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Changes in the Milling Quality and Color of Rice during Accelerated Aging of Freshly Harvested Rough Rice at Various Temperature and Time

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Abstract:
Rice milled quality can be improved through the aging process. The purpose of this study was to evaluate the effect of temperature and time on accelerated aging of freshly harvested rice to the milling quality and color of the rice. Accelerated aging was done at room temperature, 40, 50, and 60 ° C, and the aging time was 4, 8, 12, 16 and 20 days. The decrease of rough rice weight and moisture content during accelerated aging, DOM, TRY, HRY and color of rice were analyzed. The results showed that the temperature and time of accelerated aging affect the quality of milled and color of the rice. The optimum condition for improving the milling quality and the color of rice was obtained from accelerated aging at 40 °C for 16 days.

Keywords: *accelerated aging, degree of milling, head rice yield, rice color, total rice yield*

1. Introduction

Rice is a dietary source of carbohydrates and energy, which is generally consumed in the form of whole grains of white rice obtained by milling (dehulling and polishing) rough rice (Payakapol et al., 2011). Commercial milling is a process consisting of various stages where firstly paddy or rough rice go through dehusking process and then the outer brown bran layer is removed during whitening process. In the final step, adhering bran is completely removed from the grain surface and is known as polishing. Puri et al., (2014) stated that quality of milled rice is depreciated by two important parameters i.e. whiteness of the kernel and head rice yield (HRY). Milling quality is normally evaluated as the total rice yield (TRY) and HRY (Pal et al., 2013; Pan et al., 2007). Sadeghi et al. (2012), two important factors in rice milling quality are head rice yield (HRY) and degree of milling (DOM). Furahisha et al. (2016) and Yadav and Jindal (2008) stated that milling quality is related to TRY, HRY and whiteness.The milling quality and the color of milled rice were an important factor determining consumer acceptance and commercial value of rice

Improving the quality of milled rice can be done by the aging of rough rice with storage for several months (Faruq et al., 2003). Aging during storage results in numerous changes in the chemical and physical properties of rice (Pantindol et al., 2005; Singh et al., 2006; Sodhi dan Singh, 2003; Sowbhagya dan Bhattacharya, 2001; Zhou et al., 2002). The changes in physico-chemical properties of aged rice are caused by changes in lipids, proteins and other substances produced from enzyme activities and oxygen during storage (Chrastil, 1994; Soponronnarit et al., 2008). Several studies have shown that rough rice aging may alter the properties of rice such as rice head yield, physical and chemical properties of rice, color, taste, quality and taste (Pantindol et al., 2005; Perdon et al., 1997; Singh et al., 2006; Sodhi dan Singh, 2003; Sowbhagya dan Bhattacharya, 2001; Zhou et al., 2002). These changes in pasting properties, color, flavor, and composition affect rice cooking and eating quality (Teo, Karim, Cheah, Norziah, & Seow, 2000). The overall changes may depend on the rice variety, storing conditions and further treatment (Faruq et al., 2003).
The conventional aging of rice takes a relatively long time, approximately 4-6 months. This aging method also requires much space for storage of paddy or rough rice, thus leading to high operating cost. Furthermore, rough rice undergoing aging is susceptible to damage from insects, microorganisms and rodents (Soponronnarit et al., 2008). Therefore, it is necessary to reduce the aging time and operating cost, while, at the same time, can maintain the rice properties such as appearance and milling quality to be similar to those obtained by the conventional aging process. The important factors affecting aging are temperature and time (Tananuwong and Malila, 2011; Zhou et al., 2015). Rosniyana et al. (2004) states that aging of grain can be accelerated by dry or wet heating, and the process at least takes minutes to several hours, even more than ten days (Le & Songsermpong, 2014). Likitwattanasade (2009) stated that the results of Parnsakhorn research showed that the effect of accelerated aging of Kao Dok Mali (KDML-105) polished rice by using heat treatment at equilibrium moisture content of 60 °C, 81% RH for 4 days could change the color, water absorption of rice grain and hardness of cooked rice like naturally aged rice stored at 30 °C for 5 months. In this research, accelerated aging on freshly harvested rough rice at various temperatures and times. The research objective was to determine the effect of temperature and time accelerated aging on the milling quality and color of the milled rice.

