Jurnal 5

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Impact of dry- and hydro-thermal treatments on swelling power, water absorption and water solubility on red-rice flours

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Abstract: The impact of dry- and hydro-thermal treatments on swelling power (SP), water absorption (WA) and water solubility (WS) of red-rice flour (RRF) were investigated. The dry-thermal treatment was conducted at RRF's moisture content (mc) of 10%, and the hydro-thermal treatment was performed at the mc of 25%. There were two heating methods applied on RRF: oven (80°C) and autoclave (121°C) heating. The exposure duration was 8, 10 and 12 hours in an oven-heating; 15 and 30 minutes in an autoclave-heating. Results showed that exposure durations, moisture content and their interaction had significant effect on SP and WS of RRF for the autoclave-heating. WA and WS increased with longer exposure duration to heat, and at a higher heating temperature. WA of RRF (40.34%) at 8 hr of exposure duration increased to 51.43% after 12 hr of exposure duration (for dry-thermal treatment) and 45.36% to 50.76% for hydro-thermal treatment. Modification of RRF by hydro-thermal treatment in an autoclave gave better physical properties than that of heating in an oven with higher values on SP and WA, and lower value of WS.

Keywords: red rice, dry and hydro thermal, swelling power, water absorption, water solubility

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1 Introduction

Rice is the most consumed cereal in Indonesia since it is the staple for a majority of the population. Unfortunately, the most consumed rice is milled rice which bran layers and embryo removed during rice milling. According to the national socio-economic survey conducted by Central Bureau of Statistics (2015), the consumption of milled rice in Indonesia is 98 kg/capita/year; this amount is higher than rice consumption in Thailand and Malaysia which is 80 kg/capita/year. Due to this high rice consumption in Indonesia, milled rice is to blame in some diseases.

Recently, people start to turn to pigmented rice. Pigmented rice (red or black rice) is rice that contains substantial amount of pigments. Pigmented rice consumption is rapidly growing presently because it is healthy functional food. There is no doubt about the health benefits given by pigmented rice, particularly the antioxidant (Walter et al., 2013; Chay et a., 2017; Nam et al., 2006; Chakuton et al., 2012); however, the use of native pigmented rice flours in food product is limited. The texture of pigmented rice flours-based food products is unfirmed; therefore the rice flour based product is used to be mixed with flour of other cereals or tubers. The unfirmed texture of native pigmented rice flours could be improved by modification. Starch can be modified by chemical, physical and enzymatic methods in order to promote specific functional properties (Andrade et al., 2014). Although starch is not the only component in rice flour, rice flour can be modified due to starch is the most abundant component in rice flour. Among the modification methods, physical modification is more preferred due to its environmentally friendly without any chemical substances added.

One of those physical starch modifications is heat-moisture treatment (HMT) (Syamsir et al., 2012, Senanayake et al., 2013; Khunae et al., 2007; Zavareze

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and Dias, 2011). HMT is one of hydrothermal treatments that change the physicochemical properties of starches by facilitating starch strain interaction within the amorphous and crystalline domains and/or by using disrupting starch crystallites (Hoover, 2010). HMT involves heating starch at a moisture content of less than 35% for certain of time and temperature. HMT is used to improve functional properties of starch without disrupting its granular structure (Shih et al., 2007). HMT involves treatment of starch granules at low moisture content (<35%) and high temperatures (Andrade et al., 2014). The general effects of HMT starch show a decrease in peak viscosity (Chaichaw et al., 2011), and an increase of swelling power (Adebowale et al., 2005; Alam and Hasnain, 2009; Demiate et al., 2001; Henshaw and Adebowale, 2004; Olu-Owulabi et al., 2014; Nor Nadiha et al., 2010; and Senanayake et al., 2013).

