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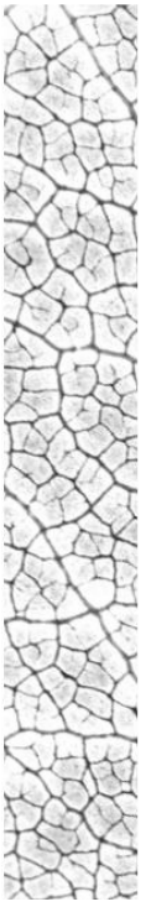

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Modification of native and hydrolyzed tannia (*Xanthosoma sagittifolium*) starch by succinic acid (succinylation)

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Abstract
Background: Tannia (Xanthosoma saggitifolium), a staple corn crop grown in many tropical countries including Indonesia, is used to make flour. Tannia is a potential source of industrial food starch, but the use of native starch in food production is highly limited due to retrogradation and instability under acidic conditions and at high temperatures. To overcome these challenges and extend starch application, native starch is modified by chemical, physical, and enzymatic procedures. Succinylation is one such modification method, using succinic acid to increase the utilization of native starch. Methods: In this study, tannia starch was modified by different concentrations of succinic acid (2.44, 4.76, and 9.09%) and type of starch (native or hydrolyzed starch enzyme α-amylase). The modified starches were analyzed for yield determination, moisture content, ash, degree of substitution (DS), dextrose equivalent (DE), syneresis, swelling power, gelatinization properties, and viscosity. Results: In general, starch characteristics were significantly affected by the concentration of succinic acid. Conclusion: Resulting characteristics of starch were closest to ideal using 9.09% succinic acid.

Keywords: Xanthosoma sagittifolium, Native starch, Hydrolized starch, Succinylation, Succinic acid

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INTRODUCTION

Tannia (*Xanthosoma saggitifolium*) is an important staple crop that can be planted throughout the year and used mainly for direct consumption. The major component of the tannia corn is starch, which, in natural and modified forms, could be promoted as an ingredient in the food industry (Patricia et al. 2014). Native starches are widely used in food industry. However, unmodified starches present many production challenges, such as insolubility in cold water, lack of pasting consistency and stability when dispersed and heated in water, the loss of viscosity by acids or mechanical shear, lack of clarity and the tendency to retrograde during storage, and the lack of emulsification. These have limited their potential in many commercial applications and paved the way for the development of modified starches having desirable functional properties such as solubility, adhesion, texture, dispersion, and heat tolerance (Yanjie et al. 2011). To overcome these problems and extend potential starch applications, native starch must be modified by chemical, physical, and enzymatic procedures (Piotr and Christopher, 2004).

The chemical modification involves the introduction of functional groups into the starch molecule, resulting in markedly altered physicochemical and functional properties such as gelatinization, pasting, and retrogradation behavior. This type of modification performed generally through oxidation, etherification (carboxymethylation), esterification (acetylation), and succinylation.

The hydroxyl groups of starch can be reactive and, for modification, substituted by a range of functional groups. Yam starches from several species have been subjected to carboxymethylation (Wang et al. 2009), hydroxypropylation (Oluwatoyin and Katharina 2009; Nattawat et al. 2009), acetylation (Xu et al. 2008), and succinylation (Olayde, 2012), all of which increased the hydrophilic properties of starch.

The succinylation process confers many advantages, such as high solubility in cold water, high viscosity, better thickening power, increased paste clarity, retarded retrogradation, freeze–thaw stability and and a lower retrogradation rate of starch (Abeera et al. 2016). Succinylation is the esterification of a hydroxyl group in the starch molecule by succinic acid. It results in higher viscosity, greater thickening power, and a lower retrogradation rate of starch. Previous studies on

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modification by succinylation were conducted on yam starch (Jairo et al. 2016), sorghum starch (Teli and Arabinda 2015), corn starch (Ariyantoro et al., 2018), rice starch, tapioca starch (Ali et al. 2015), and corn and amaranth starch (Ritu et al., 2018).