2. Materials and Methods

2.1. Materials
Freshly harvested rough rice IR 64 varieties have been dried by the sun drying to a moisture content of approximately 13±2%, obtained from a farmer in Senoboyo, Seyegan, Tempel, Sleman, Yogyakarta, Indonesia.

2.2. Accelerated aging
Rough rice weighed 1000 ± 50 g were put in a black plastic bag and stored at four different temperatures, i.e. room temperature (range from 26 - 30 ° C), 40, 50, and 60 ° C for 20 days. Observations were made every four days by removing rough rice samples from incubator for each treatment temperature. Rough rice samples were weighed and measured water content, then placed at room temperature for 24 hours for tempering before milling. As the control, dried rough rice without accelerated aging was used.

2.3.Milling
Rough rice milling was done in two stages, first to remove husks from grain to obtain brown rice and continued by polishing to remove bran layer to produce white rice or milled rice. Polishing was done for 30 seconds with a load of one kilogram.

2.4. Weight loss and moisture content of rough rice
During accelerated aging, weight loss measured by weighing the rough rice after removal from the incubator and continued with the measurement of water content using digital grain moisture meter.

2.5. Milling quality
Milling quality observation included degree of milling, yield of milled rice, moisture content of milled rice, percentage of rice head. The degree of milling was calculated based on Puri et al. (2014) with the following formula:

$$\text{Degree of milling} = 1 - \left(\frac{\text{weight of milled rice}}{\text{weight of brown rice}} \text{ x } 100\% \right) \quad \text{.....(1)}$$

While total rice yield (TRY) was determined based on Pan et al. (2007) and head rice yield (HRY) was calculated based on Alizadeh and Ajdadi (2011) with the following formula:

$$\text{Total rice yield (TRY)} = \frac{\text{weight of milled rice}}{\text{weight of rough rice}} \text{ x } 100\% \quad \text{.....(2)}$$

$$\text{Head rice yield (HRY)} = \frac{\text{weight of head rice}}{\text{weight of milled rice}} \text{ x } 100\% \quad \text{.....(3)}$$

2.6. Rice Color
The color of milled rice was determined using a chromameter Minolta Type CR-400 (Konica Minolta Co. Ltd., Osaka, Japan) and was expressed as the $L*$ (lightness), $a*$ (redness-greeness), and $b*$ (yellowness-blueness). The $L*$ scale ranges from 0 (black) to 100 (white); the $a*$ value ranges from negative (greenness) to positive (redness) and the $b*$ value ranges from negative (blueness) to

positive (yellowness). The total color difference (ΔE) to control was calculated using the equation according to Popov-Raljic and Lalicic-Petronijevic (2009) as follows:

$$\Delta E^* = \sqrt{(L^* - L'^*)^2 + (a^* - a'^*)^2 + (b^* - b'^*)^2} \quad \text{……………....……………..…(4)}$$

where L'^*, a'^*, and b'^* expressed values of control.

Whiteness index (WI) represents the purity of white color and is considered as an important parameter associated with the browning process. WI of the sample was calculated using the equation as follows:

$$WI = 100 - \sqrt{(100 - L)^2 + a^2 + b^2} \quad \text{………………………………........………(5)}$$

2.7. Data Analysis

All tests were performed at least in triplicate. Data obtained were subjected to statistical Analysis of Variance (ANOVA) and the difference in means was determined by Duncan multiple range test ($p < 0.05$) using SPSS software version 20.0.

2. Results and Discussion

2.1. Weight loss and Moisture Content of Rough Rice

.Figures 1a and 1b show the weight and moisture content of rough rice after accelerated aging at various temperatures and times. Figure 1 showed that the weight loss and the decrease moisture content of rough rice was affected by temperature and time, the higher the temperature and the longer the aging time, resulting in greater weight loss and decreasing of moisture content. Weight and moisture content was relatively fixed at room temperature aging acceleration, while at temperature of 40, 50, and 60 °C there was decreasing weight and moisture content of rough rice. Hashemi dan Shimizu, (2008) stated that the higher the storage temperature, the greater the grain moisture evaporation, which in turn will lead to a decrease in moisture content and weight loss of rough rice was also large.

