

Characterization of Physicochemical and Baking Expansion Properties of Oxidized Sago Starch Using Hydrogen Peroxide and Sodium Hypochlorite Catalyzed By UV Irradiation

Eduard Fransisco Tethool*, Abadi Jading, Budi Santoso

Faculty of Agriculture and Agriculture Technology, The State University Of Papua

Jl. Gunung Salju, Amban, Manokwari, Papua Barat 98314, Indonesia

* E-mail of the corresponding author: eduard_tethool@yahoo.com

Abstract

This study investigate the effect of oxidation using hydrogen peroxide and sodium hypochlorite on physicochemical and baking expansion properties of oxidized sago starch. Type of oxidant and irradiation time (10,15 and 20 min) were studied. The extent of oxidation was determined based on starch color, carboxyl, carbonyl, and amylose contents, swelling power and solubility, and baking expansion properties of oxidized starch. The results showed that L* value increased with oxidation reaction using peroxide and hypochlorite as oxidant and longer time of UV irradiation. Carbonyl content of peroxide- and hypochlorite-oxidized starch decreased by increasing of UV irradiation time. Carboxyl content was increased by increasing irradiation time at 15 min and then decrease at 20 min irradiation time. Increasing irradiation time, increasing amylose content of oxidized sago starch. Swelling power and solubility of oxidized sago starch increase from 10 min to 15 min irradiation time and then decrease at 20 min irradiation time. Swelling power and solubility of peroxide-oxidized sago starch was higher than hypochlorite-oxidized starch. Oxidation reaction decrease the pasting temperature and increase peak viscosity, hot paste viscosity and cool paste viscosity of sago starch. The peak viscosity and hot paste viscosity of peroxide-oxidized sago starch are higher than hypochlorite-oxidized starch. Oxidation of starch using peroxide and hypochlorite catalyzed UV irradiation increased specific volume of starch. Baking expansion of hypochlorite-oxidized starch is lower than peroxide-oxidized starch. Oxidation starch using peroxide with UV irradiation for 15 min gave the highest specific volume of sago starch at 8.65 mL/g with degree of baking expansion 65,6%.

Keywords: Sago starch, oxidation, hydrogen peroxide, sodium hypochlorite, UV irradiation

1. Introduction

Native starch have been used since ancient time as a raw material to prepare different products in food and non-food industries. Sago starch is one kinds of nnative starch derived from the pith of Sago Palm (*Metroxylon sago*). Sago palm is one of the important economic plants, mainly because it has the highest yield of starch in terms of its caloric yield per hectare. Its grown in several humid tropical countries, such as Indonesia, Malaysia and Thailand (Lim et al., 1991).

Sago starch is more difficult to used as raw material for refined products in the food industry because of the limitations of its physicochemical properties (Limbongan, 2007). Tethool et al., (2009) reported that sago starch has low swelling power, whereas this properties is required in food industry, especially noodles and bakery. But the shortcomings of starch physicochemical properties may be overcome by modifications, either by chemical, physical or enzymatic methods (Ketola and Hagberg, 2003).

Oxidation of starch is one of a chemically modification. This method is important and widely used, because the resulted starch has a low viscosity, high stability, clarity, film forming and binding properties (Sanchez-Rivera et al., 2005). Oxidized starch has been used in many industries particularly in the paper, textile, laundry finishing and binding materials industries to provide surface sizing and coating properties (Kuakpetoon and Wang, 2006). One of the important properties of oxidized starches to be applied in the food industry is baking expansion properties (Bertolini et al., 2001; Demiate et al., 2000).

Oxidized starch is produced by reacting starch with a specific amount of oxidizing agents under controlled temperature and pH (Wang & Wang, 2003). Several oxidizing agents have been applied to starch oxidation including sodium hypochlorite, bromine, periodate, permanganate and ammonium persulfate. Among them hypochlorite oxidation is the most common method for the production of oxidized starch in an industrial scale, because it is very efficient and cheap (Sanchez-Rivera et al., 2005). Hydrogen peroxide, is the other oxidizing agent, has been used in a commercial practice. In the oxidation of starch, hydrogen peroxide does not produce

harmful by product, because decomposes inevitably to oxygen and water. Therefore, these chemical are safer and more environmentally friendly, making it suitable applied in the food industry (Ketola and Hagberg, 2003).

Several studies on the oxidation of starch in presence of Ultraviolet (UV) light has been done (Vatanasuchart et al., 2003; Vatanasuchart et al., 2005; Lorlowhakarn and Naivikul, 2005). El-Sheikh et al., (2010) reported that cassava starch oxidation with UV irradiation are affected on the physicochemical properties. Another research states that UV irradiation is important for baking expansion ability of cassava starch and its biscuit products (Bertolini et al., 2001; Vatanasuchart et al., 2003; Vatanasuchart et al., 2005). This is caused the oxidizing agents such as hydrogen peroxy and hypochlorite which exposed to UV light will be formed the radical groups that trigger the oxidation process (El-Sheikh et al., 2010; Wang et al., 2012).

