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Research Article

Modification of Gajah Cassava Starch Originating from East Borneo, Indonesia, using Ozone Oxidation

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Abstract

Background and Objective: Cassava is an abundant, low cost and renewable food source. The Gajah variety of cassava, which originates from East Borneo, Indonesia, has a high potential as a source of starch. Oxidation using ozone is an environmentally friendly technology that is safe and does not generate waste products. Oxidized cassava starch is a raw material for various food products. This research aimed to investigate the oxidation of cassava starch using ozone for different ozonation times and study its properties, including the carbonyl and carboxyl contents, color, swelling power, solubility and pasting ability. **Materials and Methods:** Gajah cassava starch was obtained from East Borneo, Indonesia. Oxidation of a 10% cassava starch suspension was performed using 2 ppm dissolved ozone, stirring at 300 rpm for 0, 15, 30, 45 and 60 min at 30°C. **Results:** The data showed that the carbonyl, carboxyl and amylose contents, whiteness index, solubility and starch paste clarity increased with increasing ozonation time and increased from 0.02-0.12%, 0.04-0.14%, 35.76-41.38%, 87.27-92.43%, 34.08-85.56% and 27.62-81.56% respectively. However, the swelling and pasting abilities decreased. **Conclusion:** It can be concluded that oxidation of Gajah cassava starch using ozone improves its characteristics, increasing its potential as a raw material for many food products.

Key words: East Borneo, gajah cassava starch, oxidation, ozonation time, ozone

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cassava is a source of food that is abundant, low cost and renewable[1,2]. One cassava variety is the Gajah cassava, originating from East Borneo, Indonesia. Gajah cassava has the advantage of increased tuber weight and is resistant to several diseases[3]. Wibisono[4] and Amarullah[5] stated that gajah cassava has a tuber weight range of 20-25 kg of tubers/tree at the age of 9 months and a production capacity of up to 100 t of tuber ha^{-1}. It has high potential as a source for raw industrial starch-based materials and other derivative products[6]. Natural starch has limited properties, so it needs to be modified. Modified starch has several advantages, such as new functional features and added value for some products based on diverse industry needs[7]. Chemical methods can be used for starch modification. Oxidation is one of the chemical processes used to modify starch. Hydrogen peroxide, sodium hypochlorite, calcium hypochlorite and potassium permanganate can be used as oxidizers in the process of starch oxidation[8]. However, the use of these reagents produces toxic waste[9]. The development of an alternative method that uses nonhazardous chemical reagents is necessary. Ozone is a potential oxidizing agent that is safe and environmentally friendly. It is not toxic, easily degrades into oxygen, does not cause pollution to the environment and leaves no residue in the final product[9,10]. Ozone has a reduction potential of 2.07 eV, which is higher than that of the commonly used oxidant hydrogen peroxide[11]. The oxidation of starch molecules converts hydroxyl groups to carbonyl and carboxyl groups. The carbonyl group is an intermediate product and the carboxyl group is the final product[12]. Recently, researchers have studied using ozone as an oxidizing agent in starch oxidation. However, this process has not been explored deeply for various sources of starch. It was performed mainly on Gajah cassava starch from East Borneo, Indonesia. Since this initial report, studies on ozone-oxidized starch have been carried out on rice[13], wheat[14], yam[15], corn and sago starch[16].

There are many benefits of oxidized starch. In the paper and textile industry, oxidized starch has been used extensively as a sizing agent. It can increase the mechanical properties and formation of paper films, paperboard and textiles. It is applied as a binding agent to the components of the paper web, including fibers, pigments and fillers[17]. Moreover, it increases the printability and strength of paper[18]. In the food industry, oxidized starches are used in pudding, cream pudding, whipped cream and powder dough[19]. The use of oxidized starch is reported to increase the shelf life of frozen food products[17]. Some researchers have also reported the use of oxidized starches as emulsifiers[18], bread conditioners[19] and as a substitute for gum arabic[20].