The largest weight loss and moisture content decrease were on accelerated aging at 60 °C for 20 days. Significant weight loss and moisture content of rough rice can affect milling qualities. Moisture content of rice at the time of milling play a significant role in the relationship between TRY, HRY and whiteness (Cooper and Siebenmorgen, 2007; Bautista et al., 2009; Furahisha et al., 2016). In the milling process, too low or too high moisture content of rough rice produces a low milling quality, because the rice kernel becomes more easily broken during milling.

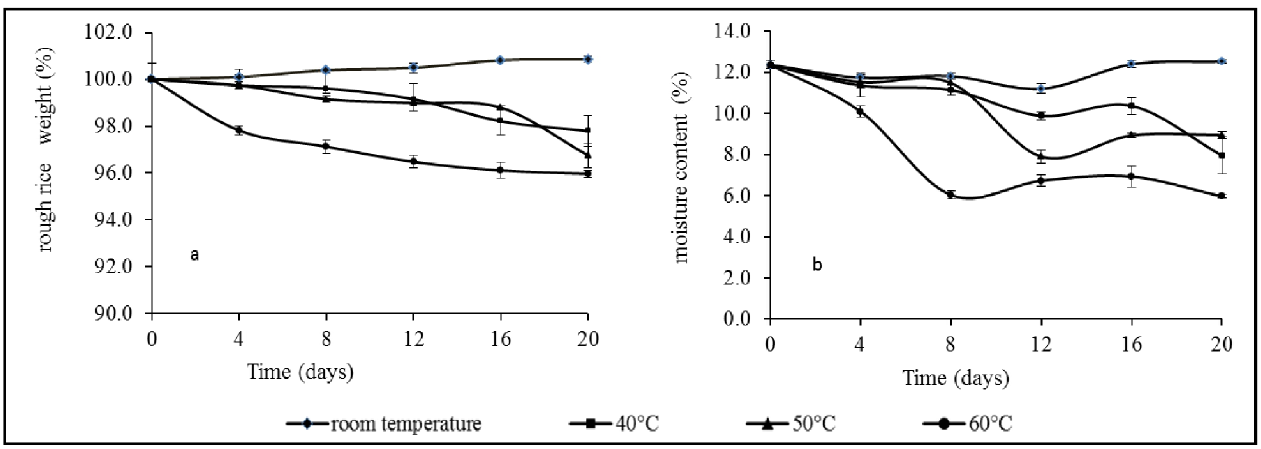

Figure 1: The effect of temperature and time of accelerated aging on (a) weight of rough rice and (b) moisture content of rough rice

2.2. Degree of Milling

Rough rice has three main layers i.e. Husk, bran and endosperm. Husk layer mainly constitutes lemma and palea making 20% of the weight of paddy. Husk is removed during milling process, the rice so obtained is called brown rice which contains the bran layer and endosperm (Puri et al., 2014). Bran layer is made up of cuticula and aleuron layer and conventionally removed during commercial milling and polishing operations. The extent of removal of the bran layer from rice kernels is defined as degree of milling (Wu et al., 2016).

The degree of milling (DOM) in this study ranged from 11.35 to 15.36%. Figure 2 showed that DOM decreased to 16 days of aging accelerated, and increased again in 20 days. The higher the temperature and the length of time aging, the DOM was decreased, but at room temperature relatively constant. The lowest DOM was produced at 60 °C for 16 days, but not significantly different from the accelerated aging at 40 and 50 °C with the same aging time (16 days) and at 50 °C for 12 days. The greater DOM could decreases of TRY and HRY, while the broken rice increased (Pal et al., 2013).

DOM decreased due to hardening of the rice kernels so that when polished the bran layer was not eroded entirely from the surface of the rice endosperm. Juliano (1979) stated that during aging rice kernels becomes progressively harder, as reflected in tensile strength, resulting in an increase in total and head-rice yields because of lower grain breakage on milling. DOM was a key factor affecting the quality of rice, such as nutritional value and physicochemical properties (Payakapol et al., 2011).

