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Physicochemical Characteristics of Instant Boiled Rice: Study of Sodium Citrate Concentration and Soaking Time

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ABSTRACT

Cooked rice (nasi liwet) is a typical rice dish of Java Island which is cooked using spices so that it has a unique taste and aroma. Making nasi liwet takes a long time, so this dish is only served at certain times. Therefore, a fast rice processing technique is needed but still has a distinctive taste and aroma. The purpose of this study is to analyze the physicochemical analysis of instant liwet rice based on the concentration and soaking time of sodium citrate. The physicochemical analysis tested were rehydration time, volume expansion, bulk density, texture, yield, ash content, and water content. The study was conducted by soaking sodium citrate (0, 2, 5, and 8% w/v) and soaking time (2, 4, and 6 hours) on rice. The results showed that the fastest rehydration time for instant nasi liwet was 4.55 minutes. The range of observation parameters such as expansion volume is 66.26-91.24%; bulk density is 0.413-0.581 g/ml; the texture is 431-1496 g/mm; yield is 89.64-92.26%; ash content is 4.11-4.45% and water content is 5.83-7.03%wb. Variations in sodium citrate concentration and immersion time increased the swelling volume and ash content, while water content, bulk density, texture, and yield tended to decrease. The best treatment based on the multiple attribute Zeleny method was immersion of 5% sodium citrate for 4 hours of immersion.

1. INTRODUCTION

Boiled rice (nasi liwet) is a staple food typical of Indonesia that is found in many areas because it has a unique aroma and taste. Boiled rice is made for a long time and is considered impractical by some people, it takes 1-2 hours to prepare. Therefore, instant boiled rice products are needed to speed up serving. Instant boiled rice is an instant rice product in general. Instant rice is considered a fast food product favored by many consumers. This is based on the raw material for making instant rice which contains starch (77.6%), protein (4.5-10.5%), crude fat (0.3-0.5%), and water content (14%ww) (Briffaz *et al.*, 2012).

Based on data from BPS (2020), Indonesia produces 54.65 million tons of dry milled unhulled rice with a conversion rate of 31.33 million tons. This is an increase of 0.07% from the previous year. This data shows that the community's dependence on rice is very high and has the potential to be developed into instant rice products as a step in maintaining food security and as a source of carbohydrates in Asia (Hsu *et al*., 2015). Instant rice provides a quick way to consume rice, which can be cooked in hot water to hydrate dry rice with a serving time of 3-5 minutes (Jiao *et al*., 2014). The decrease in starch content in instant rice is one of the advantages that consumers want (Jiao *et al*., 2014; Rewthong *et al*., 2011).

The problems that exist in processing instant rice are related to rehydration time and lower product quality compared to conventionally cooked rice and cause loss of nutrients during manufacture (Jiao *et al*., 2014; Prasert & Suwannaporn, 2009). The texture quality of cooked rice is related to the content of amylose and amylopectin (Patindol *et al*., 2010). In addition, texture is also related to protein content (Singh *et al*., 2005).

The quality of instant rice depends on the raw material and drying method. The cooking and drying process is a very important step in making instant rice products. When the rice grains are cooked, the water will be diffused into the cell wall and then into the starch. As a result of this event, rice will experience swelling and starch will experience changes in its structure and physicochemical properties (Jiao *et al*., 2014; Mestres *et al*., 2011). Sodium citrate soaking, cooking, and drying will affect the physicochemistry of instant rice (Sasmitaloka *et al*., 2019). Briffaz *et al.* (2012) reported that the rate of starch gelatinization was faster at 95 ^{o}C than at 75 ^{o}C which describes the rate of water diffusion depending on the cooking temperature.

Smith *et al.* (1985) reported that the addition of 1% sodium citrate and calcium chloride can accelerate the cooking, drying, and rehydration processes. The freezing process makes dry instant rice more porous and can accelerate the gelatinization process with hot water (Sasmitaloka *et al*., 2019). They also reported that the acceleration of the gelatinization process could not be separated from the 5% sodium citrate immersion. Studies that study the effect of sodium citrate concentration and soaking time on the physicochemical characteristics of instant liwet rice are still very limited. This study aims to analyze the physicochemical characteristics of instant liwet rice, including rehydration time, expansion volume, kamba density, texture, yield, ash content, and water content.

