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Physicochemical and Rheological Properties of Sago (MetroxylonSagu) Starch Modified with Lactic Acid Hydrolysis and UV Rotary Drying

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Modification of sago starch using acid hydrolysis will change some physicochemical and rheological properties. Sago is easy to grow in tropical areas of coastal areas, many found in eastern Indonesia has a simple ergonomic terms. Ingredients of sago starch is consist of 20-30% amylose and 70-80% amylopectin which make sago starch difficult to dissolve in cold water, easy to gelatinize, high viscosity, hard and not expands in baking process. This study will analyse modified sago using lactic acid hydrolysis method and use UV rotary drying for 20 minutes. The properties of modified sago starch were observed i.e. pH, density, solubility, swelling power, and baking expansion. Time variables hydrolysis is 10; 15; 20; 25; and 30 minutes with a rotation speed of 8 rpm at room temperature. The results showed that the solubility, swelling power and baking expansion was increase. The density results showed that the longer acid hydrolysis time can make the smaller in the density. Solubility and swelling power showed increasing significantly compared to native sago starch. Modification by using UV light changes significantly the properties characteristics of product.

Keywords : Sago Starch, Modification, Rotary Drying, Lactic Acid, Ultraviolet, Properties

INTRODUCTION

Sago is a tropical plant that grows easily in coastal areas (Flach, 1997). Sago availability is abundant but now, not widely used. Worldwide, sago production in 2010 was around in 230 million tons with an average productivity of 12.4 tons per hectare. The world's largest cassava producer is Nigeria (54 million tons per year), Indonesia (24 million tons per year), Brazil (23.5 million tons) and Thailand (22.5 million tons) (Veiga et al., 2016). Indonesia as one of the largest sago producers in the world has great potential to be developed into modified sago starch as a supporter of food diversification. Sago starch in Indonesia has traditionally been processed in a simple factory scale that produces native starch (native starch) (Tonukari, 2004).

Sago has a high carbohydrate content can be used as a substitute for wheat flour, in addition sago is very well used as a thickener that is better than tapioca (Syahariza and Yong, 2017). The starch is content of amylose and different amylopectin on sago starch determine the solubility, gelatinization, swelling power, gel stability. Sago native starch contains 70-80% more amylopectin while the amylose content is 15-30% (Wong et al., 2007). The constituent macromolecules of starch are packaged in a highly ordered and compact manner, resulting in inert, insoluble granules. The starch composed of polymers of amylose starch substance and amylopectin can be damaged by the influence of temperature changes on the cooking process (Oates, 1997).

Amylose is a long, straight, unbranched and hydrophobic chain polymer with α-(1,4) -D-glucose bonds (Nwokocha, 2008). Amylose possesses the ability to form strong gels and films, into biodegradable plastic (Lai et al., 2013), food coatings, candy making, coatings on drugs (Elham and Abdorreza, 2014; Muhammad et al., 2015). The breakdown of the amylose chain depends on the temperature, the substrate's enzyme properties and the length of the chain (Govindasamy et al., 1992). Amylose is one of the starch-forming polymers with α- (1.4) bonds of glucose forming a straight chain. β-amylase hydrolyses the amylose into a glucose residue unit by breaking the α-(1.4) chain from the non-reducing end of the amylose chain resulting in maltose (Hee-young, 2005). The characteristic of amylose in solution is the tendency to form very long and flexible coils that always move in circles. In the cooking process, starch gives a hard effect for food products (Hongsprabhas et al., 2007). Modified starch is expected to be used for the substitution of food products in many Industries (Sumardiono et al., 2016).

Sago starch tends to easily fall apart, resulting in a hard and less expanding product. Native sago starch undergoes high breakdown during heating and shearing and also exhibits relatively high retro gradation, resulting in the formation of a long cohesive gel with increased syneresis. The process of modification is done to improve the nature of natural sago starch into modified sago with gelatinization, swelling power, better solubility (Karim et al., 2008).

Various starch modification techniques such as enzyme hydrolysis (Wang et al., 1995), cross-linking (Yasir et al., 2014), oxidation (Karim et al., 2008). The weaknesses unmodified sago starch is likely to have a not pure white colours; it took a long time when the process of baking; harder pasta formed; not clearly; too sticky; and not resistant to acid (Sumardiono and Rakhmawati, 2017). The present study developed a modification using acid hydrolysis due to the inexpensive and effective method of increasing the solubility of sago starch, decreasing the molecular mass of starch, raising the temperature of gelatinization

(Abdorreza et al., 2012). The hydrolysis process occurs in the amorphous region causing surface erosion and the presence of porous grains observed using Scanning electron microscopy micrographs (Uthumporn et al., 2012).

