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Modification of Electrode using Arrowroot Starch Membrane for Uric Acid Determination

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ABSTRACT. Arrowroot starch membrane-modified glassy carbon electrode were constructed for the determination of uric acid. The membrane consist of arrowroot starch, polyvinyl alcohol, uric acid, and crosslinker. The crosslinker used was sodium tripolyphosphate, citric acid, and glutaraldehyde. Dry membrane was mixed with carbon to increase the sensitivity. Carbon is conductive and hydrophobic material. Therefore, carbon can increase conductivity of modified electrode. Modified electrode was used to analyse uric acid concentration in acetate buffer pH 5 and 0.2 M KCl using differential pulse voltammetry. The potential applied was 0-1.0 V at scan rate of 2.5 mV/s, amplitude modulation was 300 V, and time modulation was 10 ms. The composition of membrane influences the electrodes sensitivity. The best composition of arrowroot starch membrane is UA1 using 0.1% uric acid in membrane and STPP as crosslinker. The linearity concentration, sensitivity, and limit of detection were 100-500 μM, 0.0509 A/M and 76 μM, respectively.

Keywords: Arrowroot starch, crosslinker, modified electrode, uric acid, voltammetry

INTRODUCTION

Uric acid produced in liver, intestines, and endothelium. Uric acid also produced from the degradation of nucleic acid, adenine, and guanin. Normal concentration of uric acid in human serum is 3.4-7.0 mg/dL in male, 2.4-6.0 mg/dL in female, and 2.0-5.5 mg/dL in children. While the normal concentration of uric acid in urine is 1.4-4.46 mM. An increase of uric acid levels in the body can lead to the formation of monosodium urate crystals. The increasing concentration of uric acid in human body can cause joint pain, high blood pressure, kidney, and heart disorders (Ridi, and Tallima, 2017). Hence, it is necessary to develop a method for analysis of uric acid concentration in human serum and urine. Uric acid is electroactive which can be oxidized (**Figure 1**) in potential 0.46 V using buffer acetate at pH 5. Uric acid releases two protons and two electrons to form di-imine. Di-imine is not stable and hydrated two times to form imine-alcohol and uric acid-4,5-diol. At pH 5, this compound is decomposed to allantoin and carbon dioxide (Soleh, Kanatharana, & Thavarungkul, 2019). Therefore, uric acid can be analyzed using electrochemical sensor with the voltametric method.

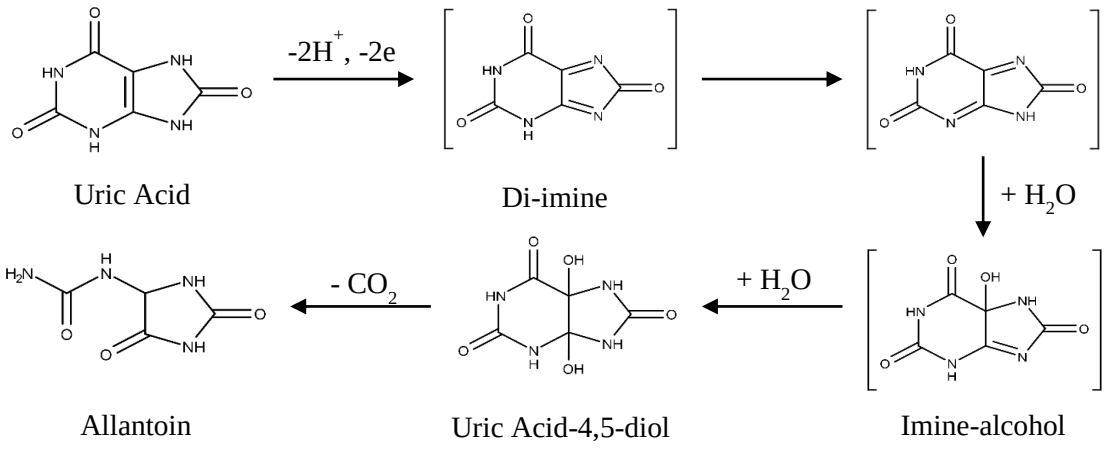

Figure 1. Oxidation of uric acid (Tukimin, Abdullah, & Sulaiman, 2017)

Electrochemical sensor with the voltametric method is a sensitive and selective method of analysis based on the current produced caused by the potential applied. The sensitivity and selectivity of electrode can be increased by adding conductive material to modified the working electrode. Modification of glassy carbon electrode (GCE) that had been done were with graphene oxide (Soleh et al., 2019), poly(3,4-ethylenedioxythiophene)/reduced graphene oxide electrode (Tukimin et al., 2017), N,Co-doped porous carbon (Liu, Liu, Wang, & Ye, 2019), and molecularly imprinted polymer (Zheng et al., 2018).