Research on the oxidation of Gajah cassava starch is needed to increase its potential for use, as well as to meet the growing industry demand for starches with specific functional characteristics, especially given the requirements of environmental and food safety. The research presented here aimed to investigate the effects of the oxidation of Gajah cassava starch using ozone for different ozonation times and study its properties, including carboxyl, carbonyl and amylose content, color, swelling power, solubility, starch paste clarity and pasting properties.

MATERIALS AND METHODS

Materials: Gajah cassava starch was obtained from a small industry, Borneo Sejahtera Mandiri, in Kutai Kartanegara, East Borneo, Indonesia.

Chemicals and reagents: Oxygen, DPD test, HCl, NaOH and HCl were purchased from Sigma Chemical Co. (St. Louis, MO, USA). All other reagents and chemicals were of analytical grade.

Preparation of Ozonated Gajah cassava starch: The method refers to Castanha *et al.*[7] with modifications. The starch suspension was made at a concentration of 10% in a volume of 1 L. Oxygen gas with a purity of 95% and a 6 L tube capacity was flowed into the ozone generator. During oxidation, the sample was subjected to continuous stirring at 300 rpm using a mixer. The oxidation reaction was carried out for 0, 15, 30, 45 and 60 min at 30°C using 2 ppm dissolved ozone content. After oxidation was complete, oxygen gas was still flowed in to the reaction for 10 min to remove any remaining ozone. The suspension was removed from the container, allowed to stand for 1 h and the slurry and liquid supernatant were separated. The slurry was dried for 12 h with a cabinet dryer at 55°C. Then, the resulting material was milled and sifted using a 100-mesh sieve. Dried oxidized starch was stored in a closed container for further analysis.

Carbonyl content (%): The carbonyl group content of the cassava starch and ozonated cassava starch was determined following the titrimetric method of Smith[21]. The carbonyl group content was measured with Smith's equation as follows:

$$\text{Carbonyl content}^{21}\,(\%) = \frac{(\text{Blank} - \text{sample})\,\text{mL}\times\text{acid normality}\times 0.028\times 100}{\text{Sample weight (g)}}$$

Carboxyl content (%): The carboxyl content of the cassava starch and ozonated cassava starch was determined using the modified method of Chattopadhyay *et al.*[20]. A 2-g starch sample was poured into a 100 mL glass beaker and = 25 mL of 0.1 M HCl was added. The starch slurry was stirred for 30 min using a magnetic stirrer. The slurry then was filtered and rinsed with 400 mL of distilled water. The starch cake was moved into a 500 mL glass beaker and distilled water was added until the volume reached 300 mL. The slurry was heated for 15 min in a boiling water bath and stirred continuously. The hot starch dispersion was diluted with distilled water until a volume of 450 mL was obtained and titrated using standardized 0.01 M NaOH to pH 8.3. A blank test was done with native starch. The carboxyl content was calculated using Chattopadhyay's[20] equation as follows:

$$\text{Milliequivalents of acidity/100 g starch}^{20} = \frac{\text{(Sample-blank) mL}\times\text{normality of NaOH}\times 100}{\text{Sample weight (g)}}$$

$$\text{Carboxyl content}^{20}\ (\%) = \frac{\text{Milliequivalents of acidity}}{\text{100 g starch}}\times 0.045$$

Amylose content: The method refers to Juliano[22]. 100 mg of cassava starch was placed into a 100 mL volumetric flask to which 1 mL of 95% ethanol and 9 mL of 1 N NaOH were added. The sample was heated in a water bath for 10 min and distilled water was added to the 100 mL mark. A total of 5 mL of the sample was pipetted into a 100 mL measuring flask and then 1 mL of 1 N acetic acid and 2 mL of iodine solution were added. Then the sample was diluted with distilled water to the 100 mL mark. After shaking, the absorbance was measured with a UV-Vis spectrophotometer at a wavelength of 620 nm.