This acid hydrolysis method of acid concentration, temperature, starch concentration and reaction time may vary depending on the nature of the starch desired. Amylose molecules are easily broken up compared with amylopectin molecules so that when acid hydrolysis takes place it will lower the amylose group. The disconnected starch will become dextrin and then split back into maltose with the end result being a simple glucose molecule. Starch thin-boiling is a modified starch obtained by hydrolysis by acidifying starch suspension to a certain pH and heating to a certain temperature until the desired degree of conversion is obtained (Atichokudomchaia et al., 2000).

In this study, hydrolysis process was added UV rays during hydrolysis and drying using UV rotary drying. Recently UV light radiation applications have grown rapidly in the world of food industry, and beverages, due to the cheaper price of UV lamps and easy to obtain, even available household-scale units, especially for drinking water treatment. Ultra Violet rays can be classified into 3 i.e. UV-A with wavelength 400-300 nm, UV-B with wavelength 315-280 nm and UV-C with wavelength 280-100 nm (Masschelein, 2002). The wavelength of UV light is called an actinic ray that involves energy waves that can provoke direct chemical changes in molecular radiation. Hydrolysis of lactic acid is capable of altering amylose, decreasing the viscosity of tapioca paste affecting its rheological properties, and also UV radiation on starch to increase the acidity and volume of bread dough during roasting (Bertolini et al., 2000).

UV rotary drying uses a long type of light for optimal UV drying process. UV use in the process of modifying sago starch hydrolysis here is developed in a simple UV rotary drying dryer. The optimum hydrolysis result was observed from the variation of hydrolysis duration which was then observed also physicochemical and rheological properties after drying using UV rotary drying. With the addition of UV in the process of hydrolysis, the desired change of physicochemical and rheological properties on the modification of sago starch will be better so that it can be further developed in the community.

MATERIALS AND METHODS

Materials

MERAPI sago starch packing by ITS-Yogyakarta traditionally has not been modified. Other ingredients used are lactic acid pa 99% (Merck), aquades and was used without any further treatment. All chemicals were of analytical grade.

Hydrolysed Modification Process of Sago Starch with UV Rotary Drying

Hydrolyse process

The hydrolysis process in the study was carried out with acid as a solvent to dissolve the original sago starch. The solvent comprises a mixture of lactic acid and aquades with measurable concentrations. The concentration of lactic acid to be used is 2.0% in 1000 ml of aquades. Lactic acid solution is used to dissolve sago pure as much as 500 grams. This treatment is mixing in a 2 litre beaker glass with a stirring magnet at room temperature. The dissolved results continue to use a magnetic stirrer at a rate of 8 rpm within 10, 15, 20, 25, 30 minutes hydrolysis time. When the suspension stirring process is irradiated with UV light during the drying process takes place. The resulting product is then filtered with 100 mesh filter paper followed by drying process.

Drying suspension on UV rotary drying

The drying and irradiation process is using rotary dryer with UV lamp for 10, 15, 20, 25, and 30 minutes. Rotary drying speed is fixed 12.0 rpm and drying temperature at 75^{0}C. The duration of the hydrolysis process is 10, 15, 20, 25, 30 minutes. The UV rotary drying can see in **fig.1**.

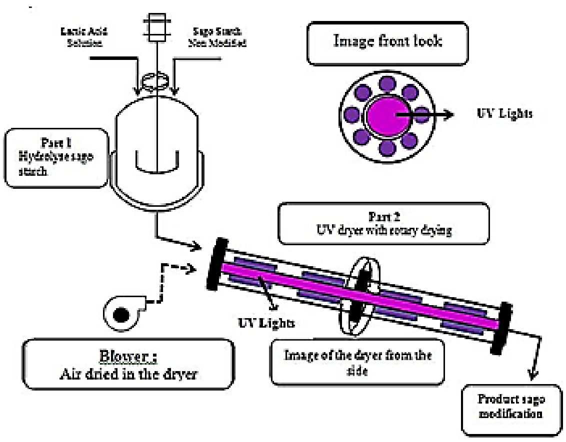

Fig. 1: UV Rotary UV DryingApparatus

Effects of acid hydrolysis and UV treatment on sago starch properties

The effect of acid and UV on hydrolysis process was analyzed and observed depend on several process of physicochemical testing. Modified results were tested for pH, density, swelling power, solubility and baking expansion. The results of the calculation analysis can show from changes the nature sago starch until it gets the optimum condition. Optimum condition of hydrolysis is seen from the best properties generated during the process

pH

The pH test was performed after hydrolysis process using pH meter by dissolving 1 gram of modified starch dissolved in 10 ml aquadest.