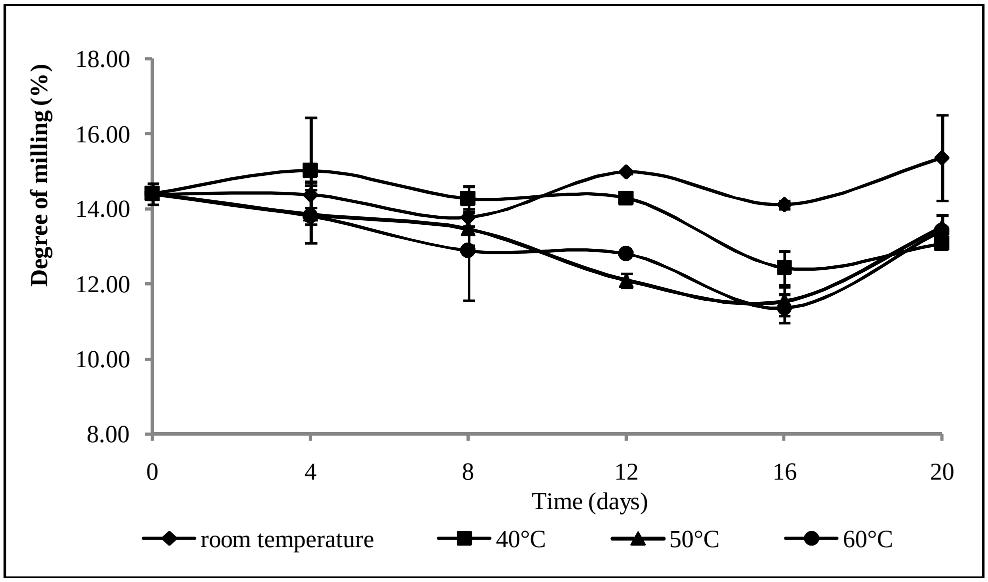

Figure 2: The effect of temperature and time of accelerated aging on the DOM

2.3. Total Rice Yield (TRY)

The TRY in this study various between 62.17-67.58% as shown in Table 1. Accelerated aging for 16 days showed a higher TRY value at all temperatures treatments although statistically non-significant. The lowest TRY was the accelerated aging at room temperature for 20 days and highest at 40 °C for 16 days. This result was lower than the research by Pan et al. (2007) who examines the relationship between rice sample milling conditions and milling quality resulted in TRY ranges between 67.6-73.0%.

TRY is influenced by the moisture content of rough rice at the milling time. TRY shows an increased if the moisture content decreased from 15.5 to 9.0% (Furahisha et al., 2016), while Nasirahmadi et al. (2014) stated that TRY increased with decreasing moisture content from 12 to 8%, for both parboiled and unparboiled samples. High TRY is produced from rough rice with moisture content ranging between 12-12.5% (Furahisha et al., 2016; Imoudu and Olufayo, 2000). In this research, accelerated aging at 40, 50 and 60 °C showed that rough rice moisture content of less than 12% (see Figure 1), it is this possibility that has led to an increase in TRY only small and non-significant.

2.4. Head Rice Yield (HRY)

The rice kernels which are three quarters or more in length as compared to length of original kernels obtained after complete milling is termed as head rice (Puri et al., 2014). HRY was generally more sensitive to the changes in milling and polishing conditions in the tested ranges than was TRY (Pan et al., 2007). The percentages of head rice yield (HRY) in this study ranges between 72.01-81.17% as presented in Table 1. The lowest HRY resulted from accelerated aging at room temperature for 20 days and significantly different from other treatments ($p > 0.05$), while the highest HRY accelerated aging temperature was 60 °C although it was not significantly different with control and all treatments except with room temperature for 20 days, and 60 °C for 4 days.

The percentage of HRY slightly increased especially at temperatures of 40 and 60 °C. The increase in HRY is thought to be caused by the hardening of rice kernels during storage, since the bonds between cells in the rice become stronger thus more resistant to friction during the milling process. According to McKeehen et al. (1999) and Zhou et al. (2015) hardening occurs due to the formation of crosslinks between phenolic acids and polysaccharides within the cell wall, so that the cell wall becomes stronger. In addition, the hardness of the kernels was also affected by the moisture content, the lower moisture content the harder rice kernel. Although this may result in a decrease in HRY because the kernel is more easily broken during milling. Begum and Kumar (2014) stated that in natural ageing of rice, the kernel hardness has increased from 0.76 kg after first month incubation time to 1.32 kg in sixth month aged rice, similarly in accelerated ageing at 100 °C for 9 hours, the hardness of kernel has increased from 0.76 kg to 1.56 kg.