According to Shih et al. (2007), HMT can improve the functional properties of starch without disrupting its molecular structure. The moisture content in rice grain plays an important role in constructing the texture of starch. The heating temperature and incubation time might vary among different commodities during heating. Qin et al. (2016) modified glutinous rice flour by dry-heat treatment at 130°C for 0, 2 and 4 h; while Bello et al. (2015) hydrated rough rice to reach grain saturation prior to heating. The low moisture content of 10% (as dry-heating treatment) and 25% (hydrothermal treatment) was applied on pigmented rice flour in the oven at the temperature of 80°C for 8, 10 and 12 hours. The heating treatment was also performed in an autoclave at 121°C for 15 and 30 minutes, it was aimed to determine the possibility of heating in an autoclave, which could produce the relatively similar properties as heating in an oven. The method of heating in an oven was time consuming. The changes of physical properties (swelling power, water absorption, water solubility) on the modified pigmented rice were investigated.

2 Materials and methods

2.1 Rice materials

The red-rice varieties used in this research was Mentik Wangi variety originated from Karangsari village, East-Ogan Komering Ulu District, south Sumatera, Indonesia.

2.2 Heat treatment on red rice flour (RRF)

2.2.1 Heat treatment in an oven

The red-rice sample was conditioned to achieve the moisture content of 10% and 25% (wet basis). The red-rice was milled and sieved pass through an 80 mesh sieve. The heat treatment was performed on a 10% (M1) and 25% (M2) moisture content of RRF. The samples as amount of 150 g were placed in a closed glass container and then incubated in an oven at the temperature of 80°C for 8, 10 and 12 hours (denoted as T1, T2 and T3). The RRF was then dried in an oven at 45°C to achieve a moisture content of 12%.

2.2.2 Heat treatment in an autoclave

The sample preparation for heat treatment in an autoclave was similar to that of heat treatment in an oven. The RRF in the closed glass containers were placed in an autoclave at 121°C for 15 and 30 minutes (denoted as T4 and T5).

2.3 Parameters determination

2.3.1 Swelling power (SP)

The SP of starch was determined according to the method of Onyango et al. (2013). *SP* is the ratio of the weight of the wet sediment (W_s) to the initial weight of dried starch (Equation (1)).

$$SP\,(\%) = \frac{W_S\,(\mathrm{g})}{\text{initial weight of dried starch (g)}} \times 100\% \qquad (1)$$

2.3.2 Water absorption (WA)

WA was determined according to the method of Onyango et al. (2013). The RRF as amount of 5 g was weighed directly into a pre-weighed 50 mL centrifuge tubes, and 25 mL of distilled water was added. The tube was stirred manually by using spatula for one minute to suspend the starch. The suspension was allowed to solvate and swell for 20 minutes with intermittent shaking at 5, 10, 15 and 20 minutes. The sample was centrifuged at 1,000 rpm for 15 minutes, the excess water in remaining sediment in the test tube was further drained by using an adsorbent-paper towel. WA was calculated according to Equation (2).

$$WA\,(\%) = \frac{W_{rs}(\mathrm{g}) - W_{ds}(\mathrm{g})}{W_{ds}(\mathrm{g})} \times 100\% \qquad (2)$$

where, W_{rs} is the weight of remaining sediment, and W_{ds} is initial weight of dried starch.

2.3.3 Water solubility (WS)

The WS of starch was determined according to the method of Onyango et al. (2013). The RRF as amount of 0.1 g was weighed directly into a screw cap test tube and 10 mL of distilled water was added. The tube was heated in a water-bath at 60°C for 30 minutes with intermittent hand-shaking for 5 s after 5, 15 and 25 minutes. The tube was centrifuged at 1.000 rpm for 15 minutes and the supernatant was carefully removed and the remaining sediment in the tube was weighed (W_s). The supernatant was dried to constant weight (W_1) in an oven at 100°C. Solubility is the ratio of the weight of the dried supernatant to the initial weight of dried RRF (Equation (3)).

$$WSI\ (\%) = \frac{W_1\ (\mathrm{g})}{0.1\ (\mathrm{g})} \times 100\% \qquad (3)$$

2.4 Statistical analysis

A factorial completely randomized design was used with two factors and each treatment was repeated three times. The first factor was moisture content of rice grains (M) that consisted of M1 (10%) and M2 (25%), and the second factor was the incubation period of rice grain in an oven (T) that consisted of 8, 10 and 12 hours. The data obtained were analyzed by analysis of variance (ANOVA) and the significantly different treatment was further analyzed by honestly significant difference test at the 5% level.