2. MATERIALS AND METHODS

2.1. Materials

The materials for this research included rice varieties IR-64 (Food Station Tjipinang Jaya Co., Ltd, Indonesia), sodium citrate (Sigma-Aldrich Co., China), water, and some spices (bay leaves, lemongrass, shallots, onions white, flavoring, and salt) purchased at traditional markets (Sidoarjo, Indonesia). The analytical tools used were analytical balance (Mettler Toledo-AL204, US), gas stove (Hock HP-200EG, Hokinda Citralestari Co., Ltd., Indonesia), electric rice cooker (Sanken SJ-135SP, Sanken Co., Ltd. , Indonesia), refrigerator (Polytron PRM430, Hartono Istana Teknologi Co., Ltd., Indonesia), Rheotex (SD-2700, Japan), Furnace (Carbolite AAF1100), Oven (LDO-080N, Daihan Labtech Co., Ltd. , Indonesia), and glassware.

2.2. Boiled Rice Preparation

The research was conducted experimentally in at a laboratory scale. The research was divided into two stage, namely the production stage and the testing stage. The production stages in general included soaking rice with variations in soaking time of 2, 4 and 6 hours and soaking materials (sodium citrate) of 2, 5 and 8%. According to the regulation of the Head of the POM No. 18 of 2013 concerning the maximum limit for the use of Bahan Tambahan Pangan (BTP) sequestrants, the use of Na-citrate of up to 8% is still allowed. After soaking, followed by the washing process, cooking using a rice cooker accompanied by the addition of seasoning ingredients, freezing in a freezer at -4 ^{o}C for 24 hours, thawing process at 40 ^{o}C, and finally drying in an oven.

Table 1. Experimental design

Soaking time (B)	Na-citrate concentration (A)			
	Control (A0)	2% (A1)	5% (A2)	8% (A3)
2 hours (B1)	A0B1	A1B1	A2B1	A3B1
4 hours (B2)	-	A1B2	A2B2	A3B2
6 hours (B3)	-	A1B3	A2B3	A3B3

The experimental design used in this method is a Completely Randomized Design (CRD) which will provide a complete design model and in accordance with the treatment groupings, namely variations in soaking time and sodium citrate concentration (Table 1). Further test using Duncan's Multiple Range Test (DMRT) was performed at α = 5%. All combination treatments were replicated 3 times.

The first stage of making instant rice is soaking the rice. In this study, each experimental unit used 150 grams of rice and 300 ml of water (ratio 1:2). The amount of water absorbed during soaking was not observed. The soaked rice was then rinsed 3 times using clean water. The washing process was carried out three times with flowing water with the aim of removing the sour taste of the product. The washed rice is then drained for five minutes. The cooking process was carried out by boiling using a rice cooker with a ratio of rice and water of 1:2.3. During cooking, seasonings are added (4 g of shallots, 3 g of garlic, 1 g of bay leaf, 1 g of lemongrass, 6 g of flavoring) for every 150 g of rice. The boiled rice was then cooled at room temperature. The boiled rice sample was then frozen at a low temperature of –41^{o}C for 24 hours to open the pores into dry, porous rice, so that the rehydration time by brewing was shorter (Sasmitaloka *et al*., 2019). After that, the dry boiled rice was blanched with hot steam (40 ^{o}C, 10 minutes) on the stove until the boiled rice under normal conditions. The boiled rice that has gone through the process of separating the grains of rice is dried using an oven at 60 ^{o}C for 6 hours.

2.3. Rehydration Time

Testing the rehydration time of instant nasi liwet was based on research conducted by Kurniasari *et al.* (2020). The rehydration time was carried out using the hot water brewing technique. Dry instant liwet rice is put in a container, then hot water is added. Determination of the length of rehydration time is when the texture of the rice becomes soft but does not develop. The purpose of the rehydration test is to determine the length of time the dry boiled rice is brewed until it is ready to serve.