The purpose of this study was to compare the physicochemical and baking expansion properties of peroxide- and hypochlorite-oxidized sago starch. Sago starch was oxidized use hydrogen peroxide and sodium hypochlorite with catalized by UV irradiations at varying oxidation times. The change in physicochemical and baking expansion behavior were evaluated and compare.

2. Materials and Methods

2.1. Source of Raw Materials

Native sago starch was obtained from traditional market in Manokwari, Indonesia. Hydrogen peroxide (30%) and sodium hypochlorite containing 10% active chlorine (w/w) was obtained from Merck (Germany), and all other chemicals for analysis were analytical grade.

2.2. Design of Photochemical Reactor

Photochemical reactor design was shown in Fig.1. The photochemical reactor equipped with stainless steel reactor tank to place the material and mechanical stirring to prevent precipitation of starch during oxidation reaction, pump to circulate slurry through a stainless steel funnel containing an UV lamp with 100-400 nm wavelength, the funnel being designed in such a way that its volume is smaller than the total volume of the slurry to be treated.

2.3. Preparation of peroxide-oxidized sago starch

Oxidation of starch was performed used UV catalizator instrument (Fig. 1), with UV light (wavelengths 100-400 nm) as an oxidation catalyst. Hydrogen peroxide oxidation of sago starch catalyzed by UV irradiation was prepared as previously described by El-Sheikh et al., (2010) with some modification. A known weight of native sago starch was mixed with a known volume of distilled water to making the starch-water slurry, with material:liquor ratio is 1:6. The starch slurry inserted into the reactor tank (No.1), and then 3% of hydrogen peroxide based on weight starch were added to the slurry. Starch slurry is pumped (No. 2) and circulated through the tube of UV irradiation (No. 4) and UV light was immersed. The process of oxidation with UV irradiation was performed for 10, 15, and 20 minutes (the time was counted after all oxidant was added and UV light was turned on). To prevent precipitation of starch during oxidation, mechanical stirring was performed (No.5). After the oxidation, the oxidized starch can be separated from reacting slurry by filtration. The separated oxidized starch were washed with distilled water and dried in a drying oven at 50 °C.

2.4. Preparation of hypochlorite-oxidized sago starch

Sodium hypochlorite oxidation of sago starch catalyzed by UV irradiation was carried out as described by Sangseethong et al., (2009) with some modifications. Oxidation with UV irradiation was performed as described in the oxidation with hydrogen peroxide. The native sago starch was mixed with a distilled water to making the starch-water slurry with 1:6 ratio, and then 3% of sodium hypochlorite based on weight starch were added. Starch slurry is pumped and circulated through the tube of UV irradiation and UV light was immersed for 10, 15 and 20 minutes. After the oxidation, the oxidized starch can be separated from reacting slurry by filtration. The separated oxidized starch were washed with distilled water and then be dried in a drying oven at 50 °C.

2.5. Starch color measurement

The color of oxidized starch in terms of L*, a* and b* values were measured by Chromameter CR-400 (Konica-Minolta, Japan).

2.6. Amylose content

Amylose content of oxidized sago starch determined by iodine assay method from AOAC (2005).

2.7. Swelling Power and Solubility

Swelling power and solubility of the oxidized starches were determined by a procedure described by Adebowale et al., (2002). A starch sample 1.0 g was accurately weighed and quantitatively transferred into a clear dried test tube and re-weighed (W1). The starch was then dispersed in 50 ml of distilled water. The resultant slurry was heated at 95°C for 30 min. The mixture was cooled to 30°C and centrifugated (500 rpm, 15 min). Aliquots (5 ml) of the supernatant were dried to a constant weight at 110 °C. The residue obtained after drying the supernatant represented the amount of starch solubilised in water. Solubility was calculated as g per 100 g of starch on a dry weight basis.

