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The Study of Plasmonic Chip of Nata de Sago-green Silver Nanoparticles for Detection of Blood Glucose

Abdul Haris Watoni[1*], La Ode A. Nur Ramadhan[1], Evy Nuryah Adha[1], and Robby Sudarman[2]

[1]Department of Chemistry, Mathematics and Natural Sciences, Halu Oleo University, Kampus Bumi Tridharma Anduonohu, Jalan H.E.A. Mokodompit, Kodya Kendari, Sulawesi Tenggara, Indonesia
[2]Department of Chemical Engineering, Bandung State Polytechnic, Jl. Gegerkalong Hilir, Ciwaruga, Kec. Parongpong, Kabupaten Bandung Barat, Jawa Barat 40559
*Corresponding author : ahwatoni@gmail.com

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Abstract: The innovation of rapid blood glucose level detectors using chemical sensors still needs to be carried out continuously. Nata de sago has good potential as a safe sensor chip for blood glucose detection. To increase the detection speed, this sensor chip can be composited with silver nanoparticles (AgNPs)-bidara leaf extract which has plasmonic properties when interacting with visible radiation. The principle of blood glucose detection with the nata de sago-AgNPs-bidara leaf extract composite chip is based on van der Waals interactions between the functional groups in nata de sago and the hydroxyl groups in glucose compounds which are strengthened by the plasmonic nature of AgNPs. This study aims to synthesize and characterize *nata de sago* cellulose composite films embedded with silver nanoparticles as blood sugar detection sensor chips. Silver nanoparticles (AgNPs) were synthesized from $AgNO_3$ precursors using bioreductors and capping agents of bidara leaf extract (*Ziziphus mauritiana L.*) with various volume ratios of precursor to bioreductor 1:1, 1:2, 1:3, 1:4, 1:5 and 1:6. The nata de sago-AgNPs-bidara leaf extract composite was made by soaking the nata de sago film in a suspension of AgNPs-bidara leaf extract for 1 hour until the film turned yellow. The film was then dried for 24 hours at room temperature to obtain a cuvette type plasmonic film which was ready for characterization and validation. FTIR analysis showed the formation of silver particles based on vibrational spectra changes of functional groups of bioreductor compounds at wave numbers 3423 cm^{-1}, 2924 cm^{-1}, 1641 cm^{-1} and 1056 cm^{-1}. Morphological analysis using a digital microscope showed that the AgNPs were not uniformly spherical. Particle size analysis using a UV-Vis spectrophotometer showed that the AgNPs formed had an estimated diameter of 32.231 – 82.261 nm. Composite film of *nata de sago*-AgNPs-bidara leaf extract can be used as a blood glucose sensor chip by UV-Vis spectrophotometry with LOD = 30.814 mg/dL, LOQ = 50.814, %*RSD* = 5.015, and %*R* 90.68. The values of these parameters indicate that the sensor chip has good precision (%*RSD*) and accuracy (%*R*).

Keywords: plasmonic chip, silver nanoparticles, blood sugar

***Abstract*:** Inovasi detektor cepat kadar glukosa darah menggunakan sensor kimia masih perlu dilakukan secara terus-menerus. *Nata de sago* memiliki potensi yang baik sebagai chip sensor yang aman untuk deteksi glukosa darah. Untuk meningkatkan kecepatan deteksinya, chip sensor ini dapat dikomposit dengan nanopartikel perak (NPAg)-ekstrak daun bidara yang memiliki sifat plasmonik ketika berinteraksi dengan radiasi sinar tampak. Prinsip deteksi glukosa darah dengan chip komposit nata de sago-NPAg-ekstrak daun bidara berdasarkan pada interaksi van der Waals antara gugus fungsi-gugus fungsi dalam nata de sago dan gugus hidroksil dalam senyawa glukosa yang diperkuat oleh sifat plasmonik NPAg. Penelitian ini bertujuan untuk mensintesis dan mengkarakterisasi film komposit selulosa *nata de sago* terinsersi nanopartikel perak sebagai chip sensor deteksi glukosa darah. NPAg disintesis dari prekursor $AgNO_3$ menggunakan bioreduktor dan capping agents ekstrak daun bidara (*Ziziphus mauritiana* L.) dengan variasi perbandingan volume prekursor terhadap bioreduktor 1:1, 1:2, 1:3, 1:4, 1:5 dan 1:6. Adapun komposit *nata de sago*-NPAg-ekstrak daun bidara dibuat dengan merendam film nata de sago ke dalam suspensi NPAg-ekstrak daun bidara selama 1 jam hingga film berubah menjadi kuning. Film ini selanjutnya dikeringkan selama 24 jam pada suhu kamar sehingga diperoleh film plasmonik tipe kuvet yang siap untuk dikarakterisasi dan divalidasi. Analisis FTIR menunjukkan terbentuknya partikel perak berdasarkan perubahan spektrum vibrasi gugus-gugus fungsi senyawa bioreduktor pada bilangan gelombang 3423 cm^{-1}, 2924 cm^{-1}, 1641 cm^{-1}, dan 1056 cm^{-1}. Analisis morfologi menggunakan mikroskop digital menunjukkan bahwa NPAg berbentuk bulat tidak seragam. Analisis ukuran partikel menggunakan spektrofotometer UV-Vis menunjukkan bahwa NPAg yang terbentuk memiliki estimasi diameter 32,231 – 82.261 nm. Film komposit *nata de sago*-NPAg-ekstrak daun bidara dapat digunakan sebagai chip sensor glukosa darah secara spektrofotometri UV-Vis dengan nilai LOD = 30,814 mg/dL, LOQ = 50,814, %*RSD* =