3 Results and discussion

3.1 SP

SP indicates the ability of starch to swell in water. ANOVA showed that the exposure duration, moisture content and the interaction between exposure duration and moisture content had significant effect ($p<0.05$) on SP of RRF heated in an autoclave, but they had no significant effect ($p>0.05$) on SP of RRF that was heated in an oven. The average of SP values of RRF heated in autoclave was relatively higher than that of SP values heated in an oven. The SP values of RRF heated in an oven and an autoclave were presented in Figure 1 and 2.

The heating temperatures were 121°C in the autoclave and 80°C in the oven. The increased temperature resulted in higher SP, as reported in previous studies performed by Adebowale et al. (2005), Alam and Hasnain (2009), Demiate et al. (2001), Henshaw and Adebowale (2005), Olu-Owulabi et al. (2014), Nor Nadiha et al. (2010), and Senanayake et al. (2013). Heating starches could facilitate the interaction between amylose and amylopectin (Hoover, 2010), thus molecular chains became more flexible (Li and Gao, 2010), and therefore easily absorbed water. Water that was trapped in the arrangement of amylose-amylopectin molecules might increase the SP of RRF values.

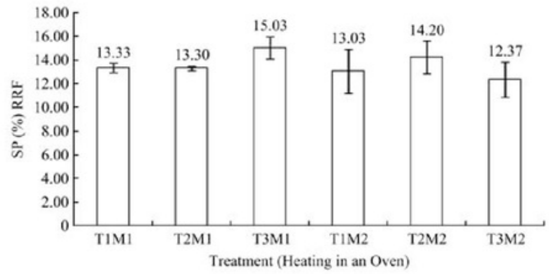

Figure 1 SP (%) of RRF heated in an oven

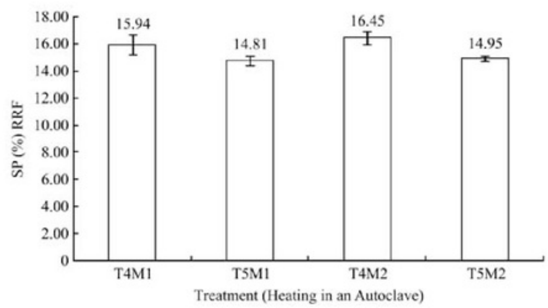

Figure 2 SP (%) of RRF heated in an autoclave

3.2 WA

Heating the RRF in an oven for 8 to 12 hours increased the WA value. The WA values of RRF heated in an autoclave were higher than that of heated in an oven. ANOVA showed that the exposure duration, moisture content and the interaction between exposure duration and moisture content had significant effect ($p<0.05$) on WA of RRF heated in an oven. The WA values of all treatment were presented in Figure 3 to 4.

