International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 62.86 | Impact Factor (2015): 3.791

Kinetic Changes of Moisture Content and Lightness of Milled Rice during Storage in Plastic Packaging

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Abstract: ***A kinetic study was carried out to assess the moisture content (MC) and lightness (L*) changes of milled rice during storage in some plastic packagings at room temperature. There were our three types of plastic packaging selected (polypropylene/PP, polyethylene/PE, polyamide/PA), as a comparison, the changes of the milled rice without packaging was also carried out. Logarithmic plot for MC and L* values produced reasonably straight lines, indicating that the increase of moisture content in milled rice kernel followed first-order kinetics to a fair approximation for all kinds of plastic bags as well as milled rice without packaging. The rate (k) of MC increases were in the range of 5×10^{-3} to 9×10^{-3} % per week. Unlike the MC, the L* values decreased during storage in plastic packaging which was noted as minus values for the rate (k) changes in the range of 7×10^{-3} to 1.6×10^{-2} per week.***

Keywords: kinetic changes, moisture content, lightness, plastic packaging

1. Introduction

Rice is a staple for a majority of the population in Indonesia. The rice consumption in Indonesia is the highest among south East Asia countries. The most preferred rice in Indonesia is milled rice in which all bran layers of rice removed from rice kernels. Milled rice that is sold in traditional markets in Indonesia used to be without an appropriate packaging, it is exposed to open-air. On the other hand, milled rice which is sold in supermarket is mostly packed in plastic packaging. Rice consumers do not notice the rice quality changes during the display of milled rice in sealed plastic packaging. The display period might be assumed as storage period. During storage or display, rice is exposed to a wide range of environmental condition, especially temperature, humidity and light that could lead to decrease in rice quality.

There had been some reports on physical and physicochemical properties changes during rice drying, milling and storage; however most of the studies concerned on the development of fissures [1], [2], [3], [4]. Those studies revealed that the fissures were mostly due to the moisture re-adsorption or desorption in the milled rice. The fissures in milled rice would result in rice breakage and it declined the milled rice quality as well as the cooking quality.

As mentioned earlier, moisture content in rice played an important role in affecting rice quality, particularly rice fissures; therefore the increase of moisture content in milled rice should be limited; one of those efforts was by packaging. Plastic packaging has been widely introduced as alternative packaging for milled rice. There were several kinds of plastic bag used for packaging milled rice, such as PP, PE, and PA plastic bags. Rice sellers in Indonesia pack milled rice in several sizes: 5, 10 and 20 kg. Those rice packages are displayed in supermarket; during which there would be physical and physicochemical changes, particularly at room temperature with high humidity.

It has been reported that plastic bag had an effect on the quality of some food products during storage [5], [6], [7], [8]. There was only some papers report on rice quality changes during storage in plastic bags; however that paper mostly focused on rice seed and brown rice. Cao et al. [9] studied on the effect of paddy hermetic plastic tent modified atmosphere packaging on free fatty acid propertied of rice during storage. Sharp and Timme [10] determined the effect of storage time and storage temperature, packaging method on shelf life of brown rice.

Despite the extensive study upon rice quality changes during storage; study regarding effect of milled rice storage in plastic packaging, especially on the moisture content and color changes were still limited. The color change in milled rice was determined as the lightness (L^*) in which the L^* value of 100% indicating the very bright white. The decreasing values of L^* showed the loss of lightness.

The moisture content and lightness changes on milled rice during storage in plastic packaging were assessed by kinetics studies as the rate of changes. Each kind of plastic packaging might have different effect on milled rice quality changes. Therefore, this study was to determine the rate of changes in moisture content (MC) and color changes particularly the lightness (L^*) value during rice storage in plastic packaging at room temperature.

2. Materials and Methods

2.1 Materials

Ciherang rice variety was derived from lowland swamp land at East Ogan Komering Ulu, South Sumatera, Indonesia. It was milled at a degree of milling of 15 per cent in which all bran layers removed.

The properties of the plastic packaging used were: PP plastic bag (Water Vapor Transmission rate (WVTR) of (3.0115±0.3011) $g/m^2/24$ jam at thickness of 76.6 µm, temperature 37.8°C, relative humidity (RH) 90%; plastic thickness (73.5±1.27) µm); PE plastic bag (WVTR of (2.9684±0.2968) $g/m^2/24$ jam at thickness of 79.80 µm, temperature 37.8°C, relative humidity (RH) 90%; plastic thickness (78.0±1.27) µm), and PA plastic bag (WVTR of (4.2049±0.4205) $g/m^2/24$ jam at thickness of 103.1 µm, temperature 37.8°C, relative humidity (RH) 90%; plastic thickness (103.2±0.49) µm).

2.2 Moisture Content (MC) Determination

MC was determined using method of [11]. Rice sample as amount of 5 g in uncovered pre-weight metal container was oven dried at 100°C for overnight. After drying, the metal container was covered with a lid and cooled in desiccators containing silica gel for two hours before weighing. MC was calculated using the expression as in (1):

$$MC\,(\%, wet\ basis) = \frac{W_1 - W_2}{W_1} \times 100 \quad \text{......................(1)}$$

Where W_1 is the weight of initial sample (g), and W_2 is the dried sample (g).