2.4. Expansion Volume

The expansion volume was measured by soaking instant liwet rice in hot water at 100°C for 10 minutes, then drained. The volume becomes larger because dry, porous rice absorbs water with varying degrees of absorption. The shrinkage of boiled rice volume at 6 hours of soaking caused the rice soaked with sodium citrate to make the boiled rice wetter. This affects the freezing and drying processes, so that the porosity formed tends to be smaller, characterized by a greater water content value, denser texture and longer rehydration time than 4 hours of immersion. Expansion volume is indicated from the difference in height of instant dry rice with and without soaking. Testing the expansion volume of instant boiled rice was based on a reference (Lindriati *et al.*, 2014) by determining the initial volume (V_a) and final volume (V_t) as in the following equation.

$$V_p = \frac{V_t - V_a}{V_a} \times 100\% \quad (1)$$

2.5. Bulk Density

Bulk density of the boiled rice was measured using the method carried out by Le & Jittanit (2015) and Singh *et al.* (2005). Determination of bulk density (B_d) used equation (2), where W_r is the weight of dry rice (g), and V_r is the volume of dry rice (ml).

$$B_d = \frac{W_r}{V_r} \quad (2)$$

2.6. Texture

Texture testing was carried out using a Texture Profile Analysis (Rheotex SD-2700, Japan) tool based on research conducted by Rahmadi *et al.* (2021) with modifications. Texture testing was carried out with a flat pressure needle on a sample of dry bolied rice. Boiled rice samples were tested with a depth of 0.8 mm.

2.7. Yield

The yield of instant boiled rice is the ratio of the weight of instant boiled rice to the weight of the initial rice. The calculation of the yield (γ) of the boiled rice was determined by equation (3), where W_i is the initial weight of the material (rice) and W_n is the weight of boiled instant rice.

$$\gamma = \frac{Wn}{Wi} x100\% \quad (3)$$

2.8. Ash Content

The ash content of the boiled rice was determined by the procedure of the Association of Official Analytical Chemists (AOAC, 2005). Two grams of boiled rice sample was put into the furnace (Carbolite AAF1100), and was burnt in two stages, namely at 350 °C (2 hours) and continued at 550 °C (4 hours). Then put into a desiccator and weighed afterwards (Ijarotimi & Keshinro, 2013). The ash content was determined using equation (4) (Putri *et al*., 2020).

$$K_{ab} = \frac{m_{ab}}{m_b} x100\% \quad (4)$$

where K_{ab} is the ash content (%), m_b is the initial mass of the boiled rice sample (g), and m_{ab} is the mass of ash (g).

2.9. Water Content

The water content of instant boiled rice was determined using the standard AOAC 2005 procedure (Santana *et al.*, 2022; Thanimkarn *et al.*, 2020; Thuy *et al.*, 2020). Instant boiled rice (2 grams) was dried using oven (LDO-080N, Daihan Labtech Co., Ltd., Indonesia) at 105 ^{o}C for 6 hours. After that, it was put in a desiccator for 30 minutes and the final mass was weighed. The water content (K_a) of the boiled rice was determined by the equation (5), where m_{ap} is the initial mass of sample (g), and m_p is the final mass of sample (g).

3. RESULTS AND DISCUSSION

3.1. Rehydration Time

The relationship of variation in sodium citrate concentration and soaking time to rehydration time is shown in Figure 1 and Figure 2. The results of analysis of variance (ANOVA) indicate that variations in sodium citrate concentration and length of soaking time have a significant effect on rehydration time ($p < 0.05$). The interaction of the two treatments did not have a significant effect on the rehydration time of instant boiled rice at the level of $\alpha = 5\%$.