Amylopectin content: The amylopectin was estimated as follows:

$$\text{Amylopectin (\%)} = 100\%\text{-amylose content (\%)}$$

Color measurement: A Minolta Chromameter series CR-400 (Konica Minolta Co., Ltd., Osaka, Japan) was used to determine the color of oxidized cassava starch. Measurement results are expressed as L* (lightness), a* (redness-redness) and b* (blueness). The L* scale ranges from 0-100, with black expressed as 0 and white as 100, the value of a* ranges from negative (green) to positive (redness) and the value of b* ranges from negative (bluish) to positive (yellowish). The whiteness value was determined using the following equation:

$$\text{Whiteness}^{23} = 100-[(100-L^*)^2+a^{*2}+b^{*2}]^{1/2}$$

Swelling power and solubility: The swelling power and solubility of cassava starch were determined using the method described by Chan *et al.*[24], with modification. A sample of cassava starch (0.2 g) was placed into a 50 mL centrifuge tube to which 10 mL of distilled water was added. The resulting mixture was vortexed for 5 min and heated in a water bath at 95°C for 30 min. The tube was cooled for 30 min and then centrifuged at 3500 rpm for 15 min. The gel and supernatant were separated. The gel was weighed for the calculation of swelling power and expressed in units of g g^{-1}. The supernatant was dried. The solubility was calculated as gram per 100 g sample.

Starch paste clarity: The paste clarity was measured using the method explained by Craig *et al.*[25]. A 1% starch suspension was heated in a boiling water bath for 30 min. It was then agitated to result in complete pasting. It was cooled in the room temperature (approximately 28°C). The transmittance of the pastes were determined using a UV-Vis spectrophotometer at 620 nm.

Pasting properties of starch: The pasting properties of cassava starch were analyzed using a Rapid Visco Analyzer-4, Newport Scientific, Australia. 4 g of cassava starch with known water content was weighed in the RVA sample container and 25 g of distilled water was added. Measurements with the RVA include the phases of heating and cooling with constant stirring (160 rpm). In the heating phase, the cassava starch suspension was heated from 50-95°C at a speed of 6°C/min and then maintained at this temperature for 5 min. After the heating phase was complete, the cassava starch paste was passed into the cooling phase. The temperature was decreased from 95-50°C at a rate of 6°C/min and then maintained at this temperature for 2 min.

Statistical analysis: The research data was analyzed using one-way ANOVA with the SPSS Version 25. If the calculation of the F count value was greater than the F table value, Duncan's Multiple Range Test at $\alpha = 5\%$ was used to determine if there was a significant difference between treatments followed.

RESULTS AND DISCUSSION

Carbonyl and carboxyl content: Table 1 shows the duration of the ozonation process with the slurry of Gajah cassava starch. Oxidized starch contained 0.0614-0.1199% carbonyl group content and 0.0350-0.1435% carboxyl group content. The carbonyl content increased significantly with increased ozonation time, rising to between 3-6 times the content in

Table 1: Carbonyl and carboxyl contents of the ozone-oxidized Gajah cassava starches with different ozonation times.

Ozonation time (min)	Carbonyl contents[1] (%)	Carboxyl contents[1] (%)
0*	0.02±0.01^{d}	-
15	0.06±0.00^{c}	0.04±0.01^{c}
30	0.08±0.01^{bc}	0.09±0.01^{b}
45	0.10±0.02^{ab}	0.12±0.01^{a}
60	0.12±0.01^{a}	0.14±0.02^{a}

0*: Without ozonation. [1]Values are given as the Means±SD of triplicate measurements. Values followed by the same superscript letter in the same column show measurements that are not significantly different from the DMRT test at α = 5%

Table 2: Amylose and amylopectin contents of the ozone-oxidized Gajah cassava starches for different ozonation times

Ozonation time (min)	Amylose content[1] (%)	Amylopectin content[1] (%)
0*	35.76±0.24^{c}	64.24±0.24^{a}
15	36.67±0.38^{c}	63.33±0.38^{a}
30	39.29±0.50^{b}	60.71±0.50^{b}
45	40.57±0.89^{a}	59.43±0.89^{c}
60	41.38±0.40^{a}	58.62±0.40^{c}