Chemical modification of *Chrysophyllum albidnum* starch reduced the values for all the non-starch components. The swelling power and solubility increased as the temperature increased between 50–90°C. Native and modified starches absorbed more oil than water, and it is pH-dependent. Pasting capability decreased after acetylation but increased after carboxymethylation and succinylation. The results of bulk density analysis showed that native and modified starches have low densities (<0.8 g/ml) (Ibinkule et al. 2019). Succinylation of *Dioscorea cayenensis* starch increased swelling and water solubility, paste clarity, PV and BD of pasting, reduced PT and SB of pasting, and syneresis of paste (Olayde 2012). The succinylation process confers many advantages, such as high solubility in cold water, high viscosity, better thickening power, increased paste clarity, retarded retrogradation, and freeze-thaw stability (Achmad et al. 2018).

In this study, tannia with high starch content was modified. First, the tannia starch was hydrolyzed with α-amylase enzyme then both tannia starch and hydrolyzate were succinylated with succinic acid. The modified starch was analyzed for its yield, moisture content, ash, degree of substitution (DS), dextrose equivalent (DE), syneresis, swelling power (SP), gelatinization properties, and viscosity. The objective of this study was to modification starch in tannia. The treatment modification was Consentration of succinic acid and, native and hydrolysis starch. Based on the above, we studied changes in the physicochemical and functional properties of modified starches.

MATERIALS AND METHODS

Materials

Tannia (also called Cocoyam or *Kimpul* (Indonesian) or *Mbote* (Javanese)) was obtained from Traditional Ground Market Darmo Trade Center, Wonokromo Surabaya, East Java, Indonesia. Analytical grade α-amylase enzyme and succinic acid were used for analysis (Sigma).

Methods

Starch production

Tannia tubers were cleaned to remove dust and other impurities. The cleaned tubers were rinsed, peeled, sliced, and soaked in 7% NaCl in 10 L distilled water for 3 h. The soaked tubers were blended and filtered. The filtrate was precipitated for 24 h until starch and water were separated. Then the water was separated by a water hose. The starch was dried in a cabinet dryer at 70°C for 5 h. The dried starch was ground and sieved (#80 mesh, 0.18 mm). The end product was referred to as native starch.

Hydrolyzation process using α-amylase

Hydrolyzed starch was prepared by diluting 100 grams of native starch in 100 ml distilled water. The starch suspension was then neutralized by 0.5 M NaOH until the pH was adjusted to 7. The suspension was soaked in a water bath shaker at 75 °C for an hour at 150 rpm. After hydrolyzation, the enzyme was inactivated by 2 M HCL to adjust pH to 3 then the suspension was filtered using filter paper. The hydrolyzed starch was dried in a cabinet dryer at 70 °C for 4 h sieved in #80 mesh.

Succinylation process

Succinylated starch was prepared by reacting native (control) and hydrolyzed starch with succinic acid, as in, with some modifications. Succinic acid (2.44, 4.76, and 9.09 grams) was diluted in 100 ml 96% ethanol then mixed using a magnetic stirrer. Native or hydrolyzed starch was added into the succinic acid solution with stirring. The suspension was then vacuum filtered using a Buchner funnel until the filtrate and starch were completely separated. The starch was dried at 150°C for 2 h, washed with ethanol 3x, then dried again at 60 °C for an hour. The dry starch was ground and sieved (#100 mesh, 0.149 mm) to obtain succinylated starch.

Moisture and ash contents

Moisture, protein, and ash contents of the Tannia starch dried under different conditions were determined by standard methods of analysis. The ash contents of the different Tannia starch were determined by a muffle furnace (WiseTherm Daihan, Korea) at 550 °C for 5 h, and the moisture content determined after samples were dried at 105 °C for 5 h.

Degree of substitution (DS)

The DS was determined using the alkali saponification method. Five g of starch was combined with 25 mL of 75% ethanol. Subsequently, 20 mL of 0.5 M aqueous sodium hydroxide was added to the solution, and the solution was stored at room temperature for 72 h, with occasional mixing. The excess alkali was back-titrated using 0.1 M hydrochloric acid until the solution reached pH 7. The following equation was used to calculate the DS (Equation 1).

$$DS = 162 \times M_{HCl} \times \frac{B_{HCl} - S_{HCl}}{1000 \times WS} \quad \text{(Equation 1)}$$