Density

The density test is carried out by measuring how much water volume changes when modified sago starch is added and the result of the density.

Swelling power of acid hydrolysis and UV-rotary drying sago starch

Swelling power was analysed by dissolving 0.1 grams of dextrin formed in 10 ml aquadest, heating the solution using water bath with temperature 60°C for 30 minutes, and separating the supernatant and paste formed using a centrifuge at 2500 rpm for 15 minutes (Leach, 1959).

Solubility of acid hydrolysis and UV-rotary drying sago starch

Dissolve 1 gram of dextrin into 20 ml of aquadest, heating the solution in water bath with temperature 60°C for 30 minutes. Separate the supernatant and paste formed using centrifuge at 3000 rpm for 20 minutes. Taking 10 ml of supernatant then dried in oven and recorded dry weight of precipitate (Kainuma, 1967).

Baking Expansion of acid hydrolysis and UV-rotary drying

Analyze the development of baking expansion by making the dough of mixing modified sago starch as much as 5 gram and 2.5 ml water until uniform and smooth. The dough is then formed into a small ball with a volume of 2-3 ml. Round dough small ball then fried for 3 minutes until cooked. Making small ball as much as 10 times to get more diverse data and. Measure the volume of the ball at the beginning (V_1) and end (V_2). The volume of ball is measured by changing the volume of measuring cup using cooking oil. The calculation is done by comparing the final ball volume with the initial ball volume (Bertolini, 2001).

RESULTS AND DISCUSSION

Hydrolysed Modification Process of Sago Starch with UV Rotary Drying

Sago modified using acids exhibit different properties such as decreased viscosity, decreased iodine binding ability, reduced granular swelling during gelatinization, decreased intrinsic viscosity, increased solubility in hot water under gelatinization temperature, lower gelatinization temperature, decreased osmotic pressure or molecular weight, increased ratio of heat to cold viscosity (Klanarong et al., 2002).

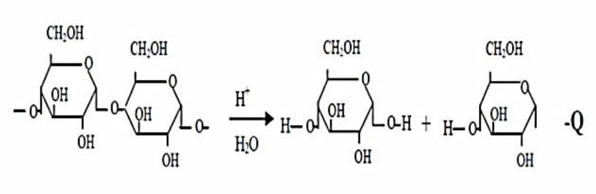

Fig. 2: Hydrolysisprocess in starch [11]

Hydrolysis process make the proportions of single helix and amorphous components as well as amylose content in starch gradually decreased, whereas the proportion of double helix components continuously increased during hydrolysis (Wang et al., 2017). The process of hydrolysis breaks the amylose chain and breaks the amylopectin bond so that the ability of the starch granules swells to be better. The increase in susceptibility to acid hydrolysis was proposed to result from defective and porous structures that resulted after pretreatment (Nakazawa and Wang, 2003). The viscosity and average molecular weight of hydrolyzed starch decreases, whereas the solubility and gel strength of the acid-thinned starch increase relative to the untreated starch (Thirathumthavorn and Charoenrein, 2005). Acid-thinned hydrolysis changes the physicochemical properties of the starch but does not alter its granular structure. Previous studies show that the gelatinization parameters of gelatinization temperature and enthalpy that increase upon hydrolysis (Abdorreza, 2012; Shi and Seib, 1992).

Table 1. Hydrolyzed time, pH, Density, Swelling power, Solubility, Baking Expansions.

Hydrolyzed (minutes)	pH	Density (gr/cm^3)	Swelling power (gr/gr)	Solubility (%)	BE (%)
10	2.3	3.16	4.26	12.10	1.33
15	2.3	2.66	4.89	13.02	1.53
20	2.8	2.40	6.92	14.06	1.60
25	2.8	1.67	7.34	14.64	1.80
30	2.9	1.25	8.66	15.86	2.00

Effects of acid hydrolysis and UV treatment on sago starch properties

The process of hydrolysis with lactic acid and UV light is done on 1% acid concentration with UV light irradiation for 20 minutes as well as duration drying of hydrolysed starch yields varies i.e.1.0; 1.5; 2.0; 2.5; and 3.0 minutes. Each treatment is then analyzed pH and density of modification product. Data modification is shown in **Table 1** and **Figure 3**.