5,015, dan %*R* 90,68. Nilai-nilai parameter ini menunjukkan bahwa chip sensor tersebut memiliki presisi (%*RSD*) dan akurasi (%*R*) yang baik.

Kata kunci: *chip plasmonic, nanopartikel perak, gula darah*

INTRODUCTION

The number of people with diabetes mellitus (DM) in Indonesia continues to increase to an estimated 21.3 million in 2030. Therefore, early detection of DM symptoms needs to be done. The first blood glucose detection device designed to be enzyme-based. This tool has disadvantages in terms of durability, because the sensor can be damaged if it is in a solution with a pH < 2 and pH > 8. Therefore, it is necessary to innovate a blood glucose level detector using a chemical sensor that can respond to analytes through chemical reactions (Putri *et al*, 2021). Chemical sensors are very important analytical instruments because they have high selectivity and sensitivity and fast response to analytes, so they can be used to quickly determine analytes with very low concentrations (Mustaghfiroh *et al.* 2019). However, most chemical sensors are quite expensive and limited to color changes only. Therefore, a cuvette type plasmonic sensor chip was developed for the detection of analytes using UV-Vis spectroscopy instruments. A cellulose-based sensor chip was designed based on colorimetric analysis to detect low concentrations of glucose (Luo *et al. 2019*). Based on this reason, it can be said that cellulose can be used in DM detection.

Cellulose, besides being produced naturally in plants, can also be produced biotechnology in glucose fermentation media using *Acetobacter xylinum* to form *nata* (Onggo *et al*. 2017). One type of cellulose is *nata de sago*. *Nata de sago* is bacterial cellulose formed from the fermentation of sago liquid waste (Yanti *et al*. 2021). Bacterial cellulose has several advantages compared to plant cellulose, such as (1) its fiber structure is nano-sized and very thin which is about 100 times thinner than membrane fibers, (2) its high level of purity, and (3) its good biocompatibility (Boby *et al*. 2021). Physically, bacterial cellulose has the features of strong cellulose. Therefore, *nata de sago* has suitable characteristics for sensor chips and is safe to use. In addition, the *nata de sago* matrix can potentially be inserted with metal nanoparticles, because *nata de sago* has a fibrous and porous structure (Yanti *et al*. 2021).

One of the metal nanoparticles that has been widely studied is silver nanoparticles (AgNPs). Due to its plasmonic property, in chemical sensors, AgNPs are used to increase sensitivity and staining in the detection of analyte sensors (Surya *et al*. 2020). The parameters that need to be controlled in the synthesis of AgNPs are size, shape, and morphology, because their optical, electrical, magnetic, catalytic and antibacterial properties are determined by their shape and size. Particle size is affected by solution temperature, precursor salt concentration, reducing agent and reaction time (Apriandanu *et al*. 2013).

AgNPs synthesis can be carried out using physical, chemical, and bioreduction methods. These synthesis methods include hydrothermal, electrochemical, sol gel, and chemical reduction (Chandraker *et al*. 2019). The chemical reduction method was chosen as the most effective method for producing AgNPs, because the procedure is easy, fast, inexpensive, and can be carried out at room temperature. In general, metal ions are reduced by reducing agents with the addition of protective agents to stabilize nanoparticles (Oktaviani *et al*, 2015). To avoid the dangers that occur in the chemical synthesis of nanoparticles, a bioreduction method was developed using reducing agents derived from plant extracts. One type of plant that can be used as a reducing agent in the synthesis of AgNPs is bidara leaf extract, because bidara leaf extract (*Ziziphus mauritiana* L.) contains secondary metabolites of alkaloids, saponins, flavonoids, steroids and tannins (Wisnuwardhani *et al*. 2019; Yulianingsih & Arwie 2019; Taba *et al*. 2019). These secondary metabolites are strong reducing agents because they have an abundance of –OH groups.