Swelling power and solubility

Swelling power and solubility were determined over a temperature range of 65–95°C. Briefly, 0.5 g of the starch sample was combined with 15 ml of distilled water. The tube was capped quickly, and the contents of the tube were homogenized. Any delay in this stage could cause the starch to clump. The tube was then incubated in a constant 85°C water bath and mixed by inverting twice at 20 s intervals for 15 min. The tube was cooled rapidly in ice water to approximately 25°C and

centrifuged at 2250 rpm for 20 min. The supernatant was carefully pipetted, evaporated, and dried at 105°C for at least 5 h until the sample reached a constant weight. A duplicate was performed to ensure reproducibility. Swelling power (SP) and solubility (PS) were calculated using the following equations (Equation 2 and 3).

$$SP = \frac{WDP}{WDS \times (100\% - SDB)} \text{ (Equation 2)}$$

$$PS = \left(\frac{WSS}{WDS}\right) \times 2 \times 100\% \quad \text{(Equation 3)}$$

Amylose content

To 20 mg of starch, 10 ml of 0.5 N KOH was added. The suspension was thoroughly mixed. The dispersed sample was transferred to a volumetric flask and diluted to 100 ml with distilled water. Astarch solution (10 ml) was pipetted into a 50 ml volumetric flask, and 5 ml of 0.1 N HCL was added, followed by 0.5 ml of iodine reagent. The volume was diluted to 50 ml, and the absorbance was measured by a spectrophotometer at 625 nm. The measurement of the amylose was determined from a standard curve developed using amylose and amylopectin blends.

Starch content

To determine starch content, 0.2 ml of the sample solution of a sample was pipetted into a test tube and diluted to 2 ml with distilled water. Standard glucose (100 mg) was dissolved in 100 ml distilled water to serve as a stock standard, then 10 ml of the stock solution was diluted with distilled water to 100 ml to serve as the working standard solution. Then 0.2, 0.4, 0.6, 0.8, and 1 ml of the working standard solution were pipetted into different test tubes and diluted to 2 ml with distilled water (2 mL of distilled water was pipetted into a separate test tube and used as the blank). One ml of Nelson reagent was then added into each test tube, and the test tubes placed in a boiling water bath for 10 minutes. The test tubes were removed from the water bath, cooled, then combined with 1 ml of arsenomolybdate reagent. The solution of each test tube was diluted to 10 ml with distilled water. After 10 minutes, the test tubes were placed in a spectrophotometer to determine the absorbance at 540 nm. The amount of reducing sugar present in the sample was calculated from the standard curve plotted.

Dextrose equivalent (DE)

The Lane and Eynon method were used to analyze the DE value of BB and RB samples. Fehling Solutions were standardized against standard dextrose obtained from the Bureau of Standards. To determine the Fehling Factor, 0.5 g of anhydrous dextrose was added to 200 ml of distilled water and used as the test solution. The Fehling factor was calculated using the following equation (Equation 4).

$$FF = \frac{FV \times DC}{100} \text{ (Equation 4)}$$

A sample solution (10 g/ 200 ml) with the known concentration of anhydrous starch was prepared. The starch solution was transferred to a 50 mL burette. To 50 ml of distilled water in a 500 ml Erlenmeyer flask, 5 ml each of Fehling A and Fehling B were added. The contents of the flask were brought to boil over a hot plate. When the water started to boil, 2 drops of methylene blue indicator was added and stirred continuously. The starch solution was added dropwise until the blue color disappeared. The volume of the starch solution used was recorded. The DE was calculated using the following equation (Equation 5).

$$DE = \left(\frac{FF}{SC}\right) \times 100\% \textit{ (Equation 5)}$$

Viscosity

Ten grams of sample was diluted in 100 ml distilled water, heated to 85°C, then rapidly cooled until 30°C. The suspension was analyzed by a viscometer (Spindel 3, 60 rpm).

Gelatinization temperature

Up to 8.0 mg of distilled water was added to a sample of starch, and the flask hermetically sealed. Samples were heated at a rate of 10°C/min from 30−120°C.

Statistical analysis

All data obtained were in duplicate and analyzed using ANOVA one way and Least Significant Difference (LSD) was performed to investigate significance for each group. Statistical analysis was carried out by Microsoft Excel 2010.