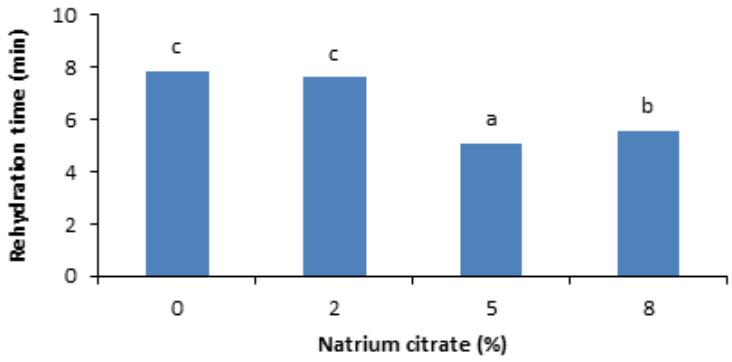

Figure 1. The Relationship of natrium citrate concentration to rehydration time of instan boiled rice

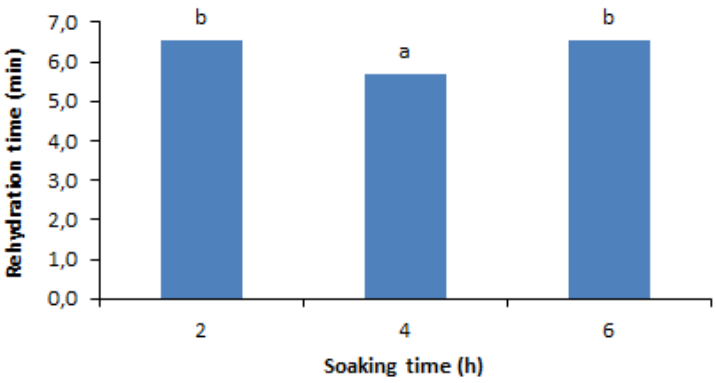

Figure 2. The relationship of soaking time to rehydration time of instan boiled rice

The results showed that the fastest hydration time was 4.55 minutes. This hydration time is faster than using infrared radiation for 5.17 minutes (Lang *et al.*, 2022). Perfectly hydrated rice is characterized by no white spot in the center of the grain. The rehydration test performed showed that sodium citrate with a high concentration and prolonged immersion tended to result in complete rehydration in a short time. The best concentration of sodium citrate is 5%. The higher the concentration of sodium citrate, the faster the rehydration time (Waluyo, 2020). The addition of sodium citrate before the cooking process acts as a modification of the protein structure which makes dry instant rice more porous (Luna *et al.*, 2015; Smith *et al.*, 1985). Porous rice results in accelerated rehydration time (Le & Jittanit, 2015; Waluyo *et al.*, 2020). Accelerated evaporation of instant rice can prevent tissue structure shrinkage (Le & Jittanit, 2015). Based on the results of research conducted by (Le & Jittanit, 2015) with stereo microscopy analysis, it was shown visually that freezing treatment could help increase the porosity of the tissue structure.

3.2. Expansion Volume

The expansion volume of instant liwet rice due to variations in sodium citrate concentration and soaking time is shown in Figure 3. The results of analysis of variance at the test level ($\alpha = 0.05$) show that variations in sodium citrate concentration and soaking time have an effect ($p < 0.05$) on the percent of expansion volume. The interaction of the two treatments gave a significantly different effect on the expansion volume of instant boiled rice.

The expansion volume of instant nasi liwet is an increase in volume that is affected by rehydration. The expansion volume of the instant boiled rice is 66.26-91.24%. The results showed that the increase in sodium citrate concentration and soaking time resulted in an increase in the expansion volume which was associated with the porosity of the liwet rice. Sasmitaloka *et al.* (2019) revealed that freezing for 24 hours provided a larger expansion volume as compared to that of freezing for 12-18 hours. The higher the concentration of sodium citrate, the better the porosity. Na-citrate is a compound that can damage and decompose the protein structure in rice so that the rice grains become more porous. But if the soaking time is longer it will cause the texture of instant rice after cooking to become wetter. This affects the cooling and drying process so that the texture when entering the drying process is more sticky and the final result is slightly denser.

