11            | 65.5±0.57 | soft       | 2                  | high              | 2.9±0.07 | 2.9±0.00 |
| 4  | Inpari 20     | 22.20±0.35            | 66.4±1.2 | soft       | 2                  | high              | 3.1±0.07 | 2.7±0.14 |
| 5  | Inpari 30     | 21.66±0.08            | 65.9±0.85 | soft       | 2                  | high              | 2.9±0.07 | 2.7±0.14 |
| 6  | Sintanur      | 19.74±1.39            | 64.8±0.07 | soft       | 5                  | intermediate     | 2.8±0.14 | 3.0±0.07 |
| 7  | Ciherang      | 21.09±0.44            | 64.7±0.0 | soft       | 2                  | high              | 3.1±0.07 | 3.2±0.21 |
| 8  | Mekongga      | 22.94±0.87            | 65.2±0.35 | soft       | 2                  | high              | 3.0±0.07 | 3.0±0.07 |
### 4. Conclusions
At the end of the six months of the rough rice storage, the physical, milling, and physicochemical qualities of all ten rice varieties decreased. Ciherang and Inpari 30 had better rice quality in terms of the unpolished yield, polished yields, and head rice percentage than the other rice varieties. However, their milling quality equally decreased during storage like the others. Therefore, it was observed that no rice variety had better quality than the others during storage.

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