RESULTS AND DISCUSSION

Native and hydrolyzed starch analysis

The results of the analysis of native and hydrolyzed tannia starch are presented in **Table 1**. Hydrolyzed starch had lower starch and amylose content than native starch. This was caused by α-amylase degradation of starch, which proceeds through two steps. In the first step, amylose is converted to maltose and maltotriose. The hydroxyl groups of starch can be reactive and substituted by a range of functional groups for modifications. This degradation occurs very fast and decreases viscosity quickly. The second step is the slow formation of glucose and maltose. The effect of α-amylase on the amylopectin molecule is the production of glucose, maltose, and α-limit dextrin. The limited dextrin is the oligosaccharide composed of 4 or more sugar-residues containing an α-1.6 bond. The activity of α-amylase can be determined by measuring viscosity and the amount of reducing that is formed. Amylose hydrolysis will occur faster than branched-chain hydrolysis of molecules such as amylopectin or glycogen. The rate of hydrolysis will increase when the level of polymerization decreases, and the rate of hydrolysis will occur faster.

Table 1. Analysis of native, hydrolyzed and succinylated starch

Starch Type	Native	Succinylated starch		
		2.44%	4.76%	9.09%
Yield (%)	11.5±0.70	81.05±0.49	82.7±0.14	85.00±0.14
Moisture (%)	6.28±0.001	3.92±0.007	3.61±0.008	3.54±0.012
Ash (%)	1.51±0.007	1.23±0.000	1.16±0.000	1.59±0.002
Amylose (%)	24.19±0.01	25.99±0.04	26.08±0.02	26.16±0.03
Degree of Substitutions (DS)	0	0.0660±0.00	0.0663±0.00	0.0667±0.00
Dextrose Equivalent (D.E)	2.21±0.00	2.76±0.00	2.89±0.00	2.93±0.007
Visosity (MPas)	2354.25±0.35	628±0.00	601.5±0.00	593.25±0.35
Starch (%)	70.95±0.91	68.49±0.21	64.49±0.29	63.19±0.01
Swelling Power (g/g)	22.565±0.07	25.82±0.01	26.20±0.01	26.97±0.01
Solubility (%)	15.67±0.08	17.84±0.02	17.62±0.09	17.35±0.08
Gelling Temperature (°C)	74.2±0.14	83.1±0.14	84.25±0.21	85.8±0.14
	Hydrolysis	**Succinylated stach**		
		2.44%	**4.76%**	**9.09%**
Yield (%)	88.8±0.28	90.65±0.07	91.65±0.49	92.1±0.42
Moisture (%)	4.12±0.009	3.64±0.002	3.50±0.009	3.30±0.008
Ash (%)	0.29±0.01	0.33±0.01	0.75±0.03	1.21±0.03
Amylose (%)	4.26±0.00	3.76±0.03	3.81±0.00	4.00±0.03
Degree of Substitutions (DS)	0	0.0414±0.00	0.0417±0.00	0.0457±0.00
Dextrose Equivalent (D.E)	11.73±0.00	13.27±0.00	13.57±0.00	13.77±0.00
Visosity (MPas)	98.25±0.35	36.25±0.35	34.50±0.00	33.50±0.00
Starch (%)	7.375±0.06	6.915±0.13	6.745±0.04	6.575±0.02
Swelling Power (g/g)	5.28±0.08	5.90±0.02	6.28±0.01	6.78±0.01
Solubility (%)	81.4±0.09	86.79±0.04	84.37±0.09	81.83±0.05
Gelling temperature (°C)	88.15±0.07	90.05±0.07	91.25±0.07	91.95±0.21

Succinylated starch analysis

Yield

The yield of hydrolyzed succinylated starch were ranging from 81.05 to 92.10% (**Table 1**) while the research of Rini (2005) produced yields hydrolyzed succinylated starch in 88.57 to 95.19%. These major discrepancies might be due to varietal differences and the kind of tannia tubers that have been used. **Table 1** shows that the concentration of succinic acid influenced the yield of succinylated starch. The yield is analyzed on a mass basis on a mass basis before and after treatment.

Succinylation of starch leads to the addition of hydrophilic negatively-charged succinyl groups, which in turn impart a hydrophilic character to starch (Sundus et al. 2015). Succinic groups weaken internal bonding in starch granules and facilitate starch solubilization even in cold water (Zhonquan et al. 2013).