Previous research on cellulose-based chips was designed based on colorimetry tests in detecting low concentrations of glucose using sensitive enzyme-based cellulose chips (Luo *et al*. 2019). In addition, research on the development of cuvette-based sensor chips using active plasmonic transparent chips has also been carried out (Oh *et al*. 2019). Based on the above studies, in this research the synthesis and characterization of a transparent *nata de sago* plasmonic chip inserted with AgNPs as a cuvette type sensor chip for rapid detection of blood sugar was carried out. This article reports the results of the synthesis and characterization of *nata de sago*, AgNPs-bidara leaf extract, and composite films of *nata de sago*-AgNPs-bidara leaf extract and performance tests of these composite plasmonic chips for blood glucose measurement. The performance of the plasmonic chip tested was calibration curve linearity, limit of detection (LOD), limit of quantization (LOQ), accuracy, and precision.

MATERIALS AND METHODS

Materials

The materials used in this study were sago waste obtained from the Tondongeu sago factory, Southeast Sulawesi, bidara leaves (*Ziziphus mauritiana L.*) from Kambu sub-district, around the UHO Campus, silver nitrate ($AgNO_3$) (Emusure Merck), ethanol

95% (C_2H_5OH) (Emusure Merck), distilled water (Water One) (Emusure Merck), sodium hydroxide (NaOH) (Emusure Merck), granulated sugar ($C_6H_{12}O_6$) (Gulaku), zwavelzure ammonium (ZA), *Acetobacter xylinum* seed starter, glucose, epoxy resin, whatman filter paper no.42, label paper (Fox), plastic wrap (Cling Wrap), aluminum foil (Klin Pak), and tissue (Nice).

The tools used in this study were beakers-50 mL, 250 mL and 500 mL (Iwaky pyrex), measuring cups-25 mL (Iwaky pyrex), measuring flasks 250 mL (Iwaky pyrex), oven (Kirin), pipettes, hot plate, vial-20 mL and 100 mL, dark bottle, stir bar, spray bottle, scale (Ohaus Explorer: max. 250 g and min. 0.001 mg), spatula, funnel, petri dish, blender (Philips), sieve (80 mesh), jar, hydroulic power press, magnetic stirrer, pH meter (WT61), burette (Iwaky pyrex), eppendorf, centrifuge (MPW-350), rotary evaporator, laminar airflow, soft cloth, scissors, gloves, ruler, mask , UV-Vis spectrophotometer (Spectraquant Pharo 300 M), FTIR (Fourier Transform Infra Red) spectrophotometer (Shimadzu FTIR QP89500), digital microscope, pressure cooker (Kirin), stand, and clamps.

Extraction, Synthesis, Characterization, and Plasmonic Film Test

Fresh bidara leaves are cleaned using running water, dried in an oven for 24 hours at 50ºC, and crushed using a blender to obtain bidara leaf simplicia powder. Furthermore, the simplicia powder obtained was filtered using an 80 mesh sieve and extracted (Bintoro *et al*. 2017). The extraction of bidara leaves was adapted from previous research through the maceration method using ethanol solvent (Haeria *et al*. 2016). As much as 250 grams of bidara leaf simplicia was macerated using 1 liter of 95% ethanol for 3 days accompanied by stirring, then filtered to separate the filtrate and residue. The residue obtained was macerated again using 500 mL ethanol for 2 times. The filtrate obtained was evaporated using a rotary evaporator at 50ºC, so that a thick extract of bidara leaves was obtained. This extract is then used as a bioreductor in the synthesis of AgNPs.

AgNPs were synthesized by green synthesis using the bioreduction method. As much as 0.85 gram of $AgNO_3$ precursor was dissolved in 500 mL of distilled water and then reacted with bioreductor of bidara leaf extract with various volume ratios of precursor : bioreductor (v/v) of 1:1, 1:2, 1:3, 1:4, 1:5 and 1:6. The mixture was stirred using a magnetic stirrer for 30 minutes until it turned brown. The color changes that occurred in the mixture were observed at 0, 10, 20, and 30 minutes. Next, the mixture was centrifuged at 3500 rpm for 10 minutes to obtain a solid powder residue that was ready to be characterized (Fabiani *et al*. 2018). The obtained suspension of AgNPs-bidara leaf extract was composited on the *nata de sago* film matrix.

Nata de sago was synthesized through the following procedure: 3 liters of sago liquid waste was heated at 50ºC to kill the microorganisms present in it. Into the liquid, put 400 grams of sugar which functions as a carbon source and 45 grams of ZA as a nitrogen source. After boiling, the mixture was cooled and added with 750 mL of *Acetobacter xylinum* inoculum and 10 mL of acetic acid to pH 4. Next, the mixture was homogenized and put into a fermenting container that had been sterilized, covered with sterile newspaper, and tied with a rubber band. This fermentation was carried out for ± 14 days. The *nata de sago* obtained was soaked in sodium hydroxide (NaOH) solution for 1 minute and washed again using running water until the pH was neutral. Furthermore, *nata de sago* was pressed using a hydroulic power press at a pressure of 300 Psi and a temperature of 150 ºC to obtain a thin film sheet. The film was cut to a size of (3 × 1) cm^2, then immersed in AgNPs suspension-bidara leaf extract for 1 hour until the color of the film turned brown. The film was dried for 24 hours at room temperature, so that a cuvette type plasmonic film was obtained which was ready to be characterized and validated.

