The effect of accelerated aging of rough rice with high-temperature storage on color and quality of milled rice

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Abstract. The quality of milled rice can be improved through the aging process. Conventional aging takes a long time, so it needs to be accelerated. The purpose of this study was to evaluate the effect of temperature and duration of accelerated aging of rough rice on the color and quality of milled rice. Accelerated aging was carried out at room temperature, 40, 50, and 60 °C, and duration 4, 8, 12, 16 and 20 days. Weight loss and moisture content of rough rice during accelerated aging were recorded, while color, degree of milling, total rice yield, and head rice yield of milled rice were analyzed. The results showed that the temperature and time of accelerated aging had an effect on the color and quality of the milled rice. The optimal conditions for improving the color and quality of the milled rice were obtained from the accelerated aging at 40 °C for 12 days.

1. Introduction
Rice (Oryza sativa L.) is staple food for more than half of the world’s population, especially in Asia, including Indonesia. Rice has an important role as fulfillment of energy needs and nutritional intake, especially as the source of carbohydrate [1]. In general, rice is consumed in the form of milled rice that goes through cooking process. The quality of rice is the combination of physical and chemical characteristic, that could be divided into 4 broad categories. The interrelated categories are: (1) milling quality; (2) cooking and eating quality; (3) appearance quality; (4) nutritional value. Milling quality related to milling process and important factor that determine rice quality. Rice quality is determined by broken rice, milled rice and head rice yield [2,3]. According to Puri et al [4], milled rice quality is depicted by two important parameter that are kernel whiteness and head rice yield (HRY), while according to milling quality, it is evaluated as total rice yield (TRY) and head rice yield (HRY). Milling quality and milled rice color are important factors that determine consumer acceptability and commercial value of rice.

Generally milled rice quality that circulating on market has low quality, because of low head rice yield and high broken rice [5–7]. Therefore, it is necessary to improve milled rice quality. One way to
improve milled rice quality is by rough rice aging [8]. Head rice yield (HRY) and eating quality could be improved by accelerated aging of rice postharvest [9].

Some research showed that storing rice for few months could change physical and physicochemical of rice, such as head rice, rice quality and amylograph viscosity peak [10–12]. The changes that occurred during storing process is called aging [12–14]. These changes include head rice yield, rice color, composition, pasting and thermal properties, cooking quality (water absorption, volume expand, length ratio, suspended solid and rice flavor) and eating quality [15,16]. Yerragopu and Vellingiri [17] stated that rough rice aging could increase TRY and HRY.

Pattern of changes that occurred during aging process is same for every rice, however rate and magnitude of changes are different depend on storage temperature, humidity, moisture content, amylose content and rough rice variety [10,18]. Higher temperature and moisture content would produce bigger changes [19,20].

Rough rice aging in conventional method required to takes a long time (relatively 4-6 months). This method also required much room to store rice and rough rice, so that it generates high operational cost. Furthermore, rough rice during aging is susceptible to harm from insect, microorganism and rodent [21]. Therefore, it is necessary to reduce aging time and operational cost, but still produce rice with appearance and milling quality as same as rice with conventional method. Important factors that influence aging are temperature and duration [16,22]. Rough rice aging could be accelerated by dry or wet heating and dry heating is more preferable because it is cheaper and easier. Accelerated aging required few minutes to few hours or up to more than ten days [9].

Rough rice aging acceleration by three rounds of microwave heating could increase head rice yield when compared with less rounds of microwave heating and without aging [9]. Likitwattanasade [23] states that the result of Parnsakhorn’s research showed that the influence of accelerated aging of polished Kao Dok Mali Rice (KMDL-105) with heat treatment on equilibrium moisture content at 60 °C, 81% RH for 4 days could changes color, water absorption on rice grain and rice harness such as rice that produced by natural aging at 30 °C for 5 months. In this research, accelerating aging was done to newly harvest rough rice on various temperature and duration. The purpose of this research is to determine the influence of temperature and duration of accelerated aging to milling quality and milled rice color.

2. Materials and methods

2.1. Materials
Rough rice varieties as IR 64 had been dried by solar dryer until moisture content is around 13 ± 2%, been purchased from farmer in Sleman, Yogyakarta, Indonesia. Rough rice was packed in polyethylene bag weighing 1 kg/unit.

2.2. Accelerated aging
Accelerated aging of rough rice would be done by packing rough rice in polyethylene bag each 1 kg/bag and be stored in different temperatures that are room temperature (around 26 - 30 °C), 40, 50, and 60 °C for 20 days. Observations were made once every four days by put out the rough rice from incubator for each temperature and then rough rice was left for 24 hours in room temperature for tempering before got milled. As Control, rough rice without accelerated aging treatment was used.