Moisture

The moisture of native succinylated starch was reported to be 2.50–3.32%, compared to the Rini's (2005) which was ranging from 1.52–1.96%. The corresponding values for native starches and hydrolyzed starches examined in this study were 3.54–3.92% and 3.31–3.64%, respectively (**Table 1**). These major discrepancies might be due to varietal differences, the kind of tubers used, the specific drying process used, and drying time. **Table 1** shows that the concentration of succinic acid was influenced by the moisture of succinylated starch. Based on these observations, the treatment affects the water content of the product produced. The moisture of modified starch generally was lower (5.97–8.64%) than that compared with the results of Heny et al. (2010). The moisture content of the modified starches was low because of the removal of water-binding proteins during the alkali extraction stage. Furthermore, the low moisture content of modified starches suggests the potential for prolonged shelf stability during storage as a result of a lack of mold growth and moisture-induced biochemical reactions (Ignatius and Akuabor, 2012).

Ash

The ash of native succinylated starch was 1.23–0.59%, while hydrolyzed succinylated starch was 0.33–1.21%. These major discrepancies between native and hydrolyzed starch might be due to the hydrolysis process affected on ash content reduced minerals on tannia starch. **Table 1** shows that the concentration of succinic acid influenced the ash content of succinylated starch.

The succinylation processes reduced the ash and crude fat content of native starch. Although both the native and modified starches had low protein content, there was less in native than modified starches. This is attributed to extensive purification through alkaline solubilization and degradation of the amylose fraction of starch granules after modification (Ibukunle et al., 2019).

Degree of substitutions (DS)

The DS is the average number of groups per anhydroglucose unit (AGU) substituted by another group. The hydroxyl (OH) group found in starch, both in the amylose and amylopectin parts, can be substituted with other groups to change the nature of the starch.

Native succinylated starches had higher DS values than hydrolyzed succinylated starches (**Fig 1**). The DS of native succinylated starch was 0.0600–0.0663%,

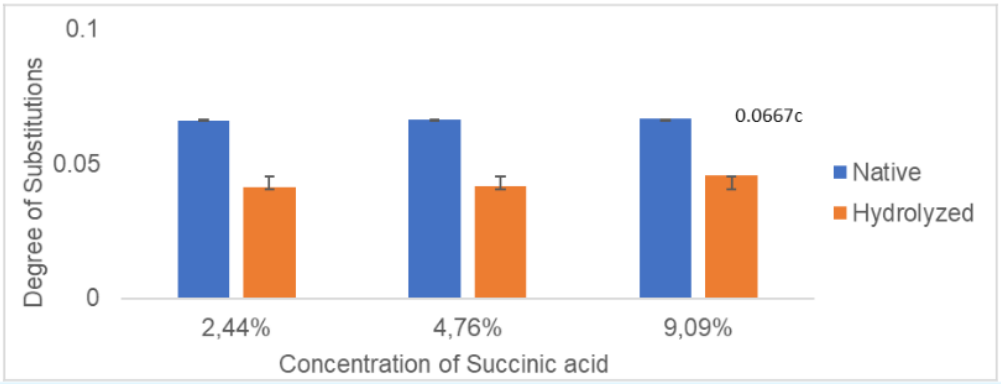

Fig. 1. DS value of succinylated starch

while hydrolyzed succinylated starch was 0.0414–0.04575%. The DS value of succinic acid has been previously reported in the range of 0.045–0.08%, or in 11-22 units, AGU of succinic acid could substitute 1 hydroxyl group (Rini 2005). The DS value of hydrolyzed succinylated starches is traced it was caused lower than 0.5.

The efficiency of a succinylation reaction is influenced by the starch granule size, reagents used, and appertaining reaction time. Peter et al. (2012) have shown a linear increase in the DS coinciding with an increase of the succinic anhydride/starch ratio due to the greater availability of anhydride molecules for starch granules.

Solvent is also an important factor in the reaction efficiency—a significantly higher DS is achieved when DMSO is used as a solvent instead of water. Reaction time is a limiting factor, but only to a certain extent (Toshio et al., 2006; Durdica et al., 2015). Further time increase from 5 h to 10 h did not significantly influence the reaction efficiency.

Succinylation is considered as an ideal modification since it provides starch derivatives with desirable properties.The results showed that an increase in the concentration of the acylating agent from 3 to 9 g gave a substantial increase in % succinyl, degree of substitution (DS) and the reaction efficiency (RE) (Kehinde et al. 2018).