0*: Without ozonation. [1]Values are given as the Means±SD of triplicate measurements. Values followed by the same superscript letter in the same column show measurements that are not significantly different from the DMRT test at α = 5%

unmodified starch. Ozonation for 60 min also resulted in the highest carboxyl content. The carbonyl group (C = O) is an intermediate product of the oxidation of a hydroxyl (-OH) group in a starch molecule. The carboxyl group is the final product expected in the oxidation of Gajah cassava starch using ozone. The carboxyl content increased by five times at 60 min of ozonation compared to 15 min of ozonation time. Castanha *et al.*[7] also reported that oxidation of potato starch using ozone for 0-60 min increases the carbonyl content from approximately 0.04-0.19% and increases the carboxyl content from approximately 0.03-0.10%. Meanwhile, Sangseethong *et al.*[26] stated that the use of sodium hypochlorite to oxidize cassava starch increased carboxyl contents from 0.4-0.7% during reactions ranging from 30-300 min but that carbonyl contents only slightly changed. In contrast to sodium hypochlorite, the use of hydrogen peroxide the oxidizer increased carbonyl contents in oxidized starch cassava from approximately 0.05-0.1%, while the carboxyl content changed only slightly. The differences in these results is probably due to differences in methods and the different oxidizing agents used.

Wurzburg[12] mentioned that the reactions that occur during oxidation were the conversion of the hydroxyl group to the carbonyl and carboxyl groups and the continued cleavage of α-(1,4)-glucosidic bonds that cause the molecular depolymerization of starch. The oxidation level of starch can be determined from the proportion of carbonyl and carboxyl groups. The hydroxyl groups in the 2-, 3- and 6- positions of the sugars is where oxidation takes place. Sandhu *et al.*[27] and Oladebeye *et al.*[15] also described that an increase in the amount of ozone or oxidant in the reaction with starch resulted in increases in the carbonyl and carboxyl contents.

Amylose and amylopectin content: As shown in Table 2, the amylose content of oxidized Gajah cassava starch increased with increasing ozonation time. The amylose content of oxidized cassava starch ranged from 35.76-41.38%. It increased by approximately 2.52-15.72% compared to native starch. Oladebeye *et al.*[15] also reported that there was an increase in the amylose content in white cocoyam, red cocoyam, white yam and yellow yam oxidized starches, which increased by 22.48, 16.03, 23.06 and 21.43% respectively, after ozonation for 10 min in the gas phase. In contrast, the amylopectin content of oxidized cassava starch decreases with increasing ozonation time. The amylopectin content of oxidized Gajah cassava starch decreased approximately 1.41- 8.74% compared to native starch. It is possible that the amylopectin chain was depolymerized and part of the branching was due to cleavage.

The molecular weight of cassava starch oxidized with hydrogen peroxide was analyzed using HPSEC and GPC[26]. The oxidized cassava starch was separated into two fractions based on retention time. The eluent does not interact chemically with the stationary phase. Amylopectin moves quickly through the stationary phase but amylose moves slowly. Amylose has a low molecular weight, which allows the sugar to enter into the pores of the stationary phase. This results in the longer retention time of amylose compared to amylopectin. Sangseethong *et al.*[26] stated that starch oxidation reduces the area of the first eluent fraction and increases the area of the second eluent fraction. This result is due to the depolymerization of the amylopectin chain and the formation of a low molecular weight glucose polymer, which increases the amylose content. Chan *et al.*[16] also reported that oxidation of tapioca for 10 min resulted in a starch with a higher molecular weight than native tapioca starch. This result was due to the formation of intermolecular cross-links. Oladebeye *et al.*[15] examined ozone-oxidized starch from red and white cocoyam and yellow and white yam cultivars. The results described an increase in the proportion of amylose content, a decrease in amylopectin content and an increase in the molecular weight of oxidized starch. This result was due to ozone oxidation, resulting in partial depolymerization of some crystalline lamellae in starch granules. The crystalline lamellae consist mostly of amylopectin chains.