The bioreductor extracts and bioreduction products obtained were characterized using a UV-Vis spectrophotometer and digital microscope, while the *nata de sago* film matrix inserted with AgNPs was characterized using an FTIR spectrophotometer. Characterization using a UV-Vis spectrophotometer aims to analyze the formation of nanoparticles based on their plamonic properties. The characterization using the FTIR spectrophotometer aims to analyze the process of formation of AgNPs based on changes in the vibrational spectra of functional groups of bioreductor compounds.

Analysis using a UV-Vis spectrophotometer was carried out on suspension of AgNPs-bidara leaf extract in the wavelength range of 380 - 950 nm with time intervals of 0, 10, 20, and 30 minutes, so that trends or absorption patterns can be observed. Particle size is estimated based on the surface plasmon resonance (SPR) wavelength (λ_{SPR}) data and the wavelength with minimum absorbance (λ_0) using the Equation (1)

$$d = \frac{\ln\left(\frac{\lambda_{SPR} - \lambda_0}{L_1}\right)}{L_2} \qquad (1)$$

where d is the particle diameter, λ_{SPR} and λ_0 are the maximum and minimum wavelengths of *SPR*, respectively, L_1 = 6.53 and L_2 = 0.0216 are values taken from TEM vs UV-Vis data (Haiss *et al*. 2007).

The plasmonic chip test was performed using glucose standards of 50, 100, 150, 200, and 250 mg/dL. Plasmonic chip of *nata de sago* inserted with AgNPs-bidara leaf extract was immersed in a cuvette containing a standard glucose solution and analyzed

using a UV-Vis spectrophotometer at maximum wavelength (393 nm) to obtain a calibration curve. This calibration curve is used as a comparison in determining the concentration of glucose in blood serum samples. Parameters of the validity of the method determined are precision, accuracy, limit of detection (LOD), and limit of quantification (LOQ).

RESULTS AND DISCUSSION

In this study, liquid extract of bidara leaves was obtained by maceration method using 95% ethanol solvent. Ethanol is relatively less toxic than methanol, cheap, easy to obtain, and the extract obtained is not easily overgrown with fungi and bacteria. In addition, ethanol is semipolar so that it allows polar and nonpolar compounds contained in simplicia to be attracted (Sukmawati *et al*. 2018). These advantages are the reason for choosing ethanol as a solvent in the maceration process. Extraction using the maceration method guarantees that the active substance extracted will not be damaged (Aisyah *et al*. 2020). During the immersion process, the cell wall and cell membrane of plant sample are broken down so that the secondary metabolites present in the cytoplasm break down and dissolve in ethanol solvent (Novitasari *et al*. 2016). Visually, bidara leaves, simplicia powder and extracts obtained in this extraction are shown in Figure 1.

Bidara leaf extract contains secondary metabolites such as flavonoids which have antibacterial, anti-inflammatory, antifungal, and anti-cancer properties (Mulyani *et al*. 2021; Widiasari 2018). These compounds act as bioreductors and capping agents in the synthesis of nanoparticles through a green chemistry approach (Zulaicha *et al*. 2021). Secondary metabolites play an important role in the synthesis of AgNPs because of their high antioxidant properties (Prasetyaningtyas *et al*. 2020). In this study, AgNPs-bidara leaf extract were obtained from the reaction between 0.01 N $AgNO_3$ precursor and bidara leaf extract bioreductor with volume ratio of precursor : bioreductor (v/v) of 1:1, 1:2, 1:3, 1:4, 1:5 and 1:6 (Figure 2). The AgNPs obtained were then referred to as AgNPs-1:1, AgNPs-1:2, AgNPs-1:3, AgNPs-1:4, AgNPs-1:5, and AgNPs-1:6, respectively. Similar to the results of previous studies, the formation of AgNPs was marked by the formation of colloid and the color change of the liquid extract from dark brown to light brown as $AgNO_3$ was added (Patabang *et al*, 2019; Al Mashud *et al*. 2022). A change in color of the mixture from dark brown to light brown indicates particle size increase (Septriani & Muldarisnur 2022).