The residue obtained from the above experiment (after centrifugation) with the water it retained was quantitatively transferred to the clean dried test tube used earlier and weighed (W2).

$$\text{Swelling of starch} = \frac{(W2-W1)}{(\text{weight of starch})}$$

2.8. Carbonyl content

The carbonyl content was determined as described by Kuakpetoon and Wang (2001). Starch sample (4g) was slurried in 100 mL of distilled water. The slurry was gelatinized in a boiling water bath for 20 min, cooled to 40 °C and adjusted to pH 3.2 with 0.1 M HCl. Then 15 mL of hydroxylamine reagent was added. The flask was stoppered and agitated in a water bath at 40 °C. After 4 h, the sample was rapidly titrated to pH 3.2 with 0.1 M HCl. A blank determination with only hydroxylamine reagent was performed in the same manner. The hydroxylamine reagent was prepared by dissolving 25g hydroxylamine hydrochloride in 100 mL of 0.5 M NaOH. The final volume was then adjusted to 500mL with distilled water. Carbonyl content was calculated as follows:

$$\text{Carbonyl content} = \frac{[(\text{blank} - \text{sample})\text{mL} \times \text{Acid Normality} \times 0.028 \times 100]}{\text{sample weight (g, dry basis)}}$$

2.9. Carboxyl content

The carboxyl content of starch was determined using a modification of FAO method described by Sangseethong et al., (2010). Starch sample (5g) was stirred in 25mL of 0.1 M HCl for 30 min. The slurry was then filtered and washed with distilled water until free of chloride ions. The filtered cake was transferred to a 600 mL beaker, and the volume was adjusted to 300 mL with distilled water. The starch slurry was heated in a boiling water bath with continuous stirring for 15 min to ensure complete gelatinization. The hot sample was immediately titrated with 0.1 M NaOH using phenolphthalein as indicator. A blank determination was run on the original sample in the same manner but being stirred in 25 mL of distilled water instead of 0.1 M HCl. Carboxyl content was calculated as follows:

$$\text{Carboxyl content} = \frac{[(\text{sample} - \text{blank})\text{mL} \times N \text{ NaOH} \times 100]}{\text{sample weight (g, dry basis)}} \times 0.045$$

2.10. Pasting properties

The RVA parameters were determined using the RVA according to Zaidul et al., (2007). Each sample of native and oxidized sagu starch was added to 25 ml of distilled water to prepare a 6% suspension on a dry weight basis (w/w).. Each suspension was kept at 50 °C for 1 min and then heated up to 95 °C at 12.2 °C/min and held for 2.5 min at 95 °C. It was then cooled to 50 °C at 11.8 °C/min and kept for 2 min at 50 °C. The pasting temperature (PT), peak viscosity (PV), hot paste viscosity (holding; HPV), cool paste viscosity (CPV) and their derivative parameters breakdown (BD = PV - HPV), and setback (SB = CPV - PV) were recorded and presented in centipoise (cP).

2.11. Baking expansion properties

The baking property of starches was determined as described by Demiate et al., (2000) with some modification. The baking property was measured by weighing 10g of starch sample and partially cooking by addition of 10 mL of boiling de-ionized water over this starch mass. This partially cooked starch was homogenized to produce a dough, that was molded to three small balls and baked on an electric oven at 200 °C for 25 min. After baking, the doughs were weighed, and made impermeable by using paraffin and their volumes determined on graduated cylinders as the volume of water displaced. The expansion was obtained by dividing volume by weight and was expressed as specific volume (mL/g).

2.12. Statistical analysis

The data obtained from this study were analyzed using analysis of variance at a 95% confidence level and comparisons significant for all treatments used LSD test. SPSS v17.0 software (SPSS Inc.) was used to analyze

the data.

3. Results and Discussion

3.1. Color evaluation of oxidized starch

Table 1 showed the effect of hydrogen peroxide and sodium hypochlorite oxidation catalyzed by UV irradiation on oxidized sago starch color. The L^* value was a parameter for characterizing starch color and it was a direct measurement of its whiteness. The L^* value increased, when UV irradiation time was increase. The L^* value close to 100 indicates white material. Increasing the L^* value due to the peroxy groups and active chlorine produced while UV irradiation time can act as bleaching agent (Sanchez-Rivera et al., 2005; Indra, 2009). But when 10 min of UV irradiation time, L^* value of oxidized sago starch was lower than L^* value of native sago starch. This is probably due to the presence of polyphenol oxidase enzyme at native sago starch that promotes enzymatic browning. This reaction cannot be completely eliminated during the modification processes (Miftahorrahman and Novariant, 2003; Flores et al., 2010). During oxidation process, aldehyde groups is formed and its presence increase the b^* value or yellownes of starch color (Chiu and Solarek, 2009).

3.2. Amylose content

Amylose content, swelling power and solubility of oxidized sago starch are shown in Table 2. Amylose content of sago starch increase with peroxide and hypochlorite oxidation process. Increasing irradiation time, increase amylose content of oxidized sago starch. Increasing amylose content might be due to depolymerization of starch molecules into the polymer chain with chain lengths shorter in greater numbers (Kuakpetoon and Wang, 2006). Besides carbonyl and carboxyl groups formed while oxidation reaction, oxidation also causes degradation of starch molecules by mainly cleaving amylose and amylopectin molecules at α -1,4 glucosidic linkages (Wang and Wang, 2003).