2.3 Lightness (L*) Value Determination

The L* value was measured by color checker (Konica Minolta CR-10). The L* value gives a measure of lightness of samples color from 100 for white and 0 for black.

2.4 Analysis the Rate of MC and L* Value Changes of Milled Rice

The general equation describing the quality loss in food during a period of time can be expressed as equation (2) as in [12].

$$-\frac{dC}{dt} = k\ C^n \quad \text{...................................... (2)}$$

Where C = a component concentration; t = time; namely the exposure time (weeks) at room temperature; $-dC/dt$ = rate of change of a component concentration with the exposure time; k = a pseudo-rate constant; n = reaction order. If n = 0 (zero-order reaction), equation (2) collapse to equation (3).

$$-\frac{dC}{dt} = k \quad \text{... (3)}$$

The integral of equation (3) yields equation (4).

$$C - C_o = k(t - t_o) \quad \text{.............................. (4)}$$

Where C_o is the concentration at time zero (t_o).

Equation (4) indicates that there is a linear relation between concentration and time, where the rate constant is the slope of the straight line. If n = 1 (first-order reaction), equation (2) becomes equation (5).

$$-\frac{dC}{dt} = k\ C \quad \text{.. (5)}$$

and the integral of equation (5) yields equation (6).

$$\ln = \ln C_o - k(t - t_o) \quad \text{............................ (6)}$$

A plot of the logarithm of the concentration versus time yields a straight line, where the rate constant is the absolute value of the slope of the straight line. In contrast to the zero-order reaction, the rate of a first-order reaction depends on the concentration of a reactant.

3. Results and Discussion

3.1 Kinetics of MC Changes

Ciherang rice variety had length of 8.01 mm and width of 3.00 mm, whereas the initial L* on the surface of rice kernel was 71.6±0.61. The MC and L* of milled rice during stored in PP, PE and PA packaging, as well as the treatment for control by exposing milled rice in an opened-air were presented in Figure 1 to 4.

Kinetic studies were carried out to determine the kinetic orders and rate of changes for the MC changes of milled rice during storage in some types of plastic packaging at room temperatures. All results of the kinetics measurements were plotted as logarithms of the MC against the storage period. Graphs of MC against time were also plotted, and used in the evaluation of the kinetic order. Lines of best fit were drawn through each set of data, where appropriate. Logarithmic plot for MC produced reasonably straight lines, indicating that the increase of MC in rice kernel followed first-order kinetics to a fair approximation, as formulated in equation (3). The determination of the reaction order was carried out by evaluating both logarithmic and non-logarithmic plots of the MC of milled rice.