Theoretically, the redox reaction mechanism between Ag^+ ions and flavonoids as well as an illustration of the formation and stabilization processes that occur during the formation of AgNPs are shown in Figure 3. The –OH group in flavonoids is responsible for reducing Ag^+ ions to AgNPs. It is possible that the tautomeric transformation of flavonoids from the enol form to the keto form can release reactive hydrogen atoms which reduce Ag^+ ions to Ag^0 (Masakke *et al*. 2015; Lestari *et al*. 2019). In this process, the growth of nanoparticles forms a cluster. Secondary metabolites act as capping agents that interact electrostatically with AgNPs so that clusters do not grow sustainably to form large agglomerates (Oktavia & Sutoyo 2021). Electrostatic interactions occur between the negative partial charges of phenolic or polyphenolic compounds and the positive partial charges of AgNPs (Yusof *et al*. 2018).

Figure 1. Bidara leaves and their extracts. (a) Fresh bidara leaves, (b) simplicia, and (c) bidara leaf extract.

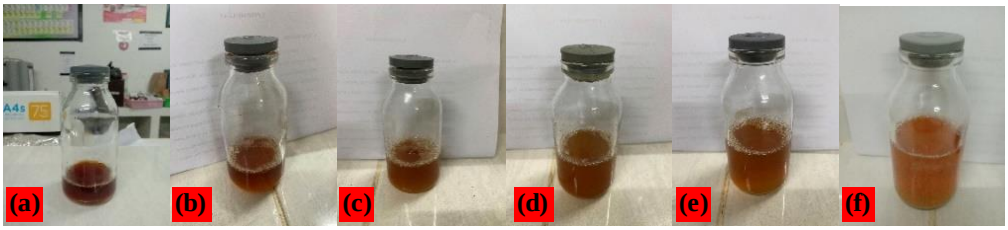

Figure 2. Reaction product between bidara leaf extract bioreductor and Ag^+ precursor with volume ratio of precursor : bioreductor (v/v) of (a) 1:1, (b) 1:2, (c) 1:3, (d) 1:4, (e) 1:5, and (f) 1:6.

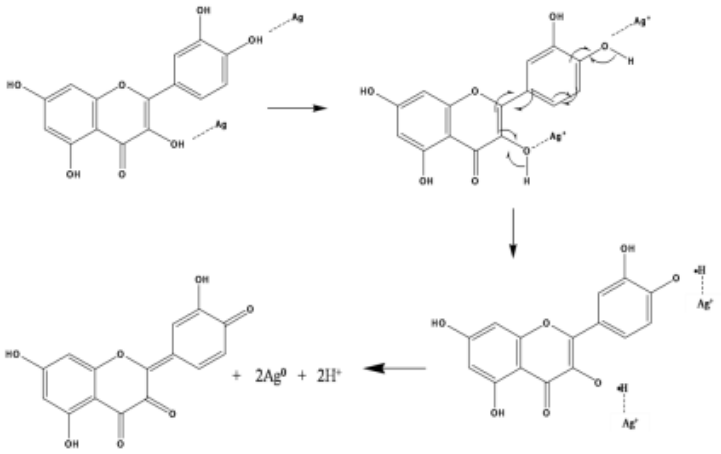

Figure 3. Reaction mechanism of AgNPs formation (Oktavia & Sutoyo 2021)

The formation of AgNps is not only observed from the change in colloid color, but can also be observed from the maximum wavelength (λ_{max}) of AgNPs from 400 to 500 nm (Oktavia & Sutoyo 2021). In this study, the AgNPs obtained had varying maximum absorption at a wavelength of 400 - 450 nm (Figure 4). The maximum absorbance value that remains in different measurement time ranges indicates that the AgNPs formed are stable (Prasetyaningtyas *et al*. 2020; Notriawan *et al*. 2020).

λ_{max} shifts to a lower value with increasing Ag^+ precursor concentration. This shows that the interaction energy of AgNPs with bioreductor compounds increases (Marslin *et al*. 2018). When the particles agglomerate, the conduction electrons that approach the surface of the particles become delocalized and shared with other particles