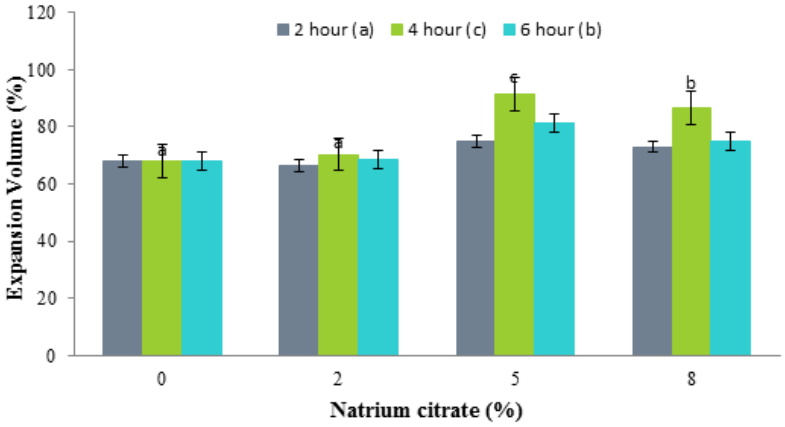

Figure 3. Expansion volume of the boiled rice after rehydration

The development of instant rice is caused by the swelling of starch which causes gelatinization. Briffaz *et al.* (2012) reported that the swelling caused by gelatinization was also due to the temperature factor. The increase in temperature also causes the gelatinization process to occur quickly and maximal.

3.3. Bulk Density

The bulk density of instant boiled rice due to variations in sodium citrate concentration and soaking time is shown in Figure 4. The results of the analysis of variance at the test level (α=0.05) show that variations in sodium citrate concentration and soaking time have an effect ($p<0.05$) to the bulk density value. The interaction of the two treatments did not have a significant effect on the bulk density of instant boiled rice.

Bulk density of the dried boiled rice is 0.413-0.581 g/ml. The data shows that the increase in the concentration of sodium citrate has an effect on decreasing the bulk density of boiled rice. In addition, the soaking time tends to decrease bulk density. At 6 hours of soaking time the bulk density of boiled rice did not increase which visually appear to be wetter and less sturdy, thus affecting the amount of water at the end of the freezing and drying process or mass loss occurs. The low bulk density indicates that dry instant rice products have many cavities (Sasmitaloka *et al.*, 2019). While the high bulk density indicates a dense structure of dry instant rice (Kurniasari *et al.*, 2020). The higher the concentration of Na-citrates, the lower the bulk density value of the instant boiled rice. According to Waluyo *et al.*, (2020), Na-citrate is a compound that break and decompose the protein structure in rice so that the rice grains become more porous and the bulk density is low.

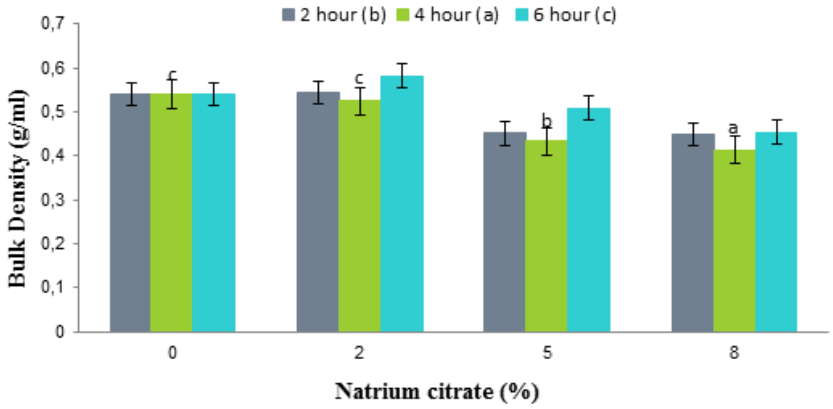

Figure 4. The relationship of Na-citrate on the bulk density of instant boiled rice

3.4. Hardness

The variation of sodium citrate concentration and soaking time on the hardness value is shown in Figures 5 and 6. The results of the analysis of variance at the test level (α = 0.05) showed that the variation of sodium citrate concentration and soaking time had an effect (p <0.05) on the hardness value. The interaction of the two treatments did not give a significant difference to the level of hardness of the instant boiled rice.