3.3. Swelling power and solubility

Swelling power and solubility of oxidized sago starch was increase from 10 min to 15 min irradiation time and then decrease. Increasing swelling power might be attributed to the formation of more hydrophilic groups ($-COOH$) during oxidation (Lee et al., 2005). Decreasing swelling power when increasing irradiation time may be due to photocrosslinking occur during oxidation reaction. Photocrosslinking inhibit swelling power of oxidized starch (Wang and Wang, 2003; Lorlowhakarn and Naivikul, 2005)

Solubility indicate a quantity of soluble starch molecules at a certain temperature. Table 2 showed that solubility of starch will increase along with peroxide and hypochlorite oxidation reaction. The UV Irradiation time until 15 min increasing solubility, but at 20 min time irradiation the starch solubility was decreased. Increasing solubility of starch after oxidation process resulting from the depolymerization and weakening structure of starch granule cause amylose leaching occured (Adebowale et al., 2002; Lorlowhakarn and Naivikul, 2005). Decreasing the starch solubility at 20 min time irradiation might be due to photocrosslinking of starch molecule was occur while oxidation reaction. These crosslinks could stabilize the swollen granules and overcome the negative impact from minor depolymerization (Kuakpetoon and Wang, 2001; Wang and Wang, 2003). Table 2 showed that swelling power and solubility of peroxide-oxidized sago starch higher than hypochlorite-oxidized starch.

3.4. Carbonyl and carboxyl content

During oxidation process, hydroxyl groups on starch molecules are oxidized to carbonyl and carboxyl groups. Kuakpetoon and Wang (2006) and El-Sheikh et al., (2010) have proposed a consecutive reaction path in which hydroxyl groups in starch molecules are first oxidized to carbonyl groups and then to carboxyl groups. It is depending on the type of oxidant used and the reaction conditions. Parallel reaction paths in which carbonyl or carboxyl groups are selectively formed by oxidation of the hydroxyl groups at C-2, C-3, and C-6 positions (Kuakpetoon and Wang, 2006).

Carbonyl and carboxyl content of peroxide- and hypochlorite-oxidized sago starch are shown in Table 3. Carbonyl content of peroxide and hypochlorite-oxidized starch decrease by increasing UV irradiation time. Decreasing carbonyl content may be due to carbonyl groups formed while oxidation reaction are converted to carboxyl groups (El-Sheikh et al., 2010; Sangseethong et al., 2010; Zavareze et al., 2010). Carboxyl content increase by increasing irradiation time at 15 min and then decrease. Increasing of carboxyl content may be due to further oxidation of the carbonyl to carboxyl groups and after 15 min reaction the decarboxylation occurs (El-Sheikh et al., 2010).

Carbonyl was a primary functional group produced in the peroxide-oxidized starches, while carboxyl was a primary functional group produced hypochlorite-oxidized starch (Vatanasuchart et al., 2005).

3.5. Pasting properties

Table 4 showed the pasting properties of peroxide- and hypochlorite-oxidized sago starch. The pasting temperature of oxidized starch was lower than native sago starch. Peak viscosity, hot paste (holding) viscosity and cool paste viscosity increase with oxidation reaction. Decreasing pasting temperature might be due to increasing hydration capacity of starch molecules, so the energy necessary to carry out the gelatinization process decrease (Zaidul et al., 2007; Wang and Wang, 2003). Increasing peak viscosity was attributed to the formation of hemiacetal or hemiketal cross-links from oxidation, which are assumed to occur mostly among amylopectin molecules and to a lesser extent between amylopectin and amylose molecules. Crosslinking was attributed to increasing molecular weight and paste viscosity (Kuakpetoon and Wang, 2006; Wang and Wang, 2003).

The peak viscosity and hot paste viscosity of peroxide-oxidized sago starch higher than hypochlorite-oxidized starch. This phenomenon might be due to hemiacetal crosslink formation and it increase of the starch molecular weight. The cool paste viscosity of hypochlorite-oxidized starch higher than peroxide-oxidized starch. Increased UV irradiation time, increasing cool paste viscosity. This phenomenon due to amylose chains were solubilized during the heating step forming a network that had a more compact structure (Sanchez-Rivera et al., 2005). This condition attribute to increasing cool paste viscosity and setback of hypochlorite-oxidized starch.