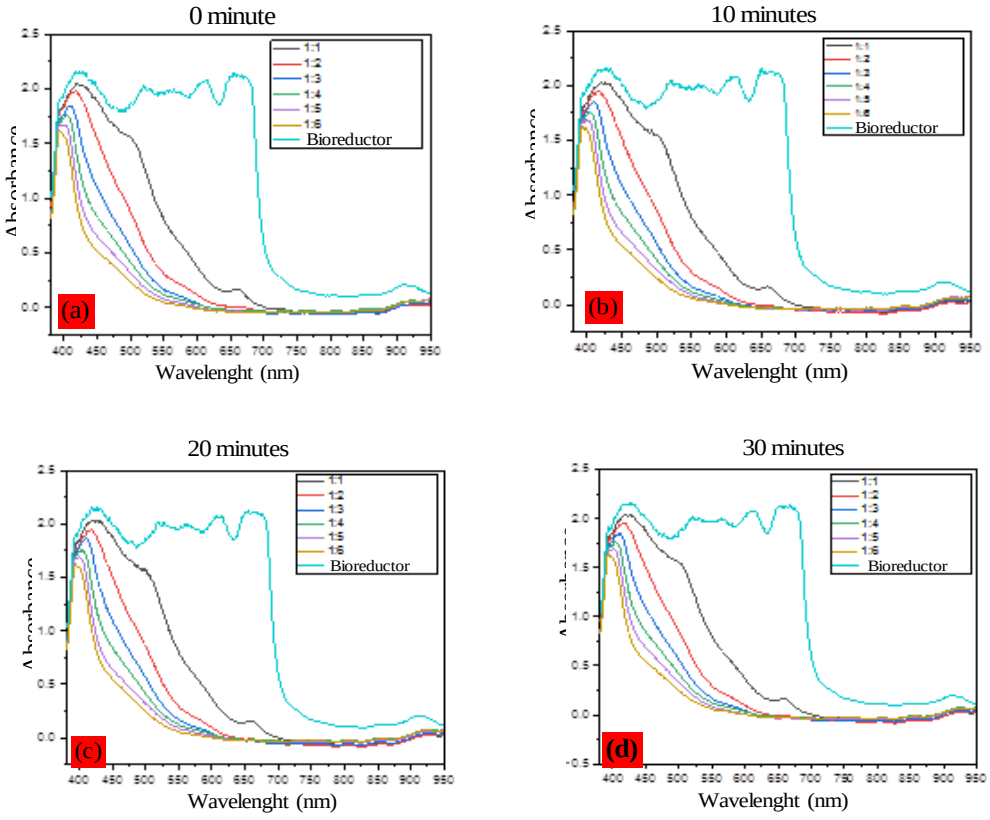

Figure 4. UV-Vis spectrum of AgNPs-bidara leaf extract in time intervals of (a) 0 minutes, (b) 10 minutes, (c) 20 minutes and (d) 30 minutes.

so that a shift in surface plasmon resonance (SPR) to a lower energy causes a shift in the absorption peak to a longer wavelength (Rahmayani *et al*. 2019). The decrease in absorbance is caused by the large number of Ag^+ ions that have not experienced aggregation (Nisa & Dwandaru 2017).

The absorbance data was also used to determine the particle size estimates of the AgNPs. Table 1 presents the particle size estimates of AgNPs determined by adapting the procedures from previous studies (Haiss *et al*. 2007). In this synthesis, the AgNPs obtained have an estimated diameter of 32.213 nm – 80.426 nm. Based on the definition that the size of the nanoparticles is 1 nm – 100 nm, it is proven that bidara leaf extract is very good for use as a bioreductor and at the same time a capping agent in the synthesis of AgNPs.

Indications of the formation of AgNPs were also confirmed using an FTIR spectrophotometer (Figure 5). The change in the peak of the vibrational spectrum of the hydroxyl group (-OH) from bidara leaf extract is an indication of the oxidation of the –OH group by oxidizing Ag^+ (Chandraker *et al*. 2019). At the same time, Ag^+ ions are reduced to Ag^0 and aggregated to form AgNPs. Figure 5(a) and Figure 5(b) clearly show changes in the vibrational spectrum of the functional groups –OH (wave number 3423 cm^{-1}, –C-H aliphatic (wave number 2924 cm^{-1}), -C=O (wave number 1641 cm^{-1}), and C-OH stretching (wave number 1058 cm^{-1}).

Observations using a digital optical microscope show particle morphology with non-uniform shapes and irregular clusters (Figure 6). Aggregation occurs through van der Waals interactions in the nanoparticle suspension. However, this observation did not illustrate the relationship between the amount of bidara leaf extract and the size of the nanoparticles formed.

In this study, a composite of nata de sago-AgNPs-bidara leaf extract was also obtained by immersing the nata de sago film/chip in suspension of AgNPs-bidara leaf extract (Figure 7(b)). The absorption mechanism of AgNPs into the bacterial cellulose matrix is thought to occur through van der Waals interactions between AgNPs and hydroxyl oxygen atoms in bacterial cellulose and bidara leaf extract compounds (Figure 8). This interaction causes AgNps to be trapped in the pore of bacterial cellulose (Rohaeti *et al*. 2016). In addition, there is the possibility of intermolecular interactions between bidara leaf extract compounds and bacterial cellulose. These two interactions made it possible to form the composite *nata de sago*-AgNPs-bidara leaf extract. The trapped AgNPs have plasmonic properties which enable this plasmonic chip to detect blood glucose. Glucose detection with the chip is possible through van der Waals interactions between the functional

Table 1. Estimation of Particle Size of AgNPs-Bidara Leaf Extract

Sample Code	λ_{SPS} (nm)	λ_0 (nm)	Particle Diameter Estimation (nm)
AgNPs-1:1	419.1	380.5	82.261
AgNPs-1:2	417.6	380.5	80.426
AgNPs-1:3	410.6	380.5	70.746
AgNPs-1:4	404.4	380.5	60.068
AgNPs-1:5	393.6	380.5	32.231
AgNPs-1:6	393.6	380.5	32.231