2.3. Milling
Milling rough rice was done in two steps. First, disposed the husk from rough rice to obtained brown rice and then polished it to get rid of bran coating to produced white rice or milled rice. The polishing was done for 30 seconds with loads of one kilo.

2.4. Degree of milling (DOM)
DOM was calculated based on Puri et al [4] with formulas as follows:
Degree of milling (DOM) = 100 - \left[ \frac{\text{weight of milled rice}}{\text{weight of brown rice}} \times 100\% \right] \hspace{1cm} (1)

2.5. Milling quality
Observation of milling quality include moisture content, total rice yield, head rice yield and broken rice. Moisture content is measured with digital grain moisture tester, while TRY was determined based on Pan et al [2], HRY and broken rice was calculated based on Yerragopu and Vellingiri [17] with formulas as follow:

Total rice yield (TRY) = \frac{\text{weight of milled rice}}{\text{weight of rough rice}} \times 100\% \\
Head rice yield (HRY) = \frac{\text{weight of head rice}}{\text{weight of milled rice}} \times 100\% \\
Broken rice = \frac{\text{weight of broken rice}}{\text{weight of milled rice}} \times 100\%

2.6. Rice color
Rice color was determined with Chromameter Minolta Type CR-400 (Konica Minolta Co. Ltd., Osaka, Japan). The measurement results were expressed in the Hunter system which is characterized by the notations L*, a* and b*. Notation L* expressed whiteness parameter which has value from 0 (black) to 100 (white). Notation a* expressed red-green mixed chromatic color with value +a (from 0 to 80) is red and –a (0 to -80) is green, while notation b* expressed yellow blue mixed chromatic color with value +b (0 to 70) is yellow and value –b (0 to -70) is blue. Whiteness Index (WI) showed whiteness level of rice which was calculated based on Yerragopu and Vellingiri [17] with formula as follow:

WI = 100 - \sqrt{(100 - L*)^2 + (a*)^2 + (b*)^2}

2.7. Data analysis
Every test was done 3 times. The obtained data was carried out Variance Analysis (ANOVA) and if the effect was significant was continued with Duncan’s multiple range test (p <0.05) with SPSS version 20.0.

3. Result and discussion

3.1. Degree of milling (DOM)
Rough rice has three layers that are husk, bran and endosperm. The husk was removed during milling process and obtained rice is called brown rice which contain bran and endosperm [4]. The bran consists of cuticular and aleurone layer which removed during commercial milling and polishing operation [24]. DOM could be defined as the extent of removal of germ or layers of bran from brown rice kernels during various milling operations [4].

DOM of this research was around 11.35 – 15.36%. Figure 1 showed that DOM decreased until 16th day of accelerated aging and increased after the 20th day. Higher temperature and longer duration of aging made DOM more decreasing, however at room temperature, DOM relative constant. The lowest DOM was made at 60 °C for 16 days. However, it was not significantly different with accelerated aging at 40 °C for 16 days and at 50 °C for 12 days. Higher DOM could decreased TRY and HRY, but broken rice would increase [25].
Figure 1. The effect of temperature and time of accelerated aging on the DOM

The decrease of DOM was caused by hardening of rice grain so when it was polished the bran was not removed entirely from the surface of endosperm. Storage conditions had significant effects on tensile strength, crushing and breaking hardness and resistance to milling increased after ageing [14], which resulted to the increasing of TRY and HRY. DOM is the key factor which influence rice quality such as, nutritional value and physicochemical characteristic [26].

3.2. Milling quality

3.2.1. Moisture content. Moisture content which was produced from accelerated was low, ranges between 6.50-11.50% as shown in Figure 2a. The low moisture content due to the moisture content was low from start (12.37±0.21%) and during accelerated aging, especially at 50 and 60 °C occurred evaporation from rough rice and the packing could not held the steam. The decreasing of moisture content was occurred during rough rice storage which was influenced by temperature and storage duration [27]. High storage temperature would gave effect drying, the higher the temperature then the rate of drying increase [28].

3.2.2. Total rice yield (TRY). TRY in this research was ranged between 62.17-67.58% as showed in Figure 2b. The result was lower than the research of [2] which study the correlation between the condition of milling of rice sample and milling quality that produced TRY ranged between 67.6-73.0%, but same as Hasbullah and Dewi [29] that ranged between 60.80 – 67.80%. Accelerated aging for 16 days showed TRY value was higher than other temperature treatments and the highest TRY was obtained from accelerated aging at 40°C, although statistically did not have significantly difference with accelerated aging at 60 °C. The lowest TRY was at accelerated aging at room temperature for 20 days.