3.6. Baking test

Table 5 showed baking expansion properties of peroxide- and hypochlorite-oxidized sago starch. The starch oxidation using peroxide and hypochlorite catalyzed by UV irradiation are effectively increasing specific volume of the oxidized starch. Oxidation using peroxide with UV irradiation time for 15 min produce the highest specific volume of sago starch at 8.65 mL/g with degree of baking expansion 65,6% compared to native sago starch. While oxidation using sodium hypochlorite with UV irradiation time for 10 min gave the lowest specific volume at 7,35 mL/g with degree of baking expansion 40,7%. Figure 2 showed baking expansion of oxidized sago starch.

Increased degree of baking expansion due to carbonyl and carboxyl groups formation while oxidation reaction. Carbonyl and carboxyl groups are affect to increasing hydration capacity of oxidized sago starch (Wang and Wang, 2003). Increased hydration capacity of starch contribute to water bonding increase in starch molecules, and it affect increasing water vapor and internal pressure during baking process. Increased the baking expansion due to the formation of matrix amorph structure along with hydrogen bonds (Bertolini et al., 2001). Baking expansion of hypochlorite-oxidized starch is lower than peroxide-oxidized starch. This phenomenon might be due to the formation of more compact amylose structure while gelatinization process and its inhibit increased of the baking expansion (Sanchez-Rivera et al., 2005; Vatanasuchart et al., 2003).

4. Conclusions

Oxidation sago starch using hydrogen peroxide and sodium hypochlorite catalyzed by UV irradiation are affected on physicochemical properties of oxidized sago starch. Carbonyl content of peroxide- and hypochlorite-oxidized starch decrease by increasing UV irradiation time. Carboxyl content increase by increasing of irradiation time at 15 min and then decrease at 20 min irradiation time. Increasing irradiation time, increasing amylose content of oxidized sago starch. Swelling power and solubility of oxidized sago starch increase at 10 min to 15 min irradiation time and then decrease at 20 min irradiation time. Swelling power and solubility of peroxide-oxidized sago starch was higher than hypochlorite-oxidized starch. Oxidation reaction decrease the pasting temperature and increase peak viscosity, hot paste viscosity and cool paste viscosity of oxidized sago starch. The peak viscosity and hot paste viscosity of peroxide-oxidized sago starch higher than hypochlorite-oxidized starch. Oxidized starch is suitable to improve baking properties. Oxidation starch using peroxide with UV irradiation time for 15 min gave the highest specific volume of sago starch at 8.65 mL/g with degree of baking expansion 65.6%.

Acknowledgements

The authors gratefully acknowledge the financial support for this study provided by the Insentif Riset SINas 2012 (No. 1.50/SEK/IRS/PPK/I/2012) by The Ministry of Research and Technology, Republic of Indonesia.