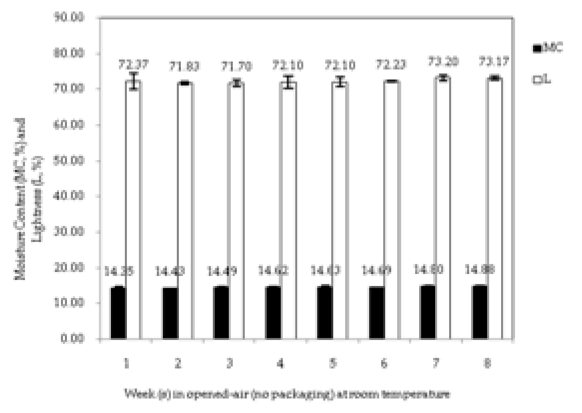

Figure 1: MC and L of milled rice without packaging

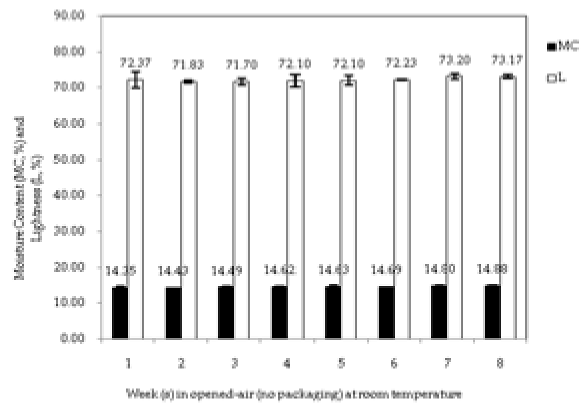

Figure 2: MC and L of milled rice in PP packaging

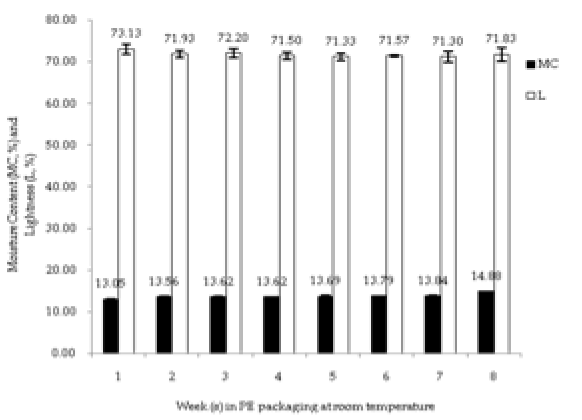

Figure 3: MC and L of milled rice in PE packaging

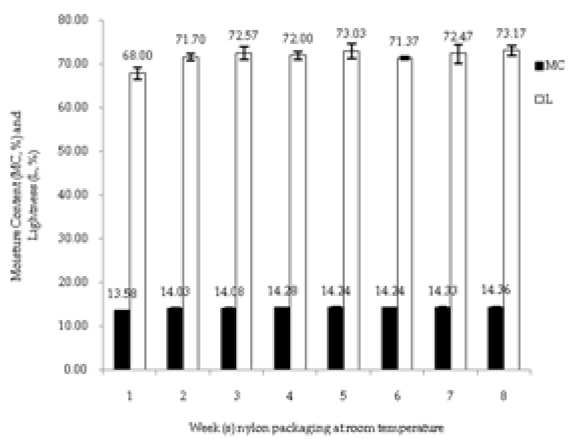

Figure 4: MC and L of milled rice in nylon packaging

It can be observed from Fig. 1 to Fig. 4 that the MC of milled rice in all cases increased with the storage period at room temperature. The analysis of the MC rate was conducted on the first week to the eight week of storage period. The initial MC of milled rice before storage was 12.81±0.05 % at the average relative humidity of 85%. The rate changes of MC during storage in PP, PE and PA plastic packaging were 6×10^{-3}; 5×10^{-3}; and 7×10^{-3} per week, respectively, whereas the highest rate of MC changes was found in without packaging which was 9×10^{-3} per week.

The MC of milled rice was highly increased from 12.81±0.05 % (initial MC) to 14.35±0.24 % (first week of storage period) for the treatment without packaging, followed by the treatment of PA, PP and PE packaging. The differences in MC increases were in relevant with the WVTR of plastic packaging used. The higher of WVTR would result in higher moisture re-adsorption into the milled rice kernel. Rice had a hygroscopic structure that can easily absorb moisture from the surrounding environment [13]. Once the moisture achieved the equilibrium moisture content with the surrounding environment (first week of storage), the MC was slowly inclined as shown in Fig. 1. On the other hand, the MC at the first week storage for the treatment of PE packaging was the lowest (13.05%); therefore the MC increases during storage in the PE packaging was the slowest among the other treatments. This result was correlated with the WVTR for the PE plastic packaging was only 2.9684±0.2968 g/m^2/24 jam.

This study was in line with the research carried by Muangkaeo et al. [14] on the influence of packaging materials and storage time on seed viability and chemical component of rice seed. They stated that the MC of rice seed stored in woven plastic bags were most increased and resulted in higher MC percentage than from other plastic bags such as PA and PE plastic bags.

3.2 Kinetics of *L** Changes

Unlike the measurement of MC, the *L** on the milled rice declined during storage in plastic packaging. The initial *L** value of milled rice was 71.6±0.61, and this value declined for all of the treatments indicating the whiteness on rice kernel decreased.

Many papers have reported on the changes of rice during storage. Most of the papers stated that storage had an effect on the physical and chemical of rice, including cooking quality, texture, volatile components, and color [10], [15], [16], [17]. Unfortunately, none of those mentioned in detail on the color changes on milled rice during storage, particularly the lightness on the milled rice surface.

Analysis of the kinetic orders and rate of changes for the $L*$ value of milled rice during storage showed that the rate of changes for $L*$ value followed the first-order kinetics for all of the treatments. The rate of decreases for the $L*$ values of milled rice packed in PP, PE and PA plastic packaging were 9×10^{-3}, 7×10^{-3} and 8×10^{-3} per week, respectively, whereas for milled rice without packaging was 1.6×10^{-2} per week. The least decreases of $L*$ value was pronounced in PE packaging, and it can be noted that there was a correlation between the MC increases and $L*$ value decreases. Furthermore, this study revealed that WVTR of the plastic packaging played an important role in moisture re-adsorption of milled rice during rice display or storage. The plastic packaging with the higher WVTR resulted in higher MC increases and lower the $L*$ value during rice storage.

4. Conclusion

The rate of MC and $L*$ changes of milled rice during storage in PP, PE and PA plastic packaging as well as milled rice without packaging followed the first-order kinetic. The rate of MC increases for milled rice packed in PP, PE and PA plastic packaging were 6×10^{-3}; 5×10^{-3}; and 7×10^{-3} per week, respectively. The $L*$ value of milled rice decreased during storage. The rate of $L*$ changes was in the ranges of 9×10^{-3}, 7×10^{-3}, and 8×10^{-3}, per week, respectively.

5. Acknowledgment

The authors wish to thank Universitas Sriwijaya for the financial support for this research.

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