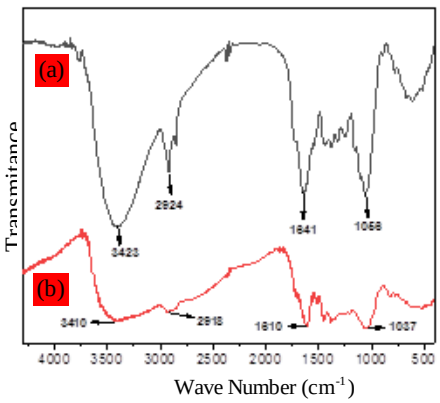

Figure 5. FTIR spectrum: (a) Bidara leaf extract bioreductor and (b) the mixture of Ag^+ bioreductor and precursor with volume rasio of 1:1.

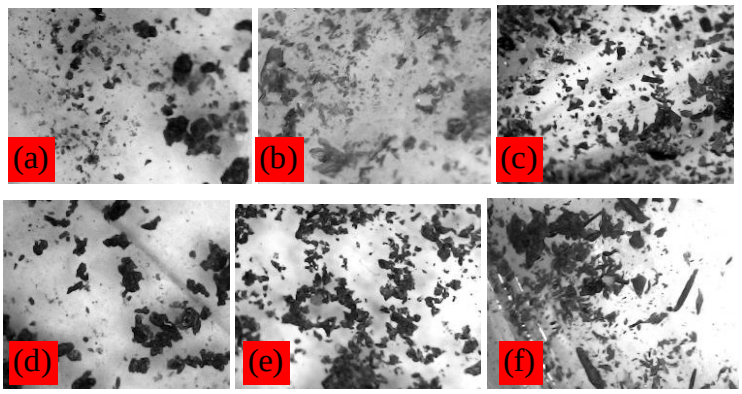

Figure 6. Results of digital optical microscope analysis at 1,000x magnification for: (a) AgNPs-1:1, (b) AgNPs-1:2, (c) AgNPs-1:3, (d) AgNPs-1:4, (e) AgNPs-1:5, and (f) AgNPs-1:6.

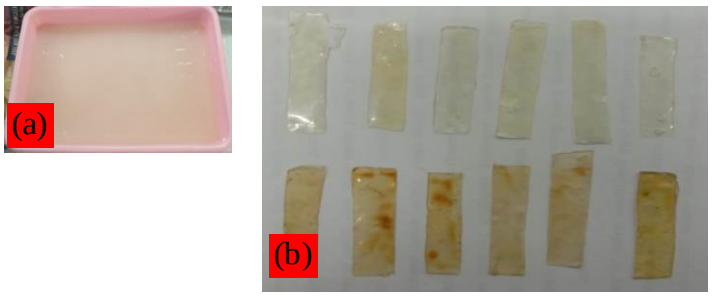

Figure 7. (a) Synthesized *nata de sago* and (b*) Nata de sago* plasmonic chips before (top) and after (bottom) composite with AgNPs-bidara leaf extract with a precursor-bioreductor composition from left to right of 1:2, 1:3, 1:4, 1:5, and 1:6, respectively.

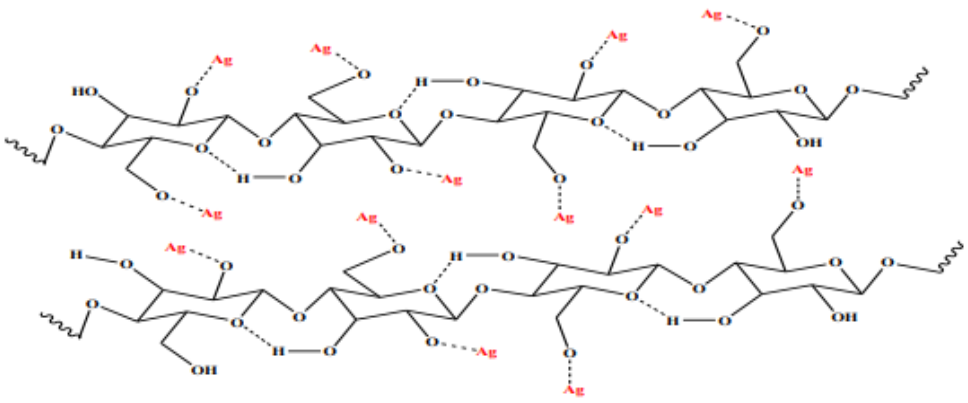

Figure 8. Proposed interaction of cellulose with silver nanoparticles (Akbar 2021)

groups in nata de sago and the hydroxyl groups in glucose compounds which are strengthened by the plasmonic nature of AgNPs

Absorbance measurements of 50, 100, 150, 200 and 250 mg/dL standard glucose solutions using a plasmonic chip containing AgNPs-1:2 produced a calibration curve with the equation $y = 0.0014x + 0.4396$ and linearity (R^2) 0.9806 (Figure 9). These data indicate that testing the glucose solution using a plasmonic chip in UV-Vis spectroscopy follows the Lambert-Beer law. The validity of the glucose measurement method using this plasmonic chip is determined based on the values of LOD, LOQ, precision, and accuracy.