References

- Adebowale, K.O., Afolabi, T.A., & Lawal, O.S. (2002). Isolation, chemical modification and physicochemical characterisation of Bambarra groundnut (*Voandzeia subterranean*) starch and flour. *Food Chemistry*, 78, 305–311. [http://dx.doi.org/10.1016/S0308-8146\(02\)00100-0](http://dx.doi.org/10.1016/S0308-8146(02)00100-0)
- Association of Official Agricultural Chemists (AOAC). (2005). *Official Methods of Analysis of AOAC International*. Arlington. Virginia. USA.
- Bertolini, A.C., Mestres, C., Lourdin, D., del Valle, G., & Colonna, P. (2001). Relationship between thermomechanical properties and baking expansion of sour cassava starch (*Polvilho Azedo*). *Journal of the Science of Food and Agriculture*, 81, 429–435. doi : 10.1002/1097-0010(200103)81:4<429: AID-JSFA833>3.0.CO;2-2.
- Chiu, C., & Solarek, D. (2009). Modification of Starches. In : R. L. Whistler & J.N. BeMiller (eds). *Starch Chemistry and Technology* 3rd ed. pp.629-655). New York: Academic Press.
- Demiante, I.M., Dupuy, N., Huvenne, J.P., Cereda, M.P., & Wosiacki, G. (2000). Relationship between baking behavior of modified cassava starches and starch chemical structure determined by FTIR spectroscopy. *Carbohydrate Polymers*, 42, 149-158. [http://dx.doi.org/10.1016/S0144-8617\(99\)00152-6](http://dx.doi.org/10.1016/S0144-8617(99)00152-6)
- El-sheikh, M. A., Ramadan, M. A., & El-shafie, A. (2010). Photo-oxidation of rice starch. Part I: Using hydrogen peroxide. *Carbohydrate Polymers*, 80, 266-269. doi:10.1016/j.carbpol.2009.11.023
- Flores, Z., Vargas-Torres, A., Gutiérrez-Meraz, F., & Bello-Pérez, L.A. (2010). Physicochemical Characterization of Dually Modified Banana Starch. *Agrociencia*, 44: 283-295. <http://dx.doi.org/10.1021/jf1035004>.
- Indra, Antonius. (2009). Pengaruh pH, penambahan hidrogen peroksida, dan benzil peroksida, pada proses pembuatan tepung singkong terhadap karakteristiknya. Tesis. Gadjah Mada University. (*In Indonesian*)
- Ketola, H., & Hagberg, P. (2003). Modified Starch. US Patent Office, Pat. No. 6,670,470.
- Kuakpetoon, D., & Wang, Y.J. (2001). Characterization of different starches oxidized by hypochlorite. *Starch/Starkë*, 53, 211-218. doi: 10.1002/1521-379X(200105)53:5<211::AID-STAR211>3.0.CO;2-M
- Kuakpetoon, D., & Wang, Y.J. (2006). Structural characteristics and physicochemical properties of oxidized corn starches varying in amylose content. *Carbohydrate Research*, 341, 1896-1915. <http://dx.doi.org/10.1016/j.carres.2006.04.013>.
- Lee, J.S., Kumar, R.N., Rozman, H.D., & Azemi, B.M.N. (2005). Pasting, swelling, and solubility properties of uv initiated starch-graft-poly(AA). *Food Chemistry* 91:203-211. <http://dx.doi.org/10.1016/j.foodchem.2003.08.032>.
- Lim, E. T., Ahmad, B., Tie, Y. L., Hueh, H. S., & Jong, F. C. (1991). Utilization of tropical peats for the cultivation of Sago (*Metroxylon* spp.). Paper presented at the Internasional Symposium on Tropical Peat Land, Kuching, 12-18.
- Limbongan, J. (2007). Morfologi beberapa jenis sagu potensial di Papua. *Jurnal Penelitian dan Pengembangan Pertanian*. 26 (1):16-24. (*In Indonesian*).
- Lorlowhakarn, K., & Naivikul, O. (2005). Modification of rice flour by uv irradiation to improve rice noodle quality. *Proceeding The 3rd Conference of Starch Technology*.
- Miftahorrhachman & Novrianto, H. (2003). Jenis-jenis sagu potensial di Sentani Irian Jaya. *Proceeding National Conference of Sago*. Manado, 6 Oktober 2003. Balai Penelitian Tanaman Kelapa dan Palma Lain, Manado (*in Indonesian*).
- Sanchez-Rivera, M.M., Garcia-Suarez, F.J.L., del Valle, V.M., Gutierrez-Meraz, F., & Bello-Perez, L.A. (2005). Partial Characterization of banana starches oxidized by different levels of sodium hypochlorite. *Carbohydrate Polymers*, 62, 50-56. doi:10.1016/j.carbpol.2005.07.005
- Sangseethong, K., Lertphanich, S., & Sriroth, K. (2009). Physicochemical properties of oxidized cassava starch prepared under various alkalinity levels. *Starch/Starkë*, 61, 92-100. doi: 10.1002/star.200800048
- Sangseethong, K., Termvejsayanon, N., and Sriroth, K. (2010). Characterization of physicochemical properties of hypochlorite- and peroxide-oxidized cassava starches. *Carbohydrate Polymers*, 82, 446-453. doi:10.1016/j.carbpol.2010.05.003
- Tethool, E.F., Sarungalo, Z.L., & Santoso, B. (2009). Sifat fisikokimia dan daya cerna empat kultivar pati sagu asal Sentani Papua. *Research Report of IRN 2008*. Faculty of Agricultural and Agricultural Technology. The State University of Papua. (*In Indonesian*).

Vatanasuchart, N., Naivikul, O., Charoenrein, S., & Sriroth, K. (2003). Effect of different UV irradiations on properties of cassava starch and biscuit expansion. *Kasetsart Journal (Natural Science)*, 37, 334-344.

Vatanasuchart, N., Naivikul, O., Charoenrein, S., & Sriroth, K. (2005). Molecular properties of cassava starch modified with different UV irradiation to enhance baking expansion. *Carbohydrate Polymers*, 61, 80-87. <http://dx.doi.org/10.1016/j.carbpol.2005.02.012>.