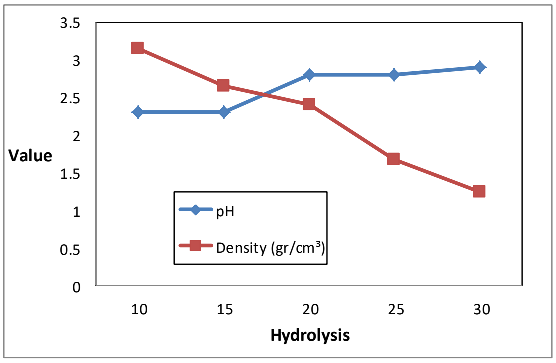

Fig. 3: Effects of acid hydrolysis with UV drying in pH and density properties.

The resulting that can be observed, pH can have the same value due to the use of lactic acid which acts as a lactic acid condition in modified starch. Lactic acid is a weak acid with another name 2-hydroxy propionate ($C_3H_6O_3$) having one hydroxyl group attached to the carboxyl group. The soluble lactic acid is weak and releases protons (H^+) in water to form lactate ions. Lactic acid is also soluble in alcohol is water-absorbing or hygroscopic. Lactic acid is selected in the process of hydrolysis of modified sago starch for its ability to absorb water, regulating a pH of between 2- 4.5, safe food preservatives and having carbonyl and carboxyl groups affecting starch viscosity properties (Kumalasari et al., 2013). The longer amount of starch and acid are irradiated with sunlight, the better resulted radiation properties are used to influence the properties of starch hydrolysis (Sumardiono et al., 2017).It is shown by decreasing of starch density which is inversely proportional to the length of hydrolysis time. The longer the hydrolysis process, was breakdown of the hydroxyl chain from UV radiation make granules broken. The granules are indicated from the density decreased in sago starch modified on **Fig.3**.

Swelling power

Swelling power is a characteristic that characterizes the developing power of a material, in this case the strength of starch to inflate. Sowing power occurs due to the increase in volume and maximum weight experienced by starch in water (Daramola and Osanyinlusi, 2006). Swelling power events occur due to non- covalent between starch molecules and occur in the amorphous (irregular) region of starch granules (Bamforth et al., 2003). The weakened hydrogen bond during the heating process causes water hydration by starch granules. The increase in swelling power values is thought to be due to the hydrophilic nature of the starch granules so as to bind to hydrogen in water molecules (Zhu, 2014).

Based on **table 1**, the value of swelling power for each variable ranges from 4.26-7.55 g / g. At variable speed of 12 rpm rotation, 75°C drying air temperature and 1.0% w / w lactic acid concentration gives the highest swelling power value of 7.55 gr / g. The acid treatment causes amylose and amylopectin on partially decomposed granules. This condition causes the water and air molecules to penetrate into the granules and is trapped in the amylose and amylopectin arrangements, so that when frying, water and air turn into water vapour that exerts out so that the volume development occurs (Ambarsari et al., 2011). In addition, the increased value of swelling power is thought to be due to the hydrophilic nature of starch granules so as to absorb water (Lee et al., 2005) and swell when heated with water (Zhu, 2014). From the other experimental results, the average of swelling power on cassava starch varieties between 3.51 to 11.25 g / g. The strength of the swell modified starch is higher than the original starch wherein the original starch swelling strength is 4.32 g/g. Increased swelling power caused by heating in aqueous media with a crystalline structure of swollen and open granules starch causes the bonding of hydrogen to break down in the amylose and amylopectin groups (Sumardiono et al., 2016).

If observed in terms of the effect of UV on the modification of starch hydrolysis using lactic acid there is a significant change. This is evidenced from the value of swelling power produced on the modification of 1% lactate with 30 minutes hydrolysis time without using UV is 7.96 g/g while the modification using UV of 9.28 g/g. This is in accordance with research conducted by (Bertolini et al., 2000) UV has a significant effect on the modification process that affects the swelling power properties of modified starch. UV light will provide chemical radiation, where the longer the radiation time will cause weakening of hydrogen bonds that connect between amylose and amylopectin, so that the starch granules will easily be hydrated by water. Thus, the value of swelling power with the long variable treatment of hydrolysis and UV irradiation gives a significant result (Bertolini et al., 2000).