Amylose

The total amylose content of succinylated tannia starch has been reported in the range of 24.5–28.7 % (Shanava 2017). The corresponding value for native starches examined in this study was 24.19–26.16 %, and these major discrepancies might be due to varietal differences. The hydrolyzed starch of tannia in this study was 3.76-4.00 % (**Table 1**). the major discrepancies between native and hydrolyzed caused by α-amylase that was decreased content starch and amylose content to maltose and maltotriose and also amylose participate in hydrolysis process, it is known to be a rapid process mostly due to its linear structure. The amylose content decreased with increasing concentration of succinic acid. Similar effects of acetylation on the amylose content of *Canavalia ensiformis* starches have been observed. The presence of succinyl groups has been reported to interfere with the functioning of amylose and amylopectin fractions of starch and affects the absorption of iodine during amylose estimation. This leads to the increased measured values of amylose.

Dextrose equivalent (DE)

Hydrolyzed succinylated starches had higher values for DE compared to native succinylated starches (**Fig 2**). The DS of native succinylated starch was 2.76–2.93, while hydrolyzed succinylated starch was 13.27–13.77. The major discrepancies between native and hydrolyzed were caused by α-amylase that decreased starch and amylose content to constituent maltose and maltotriose. Starch hydrolysates with DE < 20 are referred to as maltodextrins, while those with > 20 are referred to as maltose syrup or glucose syrups. The hydrolysis of starch can be performed enzymatically or through acid-mediated processes. Amylases are digestive enzymes that hydrolyze glycosidic bonds of starch to glucose, maltose, maltotriose, and dextrin. There are various amylases with different properties. α-amylase catalyzes the cleavage of internal α-1,4 bonds of starch, releasing oligosaccharides as the main products.

Viscosity

Native succinylated starches had higher viscosity compared to hydrolyzed succinylated starches (**Fig 3**). The viscosity of native succinylated starch was 593.25–628 MPa.s while hydrolyzed succinylated starch was 33.5–36.25 MPa.s. The major discrepancies between native and hydrolyzed values were likely caused by α-amylase interacting with granules, breaking them.

Starch

Native succinylated starches had higher starch content than hydrolyzed succinylated starches (**Table 1**). The starch content of native succinylated starch was

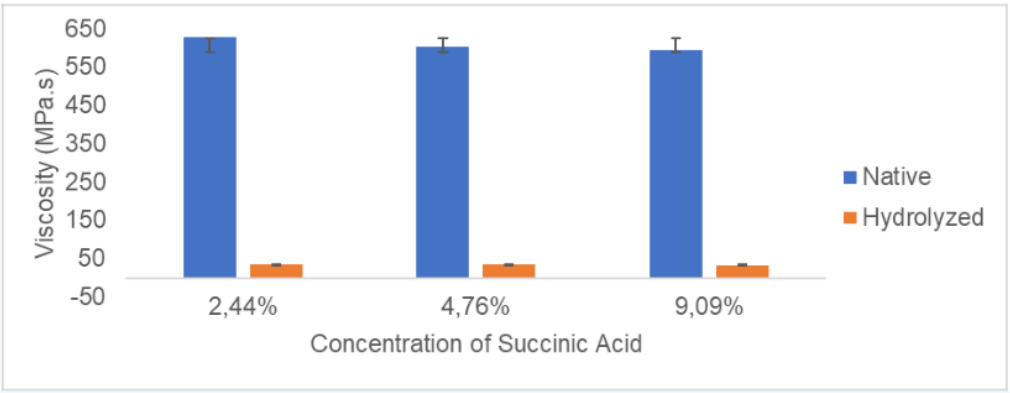

Fig. 2. DE value of succinylated starch.