Color: Table 3 shows that ozonation of cassava starch caused significant color changes in all parameters. Lightness (L*) ranged from 89.41-94.74, the value of a* ranged from

Table 3: Color of the ozone-oxidized Gajah cassava starches for different ozonation times

Ozonation time (min)	L[1]	a[1]	b[1]	WI[1] (whiteness index)
0*	89.41±0.07[e]	6.34±0.02[a]	3.10±0.04	87.27±0.07[e]
15	91.78±0.25[d]	5.60±0.01[b]	0.77±0.77	90.02±0.20[d]
30	92.71±0.05[c]	5.41±0.03[c]	-0.34±0.12	90.92±0.05[c]
45	94.14±0.15[b]	5.28±0.02[d]	-0.88±0.12	92.06±0.11[b]
60	94.74±0.26[a]	5.26±0.03[d]	-1.36±0.15	92.43±0.19[a]

0*: Without ozonation. [1]Values are given as the means±SD of triplicate measurements. Values followed by the same superscript letter in the same column indicate measurements that are not significantly different from the DMRT test at $\alpha = 5\%$

5.26-6.34, the value of b* ranged from -1.36 -3.10, while the value WI (whiteness index) ranged from 87.27- 92.43. L* and WI values increased approximately 6% at 60 min of ozonation time compared to native starch. The whiteness index of oxidized Gajah cassava starch was greater than 90. Sandhu *et al.*[27] noted that lightness of wheat flour increased from 89.0-90.50 with ozone gas treatment for 18 min. Furthermore, Mei *et al.*[28] reported that the brightness of hard wheat flour medium increased from 81.0-82.0 due to ozone gas treatment for 2.0 h. The results indicated that oxidation using ozone could improve the whiteness index of cassava starch. Increasing the ozonation time caused more ozone to react with the cassava starch. Oxidation reactions cause some pigments and proteins to be oxidized before the glucose unit, which are mostly degraded, resulting in a whiter starch color[29,30]. Wang *et al.*[31] stated that the purity of starch was indicated by a WI value of greater than 90. The high whiteness index of oxidized starch indicates that it has a high potential for use in many applications in the food and health industries[32].

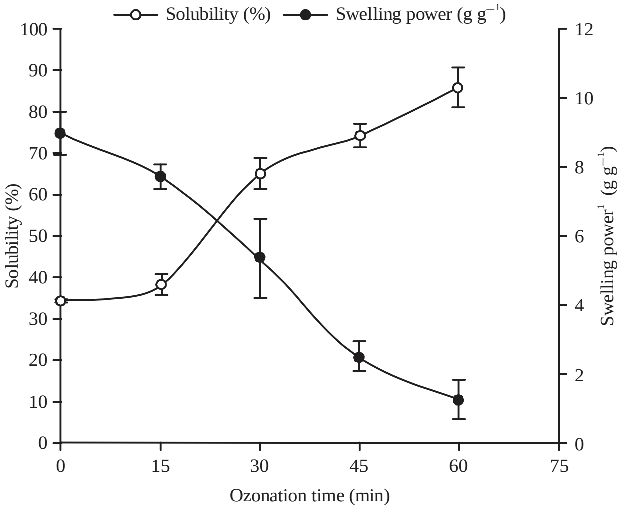

Fig. 1: Solubility and swelling power of ozone-oxidized Gajah cassava starches for different ozonation times

0*: Without ozonation. [1]Values are given as the Means±SD of triplicate measurements