The hardness level of dry instant liwet rice in this study ranged from 431-1496 g/ mm. Research data informs that increasing concentration and soaking time causes a decrease in hardness. However, the control treatment had a lower texture value because the results of the drying of the boiled rice were not crispy (crunchy). In the 5-8% sodium citrate soaking treatment for 4-6 hours produces boiled rice with fluffy and soft texture. This is based on consumers who prefer high stickiness and low hardness

(Le & Jittanit, 2015). The increase in the texture of instant rice is caused by the presence of components released from the endosperm during cooking (boiling) that are retained on the aleurone wall to form a hard layer (Lang *et al.*, 2022; Wu *et al.*, 2016).

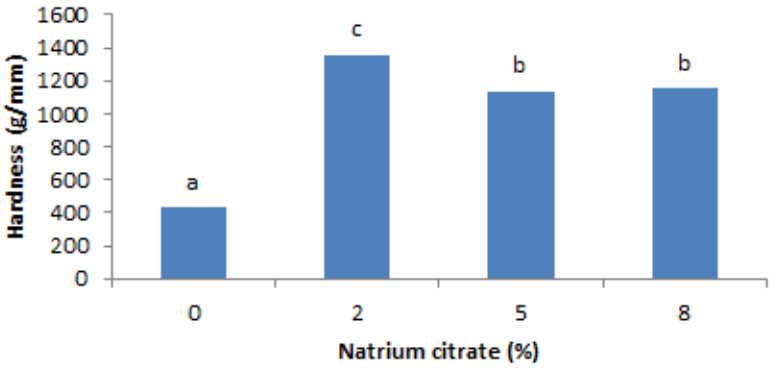

Figure 5. The relationship of Na-citrate on the hardness value of instant boiled rice

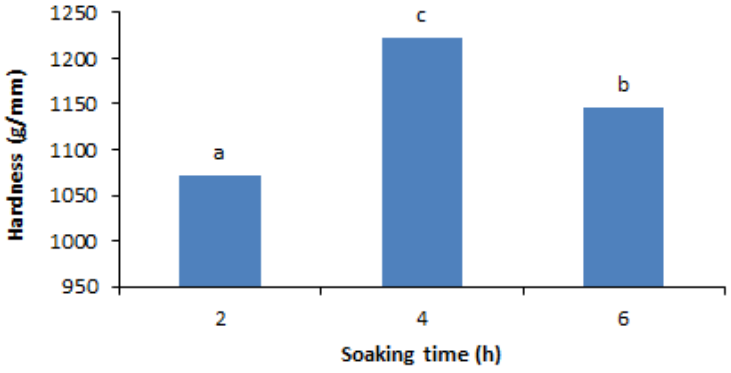

Figure 6. The relationship of soaking time on the hardness value of instan boiled rice

3.5. Yield

The relationship between variations in sodium citrate concentration and immersion time on the boiled rice yield is shown in Figures 7 and 8. The results of analysis of variance at the test level ($\alpha = 0.05$) show that variations in sodium citrate concentration and soaking time have a significant effect ($p < 0.05$) on yield. The interaction of the two treatments did not have a significant effect on the yield value of instant liwet rice.

The yield of instant liwet rice in this study ranged from 89.64–92.26%. The results of the research data showed that the increase in sodium citrate concentration and immersion time resulted in a decrease in yield. This decrease was due to the release of gel which was indicated by the cloudy color of the water during the cooking process. This phenomenon results in reduced carbohydrate content and low yields (Husain *et al.*, 2006). The higher the concentration of sodium citrate, the greater the final porosity obtained. However, the longer the soaking will affect the texture of the rice after cooking it becomes softer and stickier. This causes the process to be not optimal where after cooling it becomes more sticky and during drying the results are denser.

