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Research Article

Physicochemical and baking expansion properties of peroxide oxidized sago starch with different UV irradiation

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Abstract

Sago starch was modified by oxidation using hydrogen peroxide 3% based dry matter of starch irradiated with UV C and the drained starch was irradiated with different UV lamps (UV A, UV B, and UV C) for 8 h. The physicochemical and baking expansion properties of peroxide-oxidized starch were studied. Peroxide-oxidized starch irradiated with UV A gave the highest swelling power of 9.63±0.14%, while UV B and UV C irradiated peroxide-oxidized starch gave 8.58±0.21%, and 7.08±0.59% respectively. Treatment with different UV irradiation did not affect the solubility of sago starch. Irradiation with different UV lamps had an affect on carboxyl and carbonyl contents of peroxide-oxidized starch. Oxidation treatment did not achieve the desired baking expansion. Specific volume of peroxide-oxidized sago starch treatment with different UV irradiation gave no significant difference of specific volume. Peroxide-oxidized starch with no UV irradiation gave the lowest specific volume of 2.59 ± 0.34 cm^3/g.

Keywords: hydrogen peroxide, *Metroxylon sago,* swelling power, Indonesia.

Introduction

Sago palm (*Metroxylon sago*) is one of the important economic plants in Papua, because it has the highest yield of starch in terms of its caloric yield per hectare. [1]. Sago starch is derived from the pith of the Sago Palm. Sago starch is more difficult to use as raw material in the food industry because of the limitations of its physicochemical properties [2]. Tethool *et al.*, [3] reported that sago starch has low swelling power, whereas this property is required in the food industry, especially noodles and bakery. Its shortcomings of starch physicochemical properties may be overcome by modification, either by chemical, physical or enzymatic methods [4].

Oxidation is one of the choices for chemical modification. This method is important and widely used, because the resultant starch has low viscosity, high stability, clarity, film forming and binding properties [5]. One of the important properties of oxidized starch to be applied in the food industry is baking expansion properties [6, 7]. Oxidized starch is produced by reacting starch with a specific amount of oxidizing agents under controlled temperature and pH [8]. Several oxidizing agents have been applied to starch oxidation. Hydrogen peroxide is one such agent and it has been used in commercial practice. In the oxidation of starch, hydrogen peroxide does not produce any harmful byproducts because it decomposes inevitably to oxygen and water. Therefore, this chemical is safer and more environmentally friendly, making it suitable for application in the food industry [4].

Several reseachers have stated that UV irradiation is essential for baking expansion ability of starch [6, 9]. Vatanasuchart *et al* [10] reported that cassava starch modified with 1% lactic acid hydrolysis for 15 min and exposed to UV B and UV C radiation for 7,9 and 11 h had effective baking expansion properties.

Thus this study was aimed at examining the effect of different UV irradiation of peroxide-oxidized sago starch on the physicochemical and baking expansion properties of modified sago starch.

Materials and Method

Materials

Native sago starch was obtained from a traditional market in Manokwari, Indonesia. Hydrogen peroxide (30%) was obtained from Merck (Germany) and all other chemicals for analysis were analytical grade.

Equipment

The equipment used in this research are photochemical reactor to oxidation reaction and cabinet oven complete with different UV lamps to dry the starch. Photochemical reactor equipped with a stainless steel cylinder to material placed, pump to circulate slurry through a stainles steel funnel containing a UV lamp, the funnel being designed in such a way that its volume is smaller than the total volume of the slurry to be treated.

The cabinet ovens were equipped with ultraviolet light as the source of irradiation, that are UV-A (Philips, TL 23W) emitting radiation of 315-400 nm, UV-B (Philips TL 100W) emitting radiation of 270-310 nm and UV-C emitting radiation of 100-250 nm, as described by Vatanasuchart *et al.*, [10].

Preparation of peroxide-oxidized starch ttreatment with different UV irradiation

A known weight of sago starch was mixed with a known volume of distilled water to make the starch-water slurry with material:liquor ratio of 1:6. The starch slurry was inserted into the reactor tank and then 3% of hydrogen peroxide based on weight of starch was added to the slurry. Starch slurry was then pumped and circulated through the tube of UV light. The process of oxidation with UV irradiation was performed for 15 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. After the oxidation, the oxidized starch was separated from reacting slurry by sedimentation. The separated oxidized starch was washed with distilled water. Then the samples were placed in three different UV cabinets, which were lined with polished aluminum and supplied air circulator. The samples were dried with hot air oven and then treated with different UV lamps. There were (i) five UV A lamps (Philips, TL 23W) emitting radiation of 315 – 400 nm; (ii) two UV B lamps (Philips, TL 100W) emitting radiation of 270-310 nm; and (iii) three UV C lamps emitting energy 100-250 nm. The peroxide-oxidized starch was dried at 60^{o}C with different UV exposure periods of 8 h. The UV irradiated oxidized starch was then compared to the peroxide-oxidized starch dried in a conventional hot air oven at 60^{o}C for the same periods.

Baking expansion properties

The baking property of starches was determined as described by Demiate *et al.*, [7], 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 in 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 (cm^3/g).