This UV radiation has a great influence on the value of swelling power of modified starch. This is in accordance with the theory (Demiate et al., 2008) that the longer the number of modified starch with UV light means the higher the intensity of radiation that affects the nature of hydrolysed starch. This causes the starch chain to tend to be shorter and easier to absorb water. The water absorbed in each starch granule will make starch granules expand (Hee-Young, 2005) and coincide with each other thus increasing the value of its swelling power.

Solubility

Solubility is the ability of starch to be absorbed in water, so there is no emulsion. The amount of water-soluble starch can be measured by drying the resulting supernatant during the swelling power process. Based on **Table 1**, it can be seen that the solubility value in each variable ranges between 3% - 6%. In general, the modified starch solubility value is higher than natural starch which has a solubility value of 3.8%. The amorphous region is an expanding part and is susceptible to chemical reactions such as hydrolysis by acid or reacts by a functional group (Lee et al., 2005). The increase in the solubility of the modified starch is due to the stretching structure of starch due to the warming temperature rise. The heat will weaken the hydrogen bonds so that the starch structure is primarily an area that has many amylose molecules and branches of amylopectin becomes stretched (Rukmi and Siwi, 2010). In addition, the amylose and amylopectin chains are degraded by radiant energy from UV rays in the dryer and the process of hydrolysis with lactic acid which can decrease the molecular weight of starch so as to increase its solubility (Henry et al., 2010; Omojola et al., 2011). It also affects viscosity resulting in a decrease in viscosity where the bonds between molecules will also be low, so the water binding will be easier.

In **Table 1** it can also be seen that the data obtained solubility results vary greatly. Differences in solubility values in modified sago may occur due to differences in amylose and amylopectin levels. The reported that starch containing different amylose content would have different swelling power and solubility values (Chen et al., 2011). According to Flach (1997), when the starch molecule is completely hydrated, the molecules begin to spread to the outer media. The first molecule out is the amylose molecules that have short chains. During heating will occur breakdown of starch granules, so that starch with higher amylose content, granule will release more amylose. The solubility pattern can be determined by measuring the weight of the supernatant that has been dried. There is a positive correlation between amylose and starch solubility.

Baking Expansion

The ability to inflate modified tapioca starch is strongly influenced by amylose content. Amylose can bind water well, so it gets taller the amylose content in the starch then the dough gets expanded (Moorthy et al., 2006). According to, the level of development and texture of food mild (snack) is affected by the ratio of amylose and amylopectin (Sumardiono et al., 2016). Starch that has high amylopectin content tends to give the character of fragile product, easily broken and gelatinization (Shi and Seib, 1992). Amylose will provide a more resistant texture easy to break (crunchy).

Starch modification is using lactic acid in food application has been carried out with lactic acid concentration ranging from 1% to 5.4% (Sumardiono et al., 2016). The addition of lactic acid causes the starch to degraded, so the starch viscosity is reduced because amylopectin starch in starch dissolved in lactic acid. It will lead to an increase of baking expansion (Sumardiono et al., 2016).

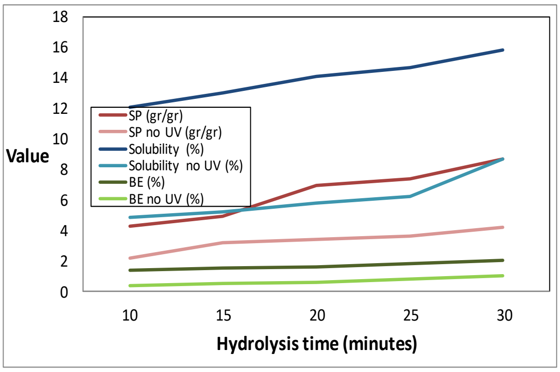

Fig. 4: Effects of acid hydrolysis and UV treatment

CONCLUSIONS

Hydrolized can changes the physicochemical and reology in sago starch product. Modification of sago with lactic acid in UV rotary drier gives effect to physicochemical properties of sago in the form of increasing of swelling power and solubility value. The best result of modified starch was obtained at 30 minutes Hydrolysis variable time in pH 2.9 and UV drying at temperature 75^{0}C, and acid concentration1.00% w/w. The results of the analysis was obtained conditions of swelling power, solubility, and baking expansion development in a row; 8.66%; 15.86 g/g; and 2 %. Results of the study appear to changes in the rheological properties of psychochemicalis significant between native sago starch and the modified starch with swelling power and solubility.

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