TRY was influenced by moisture content during milling. TRY showed increasing if moisture content decreased from 15.5 to 9.0% [30], while Nasirahmadi et al [31] stated that TRY is increasing with a decrease of moisture content from 12 to 8%, both for parboiled and unparboiled rough rice. High TRY was produced from rough rice with moisture content ranged between 12-12.5% [30]. In this research, accelerated aging at 40, 50 dan 60 °C showed that moisture content lower than 12% (Figure 2b), could be the reason why TRY was low.
3.2.3. Head rice yield (HRY). HRY is rice kernel that have the size of 3 quarter or more than normal rice grain which obtained after milling. In general, HRY is more sensitive to changes on milling and polishing condition than TRY [2]. In this research, HRY ranged between 72.01-81.17% as seen at Figure 2c. The highest HRY was obtained from accelerated aging at 60 °C for 12 days, but it did not have significant differences with accelerated aging at 60 °C for 16 days and at 40 °C for both 12 and 16 days, while the lowest HRY occurred in accelerated aging at room temperature for 20 days. HRY increased slightly at 40 and 60 °C. The increase of HRY was presumed due to hardening of rice kernel during acceleration aging process, because cell structure in rice kernel became more rigid so that more resilient from friction during milling process. The hardening occurred due to cross linkage formation between phenolic acid and polysaccharides on cells wall, so that cells wall become more rigid [16]. Other than that, kernel hardness also was influenced by moisture contents, the lower the moisture content of the kernel, the kernel would be more rigid. Although, it might result the decrease of HRY due to the kernel is more susceptible to break during milling. The hardness of kernel increase from 0.76 kg to 1.32 kg after stored for 6 months, as well as on accelerated aging at 100 °C for nine hours, the hardness of kernel increased from 0.76 kg to 1.56 kg on natural aging [32].

Accelerated aging of rough rice at room temperature for 20 days showed the decrease of HRY significantly, as presumed due to the decrease of broken rice that indicated by higher DOM which compared to other treatment (see Figure 1). Higher DOM indicated soft kernel so that during polishing more bran layer would remove [33]. Lower HRY value also interrelated to broken rice which broken rice on accelerated aging at room temperature for 20 days showed the highest value as showed at Figure 2d.

3.2.4. Milled rice color. Color is one of parameters physical quality of rice that could be observed first by consumer. Rice color is important criteria to assess the quality and price [21]. The factor which influence rice color are temperature, humidity, moisture content and incubation duration [34].

Figure 2. The effect of temperature and time of accelerated aging on milling quality (a. moisture content; b. TRY; c. HRY; d. rice broken)
Figure 3. The effect of temperature and time of accelerated aging on rice color (a. L*; b. a*; c. b*; d. WI)

Color parameters included L*, a*, b* value and WI milled rice which showed at Figure 3. Although there was no difference at L*, a* dan WI on milled rice, but b* increased along the increasing temperature and aging duration. The increase of b* value indicated the changes in rice color to be more yellowish especially at 60 °C. Rice was stored at 25 °C had b* value higher than rice which stored at 5 or 15°C after stored for 12 months [27]. The change in rice might occur due to lipid oxidation, Maillard reaction and pigment movement contained in bran and husk to rice endosperms [35].

WI showed whiteness of milled ranged around 66.51-67.93. This result almost the same with Furahisha et al [30] report that is 63.51-67.75, and higher than Jang et al. [27] report that is 39.4-40.6 and Pan et al [2] report that is 36.8-42.8. Higher WI indicated whiter rice [2]. WI was important factor that influence rice quality and used as quality index for milled rice and the acceptable value is more than 38 [1,36].

4. Conclusion
Temperature and duration of accelerating aging of rough rice affected to DOM, TRY, HRY and rice color. The higher temperature and the longer duration accelerated aging resulted to decreased DOM while TRY, HRY and rice color based on b* value increased. The result of research indicated that the Highest TRY and the lowest DOM was produced by accelerated aging for 16 days all temperature treatment. Accelerated aging which produced the highest HRY that was accelerated aging at 40 and 60 °C for around 12-16 days. WI was not different between each treatment, although b* value as indicator of yellowing of rice increased significantly at 40, 50 and 60 °C. Based on TRY and HRY value, temperature and duration of aging which recommended was at 40 °C for 16 days.

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