Accelerated aging at room temperature for 20 days showed a significant decrease in HRY, this was associated with higher DOM than other treatments (see Figure 2). The decrease in HRY was a result of removing greater bran layer as well as the increased breakage in weak rice kernels (Saleh and Meullenet, 2013). According to Buggenhout et al. (2013) the impact of the initial rough rice moisture content and temperature on HRY may be due to their impact on DOM rather than to their impact on kernel breakage.

Temperature (°C)	Time (days)	TRY	HRY
Room temperature	0	64.45 ± 0.60	78.46 ± 2.20^{bc}
	4	62.98 ± 1.01	78.24 ± 1.51^{bc}
	8	63.81 ± 0.96	78.10 ± 3.74^{bc}
	12	63.38 ± 0.17	78.12 ± 3.06^{bc}
	16	65.14 ± 1.67	79.53 ± 0.47^{bc}
	20	61.89 ± 0.60	72.01 ± 5.71^{a}
40 °C	0	64.44 ± 0.60	78.46 ± 2.20^{bc}
	4	64.09 ± 1.80	76.01 ± 2.14^{b}
	8	63.23 ± 2.89	78.54 ± 2.06^{bc}
	12	63.58 ± 0.52	80.25 ± 1.17^{c}
	16	66.30 ± 1.14	80.52 ± 1.01^{c}
	20	62.82 ± 2.04	79.49 ± 1.48^{bc}
50 °C	0	64.45 ± 0.60	78.46 ± 2.20^{bc}
	4	63.60 ± 0.89	76.28 ± 1.78^{b}
	8	64.13 ± 1.32	79.49 ± 0.93^{bc}
	12	65.31 ± 0.49	78.41 ± 0.22^{bc}
	16	65.70 ± 0.49	78.52 ± 0.75^{bc}
	20	62.58 ± 1.26	78.49 ± 1.48^{bc}
60 °C	0	64.45 ± 0.60	78.46 ± 2.20^{bc}
	4	64.28 ± 1.72	74.53 ± 1.26^{ab}
	8	62.94 ± 1.56	79.52 ± 3.20^{bc}
	12	64.40 ± 0.48	81.17 ± 1.09^{c}
	16	66.00 ± 0.48	80.07 ± 1.45^{c}
	20	65.10 ± 1.08	78.81 ± 1.99^{bc}

Table 1: The effect of temperature and time of accelerated aging on total rice yield (TRY) and head rice yield (HRY)

Different superscripts in the column mean that the mean values are significantly different at $p < 0.05$

The WI value of milled in this study was 49.95-51.87 higher than reported by Jang et al. (2009) was 39.4–40.6 and Pan et al. (2007) was 36.8-42.8, but lower than reported by Furahisha et al. (2016) was 63.51- 67.75. A higher WI number indicates whiter rice (Pan et al., 2007). Whiteness value 40 has been suggested as a guide for milled rice quality control in the U.S. milling companies (Jang et al., 2009). Whiteness has been found to be an important factor affecting the quality of cooked rice and it is used as an index of quality for milled rice (Ahmad et al., 2017).