Pasting properties

The RVA parameters were determined using the method according to Zaidul *et al.*, [11]. Each sample of native and oxidized sago 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 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).

Determination of carbonyl and carboxyl content

The carboxyl contents of the oxidized starches were determined using a procedure described by Paruvouri *et al* [12]. Starch sample 5 g was slurried in 25 ml of 0.1M hydrochloric acid and the solution was stirred occasionally over a period of 30 min. The slurry was then filtered and the residue was washed with distilled water until it was chloride-free.The sample was transferred to a beaker and suspended in 300ml of distilled water. The suspension was heated in a boiling water bath with continuous stirring for about 10 min to ensure complete gelatinization. The hot sample was titrated to pH 8.3 with 0.025 M sodium hydroxide solution.

The carbonyl contents of the oxidized starches were determined by a hydroxyl amine method described by Paruvouri *et al* [12]. Starch sample 2 g was suspended in 100 ml of distilled water and the suspension was gelatinized by heating in a boiling water bath and then cooled to 40°C. The pH was then adjusted to 3.2 and 15 ml of hydroxylamine reagent was added. The hydroxylamine reagent was prepared by dissolving 25 g hydroxylamine hydrochloride in distilled water, adding 100 ml of 0.5M sodium hydroxide and diluting the mixture to 500ml. The sample was covered with aluminium foil and placed in a water bath at 40°C. After 4 h the excess hydroxylamine was determined by rapid titration of the reaction mixture to pH 3.2 with 0.1M hydrochloric acid.

Swelling power and solubility

Swelling power and solubility of the oxidized starches were determined by a procedure described by [13]. A starch sample 1.0 g was accurately weighed and quantitatively transferred into a clear dried test tube and re-weighed (W_1). 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 (W_2).

Swelling of starch = $W_2 - W_1$/weight of starch

Statistical analysis

Factorial in Completely Randomized Design (CRD) was used as an experimental design. The SPSS v17.0 was employed to analyse the results which were obtained from three replications. Means and standard deviations for analyzing baking expansion, carbonyl and carboxyl contents, swelling power and solubility were calculated and the analysis of ANOVA and DMRT were used to compare the difference of the mean values at the 0.05 confidence level.

Results and Disscusion

Baking expansion properties

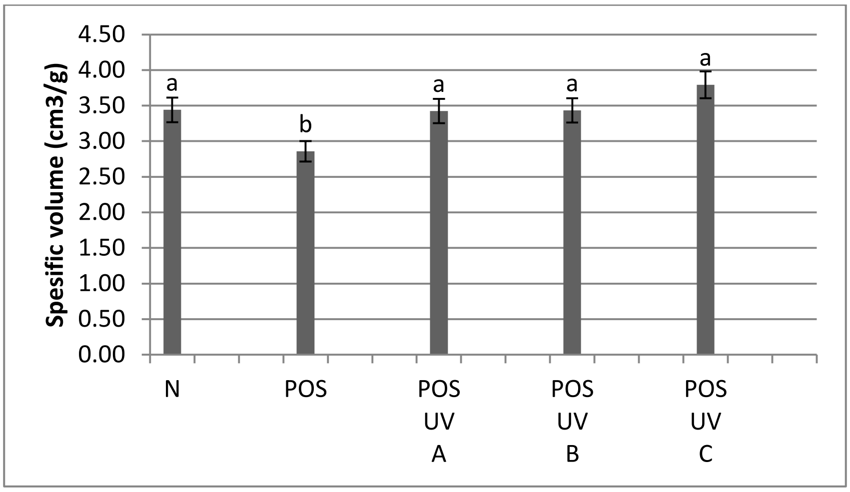

Figure 1. Specific volumes of peroxide-oxidized sago starch.
(bars not sharing a common letter are significantly different at P<0.05)
N : Native sago starch ; POS : Peroxide-oxidized starch; POS UV A : Peroxide-Oxidized starch irradiated with UV A; POS UV B : Peroxide-Oxidized starch irradiated with UV B; POS UV C : Peroxide-Oxidized starch irradiated with UV C.

The spesific volume of peroxide-oxidized sago starch with different UV irradiation is shown in Figure 1. The results showed that no significant difference in specific volume for native sago starch, oxidized starch treated with UV A, UV B and UV C irradiation with spesific volume 3.44 ± 0.09 cm^3/g; 3.42 ± 0.11 cm^3/g; 3.43 ± 0.22 cm^3/g and 3.79 ± 0.20 cm^3/g. Peroxide-oxidized sago starch treated with no irradiation showed the lowest baking expansion with specific volume 2.59 ± 0.34 cm^3/g. UV irradiation of starch molecules lead to oxidative degradation at glycosidic bonds, both amylose and amylopectin [6] and formation of cross linking structure under a long period of irradiation [14]. The increasing of baking expansion presented a model for dough expansion during oven rise and stages of the bubble growth in viscous fluid. Increasing viscosity and increasing internal bubble pressure gave rise to larger tensile stresses on the cell surface which resulted in cell rupture at the end of oven rise [10].

Pasting properties

Table 1. Pasting properties of native sago starch and peroxide-oxidized sago starch treated with different UV irradiation.