Wang, D., Bolton, J.R., & Hofmann, R. (2012). Medium pressure UV combined with chlorine advanced oxidation for trichloroethylene destruction in a model water. *Journal of Water Research*. 46 (15):77-86. <http://dx.doi.org/10.1016/j.watres.2012.06.007>

Wang, Y.J., & Wang, L. (2003). Physicochemical properties of common and waxy corn starch oxidized by different level of sodium hypochlorite. *Carbohydrate Polymers* 52 : 207-217. [http://dx.doi.org/10.1016/S0144-8617\(02\)003041](http://dx.doi.org/10.1016/S0144-8617(02)003041)

Zaidul, I.S.M., Norulaini, N.A.N., Omar, A.K.M., Yamauchi, H., & Noda, T. (2007). RVA analysis of mixtures of wheat flour and potato, sweet potato, yam, and cassava starches. *Carbohydrate Polymers*, 69, 784–791. [doi:10.1016/j.carbpol.2007.02.021](http://dx.doi.org/10.1016/j.carbpol.2007.02.021)

Zavareze, E.d.R., Tavares, A.C.K., Elton Z., Elizabete H., Dias, A.R.G. (2010). The effects of acids and oxidative modification on the expansion properties of rice flour with varying levels of amylose. *LWT Food Science and Technology* 93 : 1213-1219. <http://dx.doi.org/10.1016/j.lwt.2010.04.007>

Table 1. Effect of hydrogen peroxide and sodium hypochlorite oxidation catalyzed by UV irradiation on oxidized sago starch color

Sampel treatments		Starch color		
Oxidizing agent	irradiation time (min)	L*	a*	b*
Native Sago Starch		87.86	1.72	2.76
H ₂ O ₂	10	85.32	3.45	2.85
	15	89.48	3.20	3.15
	20	90.56	2.84	3.63
NaOCl	10	84.12	3.49	2.86
	15	87.94	3.35	3.07
	20	88.45	3.26	3.20

Result are expressed as an average of three replications. Means in a column with different superscripts are significantly different at P<0.05 by ANOVA and LSD

Table 2. Effect of hydrogen peroxide and sodium hypochlorite oxidation catalyzed by UV irradiation on amylose content, swelling power and solubility of oxidized sago starch

Sampel treatments		Amylose content (%)	Swelling (%)	Solubility (%)
Oxidizing agent	irradiation time (min)			
Native Sago Starch		31.9 ± 0.25 ^a	38.1 ± 0.92 ^d	25.3 ± 0.47 ^c
H ₂ O ₂	10	33.7 ± 0.41 ^b	36.2 ± 0.12 ^c	28.2 ± 0.36 ^d
	15	33.8 ± 0.14 ^{bc}	40.1 ± 1.37 ^e	35.1 ± 0.35 ^f
	20	34.5 ± 0.46 ^{cd}	37.8 ± 0.15 ^d	33.6 ± 0.18 ^e
NaOCl	10	33.3 ± 0.48 ^b	33.5 ± 0.57 ^{ab}	18.4 ± 0.02 ^a
	15	33.8 ± 0.54 ^{bc}	34.6 ± 0.19 ^b	23.6 ± 0.14 ^b
	20	34.8 ± 0.16 ^d	32.8 ± 0.22 ^a	17.9 ± 0.23 ^a

Result are expressed as an average of three replications. Means in a column with different superscripts are significantly different at P<0.05 by ANOVA and LSD

Table 3. Effect of hydrogen peroxide and sodium hypochlorite oxidation catalyzed by UV irradiation on carbonyl and carboxyl content of oxidized sago starch

Sampel treatments		Carbonyl content (%)	Carboxyl content (%)
Oxidizing agent	irradiation time (min)		
Native Sago Starch		0.45 ± 0.02 ^{ab}	0.33 ± 0.03 ^b
H ₂ O ₂	10	0.52 ± 0.04 ^c	0.23 ± 0.02 ^a
	15	0.49 ± 0.04 ^{bc}	0.44 ± 0.04 ^c
	20	0.44 ± 0.02 ^{ab}	0.35 ± 0.03 ^b
NaOCl	10	0.49 ± 0.03 ^{bc}	0.30 ± 0.04 ^b
	15	0.43 ± 0.03 ^a	0.32 ± 0.04 ^b
	20	0.41 ± 0.02 ^a	0.29 ± 0.03 ^b

Result are expressed as an average of three replications. Means in a column with different superscripts are significantly different at P<0.05 by ANOVA and LSD

Table 4. Effect of peroxide and hypochlorite-oxidized with UV irradiation on pasting properties of oxidized sago starch