Swelling power and solubility: The swelling power of oxidized Gajah cassava starch ranged from 7.68-1.23. Figure 1 shows a decrease in swelling power with increasing ozonation time. In ozonation reactions of 15-60 min, the swelling power decreased (16-86%) compared to native starch. The solubility values ranged from 34.08-85.56%. Figure 1 showed that the solubility of oxidized cassava starch increases compared to native starch with increasing ozonation time. The increase was from 12-144%. Zavareze *et al.*[33] noted that oxidation using potato starch increases solubility from 2.49-5.68% and sodium hypochlorite treatment with 0.5% active chlorine in conversely, decreases swelling power from 16.64 (g g^{-1}) to 10.75 (g g^{-1}). In general, the decrease in swelling power in oxidized starch is caused by structural disintegration and the partial rupture of starch granules[32]. In starch granules, amylopectin plays a role in water absorption capacity. Wang and Wang[31] investigated the oxidation against common and waxy corn starch using sodium hypochlorite, which caused a decrease in the swelling power. This is due to the amylopectin chain undergoing hydrolysis at high temperatures and the absorption of water by the sponge structure in the starch granule during the heating process. During centrifugation, the sponge structure cannot hold the absorbed water. The same result was reported by Vanier *et al.*[34] in the oxidation of bean starch using sodium hypochlorite. The increased solubility of oxidized starch was due to the disintegration and structural weakening of the starch granules, leaching of amorphous starch granules and starch chain depolymerization. Oxidation can increase the breakdown of the glycosidic bonds in amylose and amylopectin, which increases the solubility of oxidized starch. The presence of carboxyl groups in the glucose chain of oxidized starch molecules causes increased hydrophilicity, water access to the amorphous domain is facilitated, the intragranular structure is disrupted and damage to intramolecular hydrogen bonds occurs through oxidative degradation[26,35, 36].

Starch paste clarity: Figure 2 indicates that paste clarity ranges from 27.62-81.56%. This value increases with increasing ozonation time. There was a 3-fold increase in transmittance after a 60 min reaction time. This is probably due to an

Table 4: Pasting characteristics of ozone-oxidized Gajah cassava starches for different ozonation times

Ozonation time (min)	PV(cP)[1]	TV(cP)[1]	BV(cP)[1]	FV(cP)[1]	SV(cP)[1]	PT(°C)[1]
0*	5318 ± 212^{a}	2101 ± 14^{a}	3217 ± 71^{a}	2992 ± 198^{a}	891 ± 57^{a}	70.10 ± 0.21^{a}
15	4328 ± 240^{b}	2051 ± 81^{a}	2277 ± 160^{c}	283 ± 184^{a}	780 ± 103^{a}	69.80 ± 0.14^{ab}
30	4032 ± 134^{b}	1880 ± 78^{a}	2152 ± 57^{c}	2690 ± 146^{a}	810 ± 68^{a}	69.70 ± 0.13^{b}
45	3955 ± 176^{b}	1362 ± 52^{b}	2593 ± 124^{b}	1847 ± 134^{b}	485 ± 82^{b}	69.45 ± 0.10^{b}
60	3257 ± 106^{c}	1065 ± 64^{c}	2192 ± 42^{c}	1473 ± 92^{b}	408 ± 28^{b}	68.95 ± 0.14^{c}

RVA parameters: Peak Viscosity (PV), Trough Viscosity (TV), Breakdown Viscosity (BV), Final Viscosity (FV), Setback Viscosity (SV) and Pasting Temperature (PT). 0*: without ozonation. [1]Values are given as the means±SD of triplicate measurements. Values followed by the same superscript letter in the same column indicate measurements that are not significantly different from the DMRT test at α = 5%

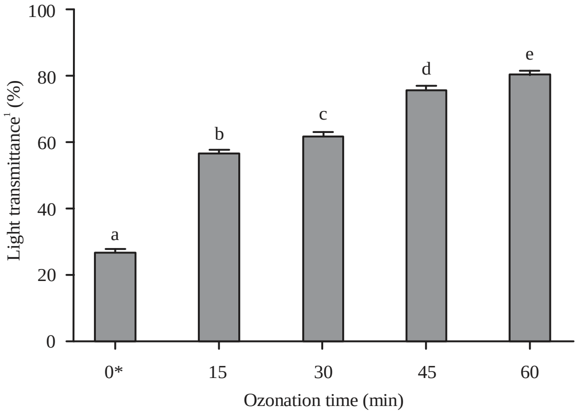

Fig. 2: Starch paste clarity of ozone-oxidized Gajah cassava starches for different ozonation times