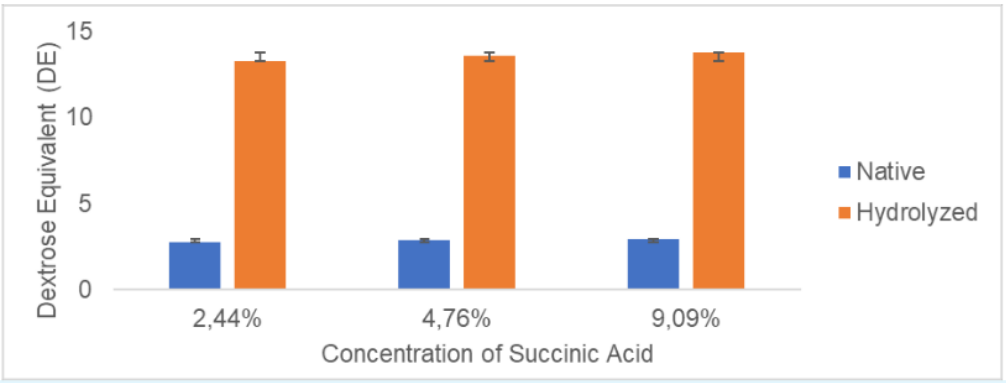

Fig. 3. The viscosity of succinylated starch

63.19–68.49%, while hydrolyzed succinylated starch was 6.57–6.91%. The major discrepancy between native and hydrolyzed was caused by α-amylase interacting with the granules and breaking them. Hydrolyzed starch has lower starch and amylose content than native starch. This was caused by the degradation of α-amylase. The way α-amylase worked was trough 2 steps. For the first degradation, amylose became maltose and maltotriose that was occurred randomly. This degradation occurred very fast and followed by decreasing viscosity quickly, and the second step occurred very slow, and that was called the formation of glucose and maltose as the final result.

Swelling power

Native succinylated starches had higher swelling power than hydrolyzed succinylated starches (**Fig 4**). The swelling power of native succinylated starch was 25.82–26.97(g/g), while hydrolyzed succinylated starch was 5.90–6.78 (g/g). Increases in swelling power were observed as the level of modification increased (**Fig 4**). The increase in swelling power with DS could be due to easy hydration. This, in turn, is a manifestation of the increasing number of hydrophilic groups incorporated into the starch. Amylopectin is well known to hydrate to a greater extent, and the effect appears to be more pronounced after succinylation. It is evident that as the temperature of the medium increases, starch molecules become more thermodynamically activated, and the resulting increase in granular mobility enhances the penetration of water, which facilitates improved swelling capacities.

It is also reasonable that following the introduction of bulky succinyl groups on starch molecules, structural reorganization occurs as a result of steric hindrance, and this results in repulsion, thus facilitating an increase in water percolation within the granules with subsequent increase in swelling capacity. Hydrolyzed succinylated starches had lower swelling power.

The efficiency of a succinylation reaction is influenced by the starch granule size, reagents used, and appertaining reaction time. Peter et al. (2012) have shown a linear increase in the DS coinciding with an increase in the succinic anhydride/starch ratio due to the greater availability of anhydride molecules for starch granules. The solvent is also an important factor in the reaction efficiency—a significantly higher DS is achieved