Sample treatments	**Peak** (cP)	**Through** (cP)	**Breakdown** (cP)	**Final** (cP)	**Setback** (cP)
Native	1551	444	1107	962	518
Non UV irradiation	1072	326	746	574	248
UV A irradiation	1455	554	901	1104	550
UV B irradiation	1419	551	868	1056	505
UV C irradiation	1175	428	747	886	458

The pasting properties of native sago starch and peroxide-oxidized sago starch treated with different UV irradiation are shown in Table 1. Peak viscosity of peroxide-oxidized starch treatment with different UV irradiation were lower than native starch. Peroxide-oxidized sago starch with treatment of no UV irradiation showed the lowest peak viscosity and setback viscosity. Decreasing viscosity may be due to degradation of starch molecules by mainly cleaving amylose and amylopectin molecules at α-1,4 glucosidic linkages [15]. It was found that there is a linear relationship between peak viscosity and spesific volume of starches. The peroxide-oxidized sago starch treated with no UV irradiation gave the lowest specific volume and showed the lowest peak viscosity. Thus, this starch could have application in bakery products although it had the lowest baking expansion. From Table 2 it can be seen that the peroxide-oxidized starch with no UV irradiation gave the lowest setback viscosity. This suggests that the retrogradation process was inhibited due to oxidation and it produced the high stability texture of the product.

Table 2. Pasting temperature properties of peroxide-oxidized sago starch treatment with different UV irradiation.

Sample treatments	Gelatinization temperature (°C)	
	Onset	Peak
Native starch	74	80
Non UV irradiation	73	79
UV A	70	79
UV B	71	79.5
UV C	73	78

The gelatinization temperatures of peroxide-oxidized starch are shown in Table 2. It was found that oxidation reaction treatment with different UV irradiation decreased the onset and peak temperatures. This might be due to lack of stability of crystalline structure induced by modification reactions [9].

Carbonyl and carboxyl contents

Table 3. Carbonyl and carboxyl contents of peroxide-oxidized sago starch treatment with different UV irradiation.

Sample treatments	Carboxyl contents	Carbonyl contents
Non UV irradiation	0.031 ± 0.02^{ab}	0.78 ± 0.06^{a}
UV A	0.070 ± 0.01^{a}	0.32 ± 0.15^{b}
UV B	0.017 ± 0.006^{b}	0.62 ± 0.16^{ab}
UV C	0.026 ± 0.02^{ab}	0.93 ± 0.07^{b}

Results are expressed as an average of three replications. Means in column not sharing a common superscript are significantly different at R<0.05 by ANOVA and DMRT

The carbonyl and carboxyl contents of peroxide-oxidized sago starch are shown in Table 3. The peroxide-oxidized starch treated with UV A showed the highest carboxyl content than that of other treatments with values. The peroxide-oxidized starch treated with UV C gave the highest carbonyl content. During oxidation process, hydroxyl groups on starch molecules are oxidized to carbonyl and carboxyl groups, contributing improved stability to starch paste. The reaction also causes degradation of starch molecules resulting in low viscosity. The relationship between the formation of carbonyl and carboxyl groups during starch oxidation is not yet completely understood. Kuakpetoon and Wang [15] and El Shafie *et al.* [16] 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 dependent 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 certain positions on the glucosidic ring are also reported.

Swelling power and solubility

Table 4. Swelling power and solubility of peroxide-oxidized sago starch treatment with different UV irradiation.

Sample treatments	Swelling power (%)	Solubility (%)
Non UV irradiation	8.69±0.83^{ab}	0.30±0.19^{a}
UV A	9.63±0.14^{a}	0.26±0.11^{a}
UV B	8.58±0.21^{b}	0.19±0.03^{a}
UV C	7.08±0.59^{c}	0.38±0.15^{a}

Results are expressed as an average of three replications. Means in column not sharing a common superscript are significantly different at R<0.05 by ANOVA and DMRT.

Swelling power and solubility of oxidized starch can be seen in Table 4. When starch is heated in excess water, the crystalline structure is disrupted and water molecules become linked by hydrogen bonding to the exposed hydroxyl groups of amylose and amylopectin. This causes an increase in granule swelling and solubility. Swelling power and solubility provide evidence of the magnitude of interaction between starch chains within the amorphous and crystalline domains. Peroxide-oxidized sago starch treatment with UV A irradiation gave the highest swelling power. The increased swelling power might be attributed to the formation of more hydrophilic groups (–COOH) during oxidation [17].

Solubility may indicate a quantity of soluble starch molecules at a certain temperature. From analysis of the results obtained by the solubility of peroxide-oxidized starch shows no significant difference.

Conclusion

In this study, the treatment with different UV irradiation did not significantly affect the baking expansion of sago starch. Thus the structure of peroxide-oxidized sago starch treatments with UV irradiation was acccesible to absorbing water and holding it during gelatinization which lead to high peak viscosities. The decreasing pasting temperature could confirm the lack of network formation in peroxide-oxidized sago starch. The peroxide-oxidized sago starch with no UV irradiation could have application in bakery products, although it has the lowest baking expansion.

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