0*: Without ozonation. [1]Values are given as the means±SD of triplicate measurements, Histograms followed by the same superscript letter indicate measurements that are not significantly different from the DMRT test at α = 5%

increase in the carboxyl and amylose contents, as confirmed in Table 1 and 2. Lawal *et al.*[37] reported that starch paste clarity in modified cocoyam starch increased from 26.49-34.56% after oxidation with sodium hypochlorite. Sandhu *et al.*[38] also reported similar results, as the percentage of transmittance of normal corn and waxy corn starch increased after oxidation compared to native cornstarch. According to Lawal *et al.*[37], the chemical substitution of hydroxyl groups in starch molecules with carbonyl and carboxyl functional groups causes an increase in the percentage transmission of oxidized cocoyam starch. This causes repulsion between adjacent starch molecules and reduces interchain associations, which facilitates increased transmittance. According to Swinkles[39] and Gani *et al.*[40], increasing the content of amylose in oxidized starch plays a role in improving the percentage of transmittance, resulting in greater paste clarity. Light transmittance is a very useful parameter in fruit paste and jelly formulations[41].

Pasting properties: Table 4 shows that oxidation decreased the Peak, Trough, Final and Setback Viscosity and Pasting Temperature of oxidized starch. The lowest data were obtained at 60 min of ozonation time. These data are possibly due to molecular weakening, the integration of starch granule structures and the partial depolymerization of glucose polymer chains, especially amylopectin. This is confirmed in Table 1 and 2, which indicate increased contents of carbonyl groups, carboxyl groups, amylose and decreased amylopectin.

Oxidation significantly reduces pasting temperature[26,35,36]. Kuakpetoon and Wang[42] reported a decrease in pasting temperature, peak viscosity and final viscosity of common corn starch after oxidation using sodium hypochlorite. During the oxidation of cornstarch, hydroxyl groups were converted to carbonyl and carboxyl groups. These groups weaken the molecular structure and results in the disintegration of the starch structure that occurs during shearing at elevated temperatures. Oxidation also results in the depolymerization of glucose polymers. These results decreased peak and final viscosity. Vanier *et al.*[34] reported lower peak and final viscosities for cocoa starch oxidized with 1.0 and 1.5% sodium hypochlorite compared to native cocoa starch.

The peak reduction and final viscosities of oxidized starch are related to partial cleavage of the glycosidic bond[34,38]. According to Catal and Ibanoglu[10], oxidized starch has a lower viscosity than the original starch. This is because the starch granules are not able to withstand shear forces and cannot maintain their original integrity. Moreover, Catal and Ibanoglu[10] reported that the oxidation of wheat flour using ozone in aqueous solutions reduced the final viscosity of the product. Sandhu *et al.*[38] reported a decrease in breakdown viscosity in common corn starch that was oxidized at pH 9.5 with sodium hypochlorite. Carboxyl groups are hydrophilic and the repulsive forces between carboxyl groups within the oxidized starch molecules decrease the tendency of retrogradation. The carbonyl and carboxyl groups are bulkier compared to hydroxyl groups and the space between the amylose chains increases, reducing the likelihood of chains being close enough to connect with each other[43].

Based on the present research, oxidized Gajah cassava starch, which as a high whiteness index, high solubility and high paste clarity but low swelling power and low viscosity may be applied in edible coatings and films, binding agents, puddings and frozen foods.

CONCLUSION

Oxidation of Gajah cassava starch using ozone is an alternative chemical method. The data indicate that oxidation with ozone has a significant effect on the carbonyl, carboxyl, amylose and amylopectin contents, color, swelling power, solubility, starch paste clarity and pasting properties. The oxidation of Gajah cassava starch increased the carbonyl, carboxyl and amylose contents, whiteness index, solubility and starch paste clarity but decreased the amylopectin content, swelling power and pasting properties. The highest effect was obtained at 60 min of ozonation. The oxidized Gajah cassava starch studied in this research can be applied as an alternative starch source in both food and nonfood industries.

SIGNIFICANCE STATEMENT

This study shows that dissolved ozone is a potential modifying agent in Gajah cassava starch. The results of this study detail the characterization of oxidized Gajah cassava starch. This study provides information regarding the whiteness index, swelling and solubility properties, paste clarity and pasting properties, which may be useful for increasing the added value of Gajah cassava starch.

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