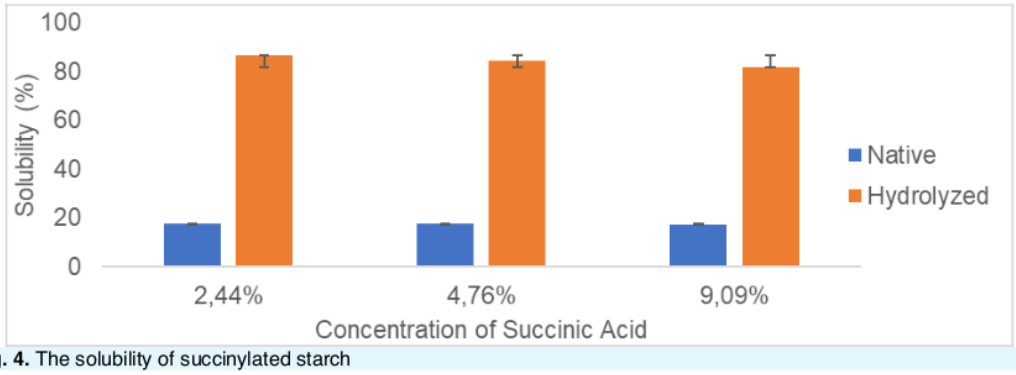

Fig. 4. The solubility of succinylated starch

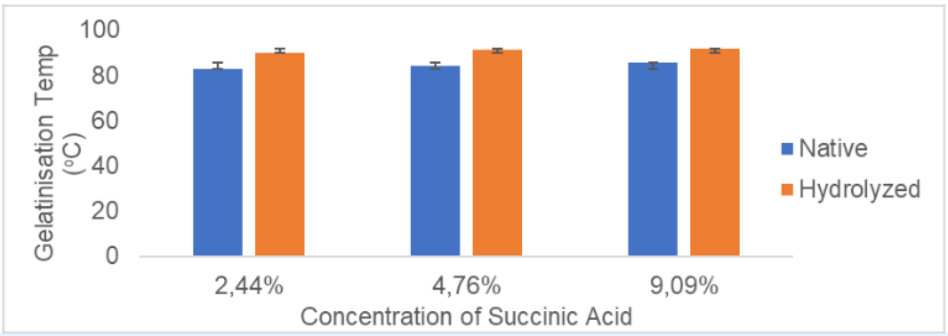

Fig. 5. Gelatinization Temperature of succinylated starch

when DMSO is used as a solvent instead of water. Reaction time is a limiting factor, but only to a certain extent.

Each treatment produces certain swelling power characteristics that do not depend on the concentration of the substrate or the concentration of acid added, but it is a form of interaction between the two factors used. Amylose content and amylopectin binding composition are primarily gelling agents (Hanjuang et al. 2005). The relationship between negative and positive effects of swelling power is related to amylopectin and amylose (Sathaporn et al. 2005). Increasing amylose levels also increase swelling power (Davies et al. 2008).

The factors influence the swelling power, such as the structure of amylopectin, complexes of V-amylose lipid, amylose content, enhancement of crystalline perfection, increment in molecular organization, and the level of interaction between amylose–amylose and/or amylose–amylopectin chains (Achmad et al. 2018; Cheow et al. 2004)

Solubility

Hydrolyzed succinylated starches had higher water solubility than native succinylated starches (**Fig 4**). The solubility of native succinylated starch was 17.35–17.84%, while hydrolyzed succinylated starch was 81.83–86.79%. Major discrepancies between native and hydrolyzed starches could be caused by processes catalyzed by acid and heating, decreasing solubility even in cold water.

In the process of modification with hydrolyzed starch, a succinic acid concentration of 2.44% produced optimal solubility. Increased succinic acid caused the solubility of modified starch in water to decrease. Structural disintegration probably weakened the starch granules after modifications and this enhanced leaching from the starch and solubility. As evident in **Fig. 4**, succinylation caused a reduction in insolubility.

Gelatinization temperature

Hydrolyzed succinylated starches had higher gelatinization temperature compared to native succinylated starches (**Fig 5**). The solubility of native succinylated starch was 17.35–17.84 °C while hydrolyzed succinylated starch in 81.83–86.79 °C. Major discrepancies between native and hydrolyzed starch were likely caused by breakage of starch crystals during hydrolysis, increasing water, and starch linking. The highest concentration of succinic acid interacting with starch and water would restrict starch linking, requiring more time for gelatinization (Rini 2005).

The succinylation of the corn starch altered its pasting properties, thereby lowering the PV and H and increasing the amphiphilic properties through the rearrangement of the amorphous and crystalline zones (Ulin et al. 2019).

You et al. (2003), conducted a study on the suitability of using corn and barley starches (native and modified starch) as to be microcapsules to prevent flavor volatile of meat.

Four different types of synthetic roasted chicken flavors, namely benzaldehyde, dimethyl trisulfide, 2-mercaptopropionic acid and benzothiazole, were prepared by mixing gelatinized native or modified starches followed by lyophilization. The flavors were determine their retention during the complex formation process with starches. The result shows that the succinylated regular corn (CRS) and succinylated regular barley (BRS) gave the best flavors retention as to compare with other modified starches and β-cyclodextrin (βCD).

The modified starch could be a solution, in order to reach those barrier properties that made them applicable to the function desired of plasctizer edible film. Structural differences between the two main polymers that form the starch granules make, possible their modification. The modification of the native starch properties addressing them to a specific use can be brought about by using chemical, physical, or biological techniques, which may improve or introduce the desire functionality in their structure (Elevina and Dufour 2017).

CONCLUSION

The modified starches were analyzed for their yield, moisture content, ash, degree of substitution (DS), dextrose equivalent (DE), syneresis, swelling power, gelatinization properties, and viscosity. Generally, all characteristics of the starch were significantly affected by the concentration level of succinic acid, and the highest concentration (9.09%) provided the best performance with regards to food production applications.

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