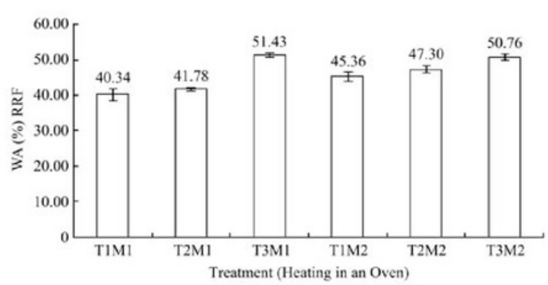

Figure 3 WA (%) of RRF heated in an oven

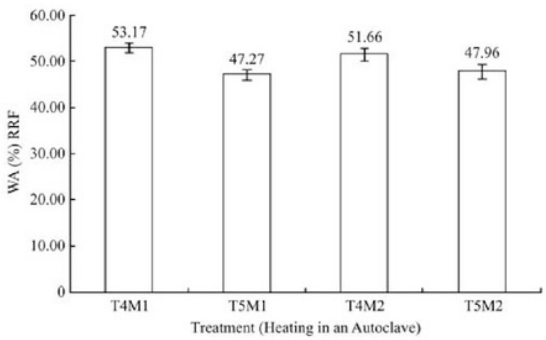

Figure 4 WA (%) of RRF heated in an autoclave

The longer exposure duration of RRF to heat source resulted in higher water absorption. As reported by Li and Gao (2010) and Zavareze and Dias (2011), moisture content in starch played an important role towards water absorption in heat moisture treatment. This could be due to the motion of water amongst starch molecular chains were weakened at a limited amount of moisture content in the sample. Amylose and amylopectin intensively interacted with each other. The thermal energy during heating might change the conformation of amylose and amylopectin (Syamsir et al. 2012; Widyastuti, 2012), and it was presumed that molecular chains became flexible, and therefore, water molecules easily penetrated starch granules. Furthermore, Adebowale et al. (2005), Singh et al. (2003) and Tsakama et al. (2013) also reported that HMT caused slight expansions of the amorphous regions, and changed some of hydrogen bonds between the amorphous and crystalline regions, and led to increased WA. The increase of heating temperature led the water molecules to have higher kinetic energy, therefore water molecules easily interacted with hydroxyl groups of amylose and amylopectin that resulted in higher WA.

WS increased with the increasing of exposure duration. It was due to the hydrogen bonding between amylose and amylopectin stretched during heating process and caused the water molecules easily penetrate into starch granules (Zięba et al., 2007), and therefore some of amylose dissolved in water.

3.3 WS

The WS of RRF heated in an oven tended to increase with the longer exposure duration of RRF in an oven, however, the WS tended to decrease for the RRF that was heated in an autoclave. ANOVA showed that exposure duration, moisture content and the interaction between exposure duration and moisture content had significant effect ($p<0.05$) on WS of RRF heated in an autoclave. The WS values of all treatment were presented in Figure 5 and 6.

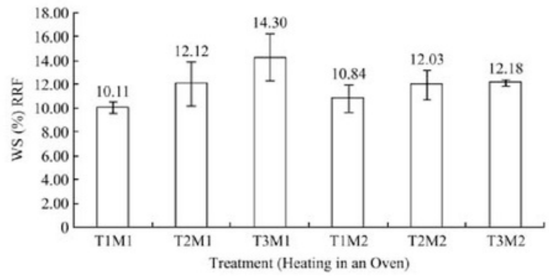

Figure 5 WS (%) of RRF heated in an oven

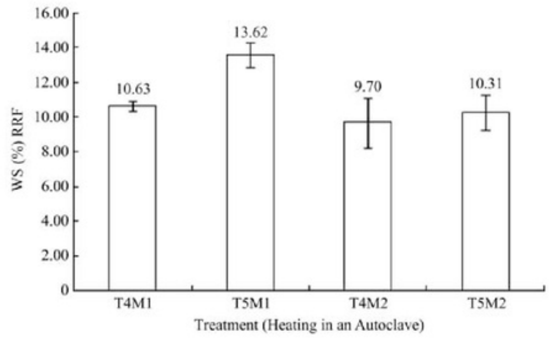

Figure 6 WS (%) of RRF heated in an autoclave

Water solubility indicates the extent to which the component of starch dissolves in water (Sawant et al., 2013). The highest water solubility indicates major degradation of starch and such condition lead to more numbers of soluble molecules in the water (Narbutaite et al., 2008). Water solubility of the treated RRF increased with the increase of the incubation times for both oven- and autoclave-heating. It was due to more starch granules damaged during heating with a longer exposure to heat. Water molecules together with hydrogen bonding linked to the exposed hydroxyl groups of amylose and amylopectin which cause an increase in solubility of starch granule.

4 Conclusions

Heat source has an impact on the physical properties of RRF. During the thermal treatment, the exposure duration as well as the moisture content of RRF played an important role in determining the physical changes such as SP, WA and WS. Increasing temperature and exposure duration tended to increase the WA and WS of RRF. The selection of heat source as well as the exposure duration and moisture content to be applied on RRF depended on the desired of physical properties of the end product of RRF. However, hydro-thermal treatment (mc 25%) in an autoclave-heating gave better physical properties (higher values on SP and WA, and lower value of WS) than that of heating in an oven.

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