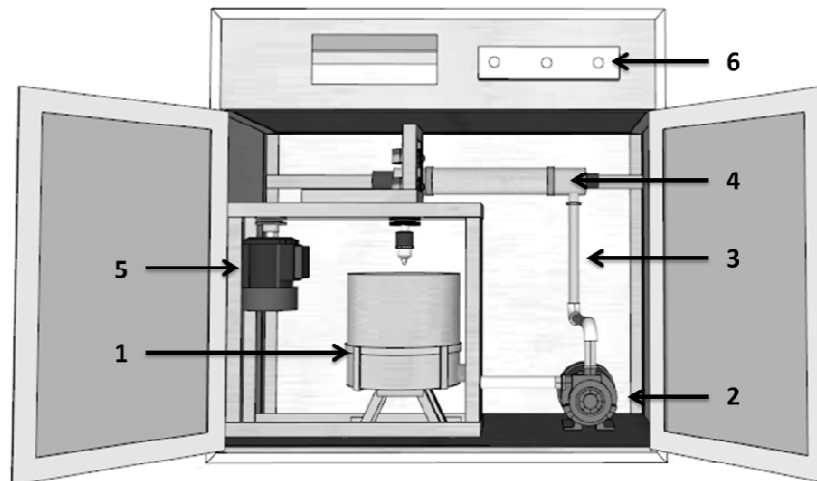
Sampel treatments		Pasting Temp (°C)	Peak Viscosity (cP)	Hot Paste Viscosity (cP)	Cool Paste Viscosity (cP)	Break Down	Set Back
Oxidizing agent	irradiation time (min)						
Native Sago Starch		72.6	471.5	480.0	865	-8.5	393.5
H ₂ O ₂	10	68.8	590.4	585.4	982.7	5.0	392.3
	15	69.2	692.0	642.8	975.0	49.2	283.0
	20	68.2	651.7	615.6	1032.9	36.1	381.2
NaOCl	10	71.6	490.5	485.4	1006.4	5.1	515.9
	15	70.5	532.0	545.0	1021.5	-13.0	489.5
	20	70.1	556.2	560.2	1038.0	-4.0	481.8

Table 5. Effect of peroxide and hypochlorite-oxidized with UV irradiation on baking expansion of oxidized sago starch

Sampel treatments		Specific volume (mL/g)	Degree of Baking Expansion (%)*
Oxidizing agent	irradiation time (min)		
Native Sago Starch		5.22 ± 0.42 ^a	-
H ₂ O ₂	10	7.58 ± 0.33 ^b	45.1
	15	8.65 ± 0.29 ^c	65.6
	20	8.43 ± 0.22 ^c	61.4
NaOCl	10	7.35 ± 0.19 ^b	40.7
	15	7.62 ± 0.23 ^b	46.0
	20	7.68 ± 0.26 ^b	47.1

Result are expressed as an average of three replications. Means in a column with different superscripts are significantly different at P<0.05 by ANOVA and LSD.

* sample treatments compare with native sago starch



Note :

- | | |
|------------------------|---------------------|
| 1. Reactor tank | 2. Circulation pump |
| 3. Circulation pipe | 4. UV lamp tube |
| 5. Mechanical stirring | 6. Control panel |

Figure 1. UV catalyst instrument.

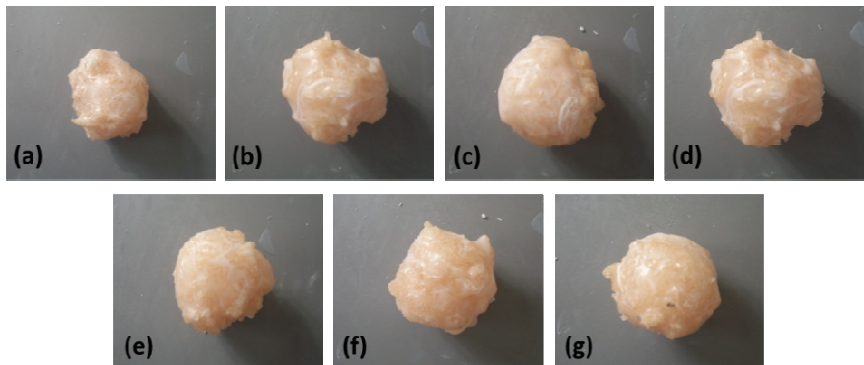


Figure 2. Baking expansion of oxidized sago starch. a) Native Starch; b) H_2O_2 for 10 min; c) H_2O_2 for 15 min; d) H_2O_2 for 20 min; e) NaOCl for 10 min; f) NaOCl for 15 min; g) NaOCl for 20 min

This academic article was published by The International Institute for Science, Technology and Education (IISTE). The IISTE is a pioneer in the Open Access Publishing service based in the U.S. and Europe. The aim of the institute is Accelerating Global Knowledge Sharing.

More information about the publisher can be found in the IISTE's homepage:

<http://www.iiste.org>

CALL FOR PAPERS

The IISTE is currently hosting more than 30 peer-reviewed academic journals and collaborating with academic institutions around the world. There's no deadline for submission. **Prospective authors of IISTE journals can find the submission instruction on the following page:** <http://www.iiste.org/Journals/>

The IISTE editorial team promises to review and publish all the qualified submissions in a **fast** manner. All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Printed version of the journals is also available upon request from readers and authors.

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digital Library, NewJour, Google Scholar