Temperature	Time of aging	Color parameter				
		*L**	*a**	*b**	ΔE	WI
Room temperature	0	50.17 ± 0.19	-0.74 ± 0.02	4.68 ± 0.07^{a}	0.00 ± 0.00	49.95 ± 0.19
	4	52.13 ± 0.34	-0.73 ± 0.04	5.00 ± 0.10^{b}	1.98 ± 0.35	51.87 ± 0.34
	8	51.95 ± 0.26	-0.70 ± 0.05	4.88 ± 0.24^{ab}	1.79 ± 0.29	51.69 ± 0.23
	12	51.78 ± 0.26	-0.75 ± 0.01	4.98 ± 0.23^{ab}	1.64 ± 0.59	51.51 ± 0.59
	16	51.86 ± 0.06	-0.73 ± 0.04	4.97 ± 0.03^{ab}	1.72 ± 0.07	51.60 ± 0.64
	20	51.84 ± 0.29	-0.78 ± 0.03	4.91 ± 0.14^{ab}	1.68 ± 0.31	51.58 ± 9.27
40 °C	0	50.17 ± 0.19	-0.74 ± 0.02	4.68 ± 0.07^{a}	0.00 ± 0.00	49.95 ± 0.19
	4	52.12 ± 0.45	-0.77 ± 0.04	5.15 ± 0.14^{bcd}	2.01 ± 0.41	51.84 ± 0.45
	8	51.91 ± 0.37	-0.79 ± 0.06	5.00 ± 0.15^{b}	1.77 ± 0.38	51.64 ± 0.36
	12	51.93 ± 0.27	-0.77 ± 0.03	5.10 ± 0.27^{bcd}	1.83 ± 0.24	51.66 ± 0.29
	16	51.56 ± 0.45	-0.70 ± 0.02	5.30 ± 0.40^{cde}	1.54 ± 0.53	51.27 ± 0.44
	20	51.67 ± 0.23	-0.77 ± 002	5.31 ± 0.15^{de}	1.63 ± 0.23	51.37 ± 0.22
50 °C	0	50.17 ± 0.19	-0.74 ± 0.02	4.68 ± 0.07^{a}	0.00 ± 0.00	49.95 ± 0.19
	4	51.49 ± 0.06	-0.77 ± 0.05	4.84 ± 0.07^{ab}	1.32 ± 0.06	51.24 ± 0.06
	8	51.37 ± 0.28	-0.79 ± 0.04	4.85 ± 0.10^{ab}	1.20 ± 0.28	51.11 ± 0.27
	12	51.45 ± 0.41	-0.77 ± 0.07	5.06 ± 0.13^{bcd}	1.34 ± 0.42	51.18 ± 0.40
	16	51.27 ± 0.43	-0.78 ± 0.04	5.01 ± 0.10^{bc}	1.15 ± 0.41	51.01 ± 0.43
	20	51.39 ± 0.34	-0.80 ± 0.05	5.01 ± 0.12^{bc}	1.26 ± 0.36	51.12 ± 0.32
60 °C	0	50.17 ± 0.19	-0.74 ± 0.02	4.68 ± 0.07^{a}	0.00 ± 0.00	49.95 ± 0.19
	4	51.30 ± 0.45	-0.80 ± 0.04	4.91 ± 0.17^{ab}	1.16 ± 0.47	51.05 ± 0.43
	8	51.49 ± 0.18	-0.78 ± 0.03	5.02 ± 0.07^{bc}	1.36 ± 0.19	51.22 ± 0.17
	12	51.42 ± 0.21	-0.75 ± 0.04	5.39 ± 0.09^{de}	1.44 ± 0.14	51.11 ± 0.22
	16	51.24 ± 0.36	-0.73 ± 0.05	5.42 ± 0.17^{de}	1.31 ± 0.33	50.93 ± 0.36
	20	51.68 ± 0.09	-0.76 ± 0.01	5.55 ± 0.03^{e}	1.74 ± 0.08	51.36 ± 0.10

Table 2: The effect of temperature and time of accelerated aging on color milled rice

Different superscripts in the column mean that the mean values are significantly different at $p < 0.05$

3. Conclusion

Temperature and time Accelerate aging of grainy rice affects the value of DOM, TRY, HRY, and the color of rice. The higher the temperature and the longer of the accelerated aging resulted in decreasing DOM, while TRY, HRY and color of rice based on the value of b* increased. The value of TRY is influenced by DOM, decreasing the DOM resulted in the increase of TRY value. The results showed that the highest TRY and lowest DOM resulted from accelerated aging for 16 days at all temperature treatments. Acceleration of aging that produces higher HRY is temperature 40 and 60 °C for 12-16 days. Whiteness of rice does not differ between treatments although value b* as an indicator of yellowing rice increased significantly at temperatures of 40, 50 and 60 °C. Based on TRY and HRY values, the recommended accelerated temperature and time of aging is 40 °C for 16 days.

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