Limit of detection (LOD) is the smallest amount of analyte in a sample that can still be detected by a measuring instrument without the need to be quantized. The quantitation limit (LOQ) is the lowest concentration limit of the analyte in the sample that meets the criteria for precision and accuracy (Afifah *et al*. 2019). Data for these three parameters is presented in Table 2. By plugging in the absorbance LOD and LOQ absorbance (*y* value) into the regression equation, the LOD and LOQ (*x* value)

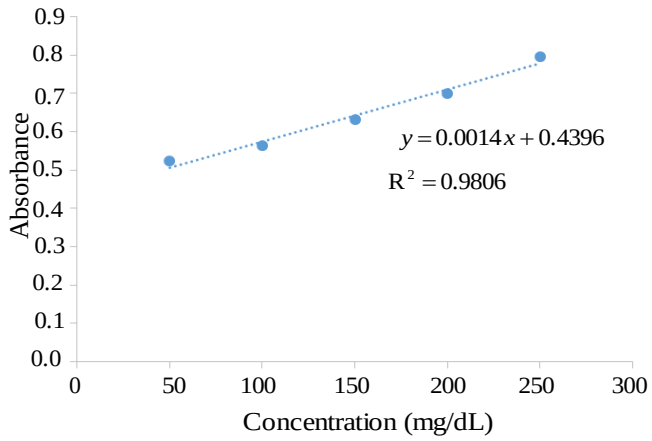

Figure 9. Callibration curve from standard glucose measurements using plasmonic films inserted with AgNPs-1:2.

Table 2. Method Validity

Measurements Repetition	Absorbance of 150 mg/dL Standard Glucose		Absorbance of Blood Sample + 150 mg/dL Spike
1	0.677		0.720
2	0.709		0.608
3	0.745		0.626
4	0.769		0.650
5	0.781		0.713
6	0.784		0.743
7	0.790		0.808
Average	0.751		
SD	0.040		
MDL = Average + 3.143 SD	0.877		
LOD = Average + 3 SD	0.871	30.814 mg/dL	
LOQ = Average + 10 SD	1.151	50.814 mg/dL	
%*RSD*	5.015		
%*R*			90.68

values are 30.814 mg/dL and 50.814 mg/dL, respectively.

Other validity parameters are accuracy and precision. Accuracy is a measure of closeness degree of the obeserved analyte levels to the actual analyte levels. The precision is the repeatability of the repeated measurements of one target (Fajriana & Fajriati 2018). Accuracy is expressed as percent recovery (%*R*) and can be determined using the standard addition method (Sasongko *et al*. 2017). The precision is determined based on the %*RSD* value. Determining accuracy and precision using this method produced %*R* and %*RSD* values of 90.743 and 5.015, respectively (Table 2). The %R value is still in the range of 80 – 110%, so it can be said that blood glucose measurement using this method has good accuracy (Sahumena *et al*. 2020). The %*RSD* value obtained indicates that blood glucose measurement using this method has a good degree of repeatability according to the results of previous studies (Pratiwi *et al*. 2016).

CONCLUSION

In this study, the manufacture, characterization, and validity test of the sensor chip for rapid detection of blood glucose based on the composite matrix of nata de sago-AgNPs-

bidara leaf extract has been carried out. Extraction through a green chemistry approach for bioreductor compounds from bidara leaves can be carried out through the application of the maceration method using ethanol solvent. The extract compounds obtained can be used as bioreductors and at the same time act as capping agents in the synthesis of AgNPs. The obtained AgNPs were non-uniformly spherical with an estimated particle size of 32.231 nm – 82.261 nm and had plasmonic properties with λ_{SPR} values of 393.6 – 419.1 nm. AgNPs-bidara leaf extract suspension can be composited in the nata de sago matrix into a plasmonic chip to detect glucose content. Glucose measurement by UV-Vis spectrophotometry in this plasmonic chip cuvette has LOD = 30.814 mg/dL, LOQ = 50.814, %RSD = 5.015, and %R 90.68. These data show that the plasmonic chip is capable of detecting glucose down to the lowest concentration of 30.814 mg/dL with good accuracy and precision. Based on the low LOD value, to improve performance, it is necessary to make a calibration curve in a wider range of concentrations starting from concentrations below 30 mg/dL. In addition, it is necessary to measure the absorbance of standard glucose with a wider concentration range to obtain a more valid actual calibration concentration range.

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