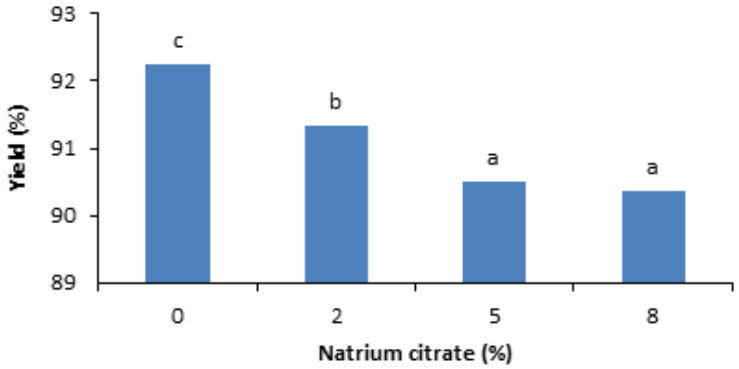

Figure 7. The relationship of Na-citrate concentration on the yield of instant boiled rice

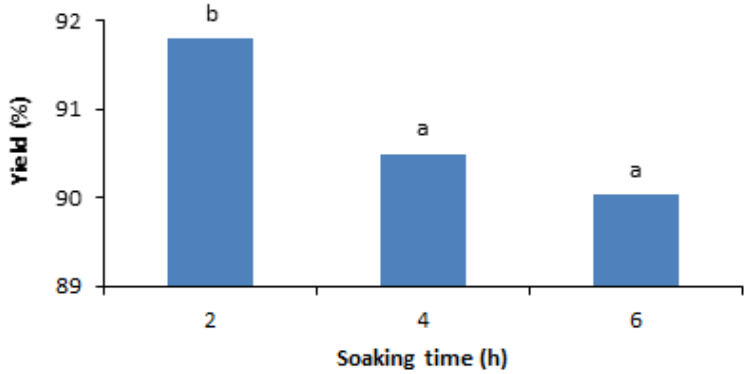

Figure 8. The relationship of soaking time on the hardness value of instan boiled rice

3.6. Ash Content

The relationship between variations in sodium citrate concentration and ash content of the instant boiled rice is shown in Figure 9. The results of analysis of variance at the test level ($\alpha = 0.05$) show that variations in sodium citrate concentration and soaking time have an effect ($p < 0.05$) on the percent ash content. The interaction of the two treatments did not give a significant difference to the ash content.

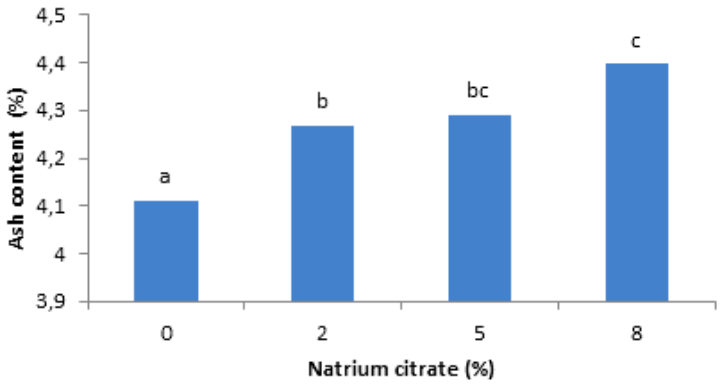

Figure 9. Relationship of Na-citrate concentration to ash content of instan boiled rice

The ash content of instant liwet rice is 4.11-4.45%. The results showed that the increase in sodium citrate concentration caused an increase in the ash content, while

soaking time resulted in a decrease in the ash content. The ash content of instant liwet rice in this study was higher than the results of research conducted by Sasmitaloka *et al.* (2019) using rice varieties Inpari 32 (0.53%) and IR-42 (0.76%). This increase in ash content is likely due to the presence of sodium citrate which is more absorbed by rice.

3.7. Moisture Content

The relationship between variations in sodium citrate concentration and immersion time on water content is shown in Figures 10 and 11. The results of analysis of variance at the test level (α=0.05) showed that variations in sodium citrate concentration and soaking time had an effect ($p<0.05$) on water content. The interaction of the two treatments gave a significantly different effect on the moisture content of the instant boiled rice.

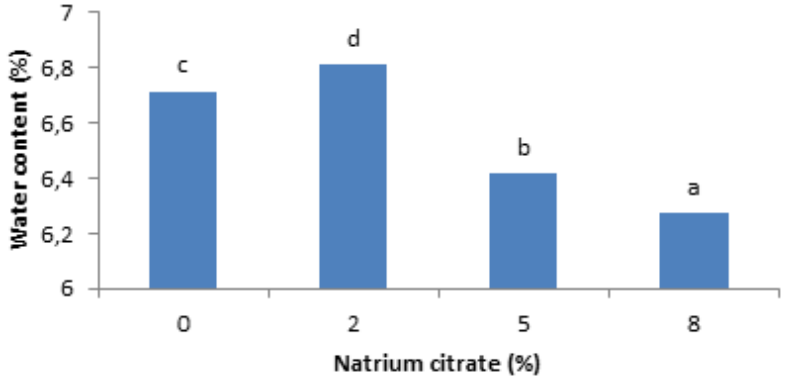

Figure 10. Relationship of Na-citrate concentration to water content of instant boiled rice

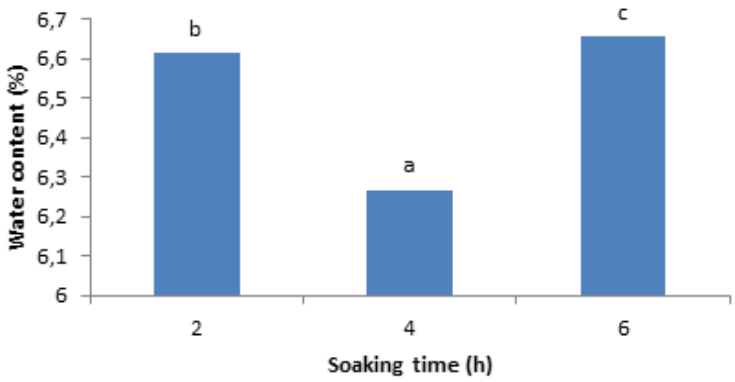

Figure 11. Relationship of soaking time to water content of instan boiled rice

The water content of instant boiled rice in this study ranged from 5.83-7.03% wt. The results also showed that the increase in sodium citrate concentration and soaking time resulted in a decrease in water content. The longer soaking time resulted in an increase in the amylose which was split so that the rice grains were limp when dried to form a hard layer and inhibit the rate of diffusion (Kurniasari *et al.*, 2020).

3.8. Best Treatment

The best treatment for instant liwet rice with sodium citrate concentration and soaking time was determined using the multiple attribute Zeleny method by calculating the

smallest value from all test results (Susilo et al., 2016) to determine the ideal value for the test parameters. Determination of the best treatment only uses data during the study so that data outside of that is not included in the calculation. The test results showed that the best treatment was soaking 5% sodium citrate for 4 hours. The physicochemical characteristics of the best treatment can be seen in Table 2.

Table 2. Characteristics of the best treatment for instant liwet rice

Physical Characteristic	Unit	Value
Water content	%wb	5.83
Ash content	%	4.25
Yield	%	90.1
Texsture (hardness)	g/mm	1157
Rehydration time	min.	4.55
Bulk density	g/ml	0.43
Expansion olume	%	91.2

4. CONCLUSION

The results showed that the concentration of sodium citrate and soaking time affected the physicochemical characteristics of instant liwet rice. With the addition of sodium citrate and soaking time the rice will reduce the value of water content, kamba density, texture, and yield. Meanwhile, the expansion volume and ash content of instant liwet rice showed an increase. Based on the parameters of rehydration time and expansion volume, it was concluded that the treatment of 5% (w/v) sodium citrate concentration with 4 hours of soaking time gave the best result.

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