In electrochemical sensor, selective membrane can be used as a receptor to recognize the analyte with a specific structure. In general, selective membrane consist of polymer that can be reacted with target analyte and crosslinker. Analyte inside the membrane is removed to form cavities that are matches with analyte's structure. Analyte can be anion, cation, or molecule (Wang, 2000). Polymer that can be used to modified electrode are natural and synthetic polymer. Arrowroot starch is a natural polymer derived from the arrowroot plant (*Marantha arundinacea*). Arrowroot starch is usually used as an edible film. In this research, arrowroot starch is used to form a membrane to modified the electrode. However, arrowroot starch membrane has high water vapor transmission rate because of the hydroxyl group in starch. So that the manufacture of membrane is carried out by the blending method, that is mixing the arrowroot starch with other materials such as synthetic polymer to reduce water vapor transmission and improve the physical and chemical properties of arrowroot starch membrane. Membrane from cassava starch can be added with chitosan, glycerol as plasticizer, and acetic acid. Membrane from sweet potato starch can be blended with polyvinyl alcohol, graphene as filler, and glycerol as plasticizer. Therefore, arrowroot starch is combined with polyvinyl alcohol. Based on the research that had been done by Sholichah, Purwono, & Nugroho (2017), adding polyvinyl alcohol with high concentration can affect the characteristic of the membrane. Arrowroot starch blend with polyvinyl alcohol will produce strong membrane because of the hydrogen bonding from hydroxyl group of polyvinyl alcohol.

Arrowroot starch is a biopolymer that is sensitive to humidity so that it affects the properties of arrowroot starch. The sensitivity of arrowroot starch to humidity can be reduced by modification using crosslinking agent. Crosslinking can reduces water absorption by preventing amorphous movement of polymer chains in arrowroot starch (Detduangchan, Sridach, & Wittaya, 2014). Arrowroot starch consist of 24.64% amylose and 73.46% amylopectin. High amylopectin in starch causes arrowroot starch to be stable. While low amylose causes the membrane formed is brittle so a crosslinker is needed (Sholichah et al., 2017). Moreover, arrowroot starch are hydrophilic and hygroscopic. In high humidity, arrowroot starch are easy to swell and the molecular movement is fast. Therefore, it is necessary to add crosslinker in the membrane to reduce swelling and molecular movement. Crosslinked arrowroot starch is insoluble in water and the crystallinity of starch decreases. Arrowroot starch have hydroxyl group which can be crosslinked with compound having carboxylic group such as citric acid (Olsson, 2013), sodium tripolyphosphate, and glutaraldehyde (Sholichah et al, 2017).

Crosslinking between arrowroot starch and STPP formed by phosphorylation. Phosphate in STPP protonated and formed mono-meta-phosphate that can react with the hydroxyl group of arrowroot starch to form mono-starch phosphate. Mono-starch phosphate can decrease the viscosity and increase the bonding capacity so that uric acid that can be trapped in the membrane increases. Moreover, polyvinyl alcohol added in the membrane can be crosslinked with STPP and arrowroot starch that increase the density of the membrane (Polnaya et al, 2013). Arrowroot starch and citric acid are cross-linked through the esterification reaction mechanism between the carboxylic groups of citric acid and the hydroxyl groups of arrowroot starch. Citric acid is converted into anhydrite form through dehydration reaction which can reacts with the hydroxyl groups of arrowroot starch. Crosslinking of arrowroot starch and citric acid result strong hydrogen bonding. Crosslinking can be formed between two polymer molecules or intramolecularly in the same polymer molecule. While intermolecular crosslinking can increase the molecular weight (Nugroho, Nizardo, & Saipudin, 2020). Crosslinking of arrowroot starch and glutaraldehyde by acetal reaction mechanism. The hydroxyl groups of glutaraldehyde protonated in acid condition. The crosslinking structure formed is an acetal bonds that connect the two arrowroot starch chains (Gadhave, Vineeth, & Gadekar, 2020).

Sensitivity of electrode can be increased using carbon materials. Carbon materials can be added to arrowroot starch membrane as a filler. The purpose of adding carbon to the membrane is to increase the conductivity and membrane density. Carbon materials are chemically stable, high conductivity, and low-cost. Carbon material had been used to modified of electrode to determination of uric acid. Modified electrode using carbon material had higher current response and lower electron transfer resistance than the bare electrode (Liu, Liu, Wang, & Ye, 2019). Khan et al. (2017) state that adding excess carbon would cause the membrane to become brittle. Moreover, excess carbon can cause the crosslinking of arrowroot starch and crosslinker become stronger so that can decrease polymer movement.

Zheng et al. (2019) state that another factor that can influence the formation of membrane is the ratio of arrowroot starch and uric acid added in membrane.

Based on the research that had been done by Zheng at al. (2019), the ratio of 2-amino-5-merkapto-1,3,4-tiadiazol with two analyte, they were uric acid and tyrosine, were 10:1, 20:1, and 30,1. The peak current increase with the increasing of the polymer/analyte ratio and the maximum peak current was at ratio 20:1. However, when the ratio was higher than 20:1 there was a decrease in current response. This can be due to the high degree of crosslinking which can cause difficulties to remove the analyte from the membrane. When the ratio was less than 10:1, result a low peak current because the amount of polymer was not enough to do crosslinking (Zheng et al., 2018).

In this study, the electrode modification using arrowroot starch membrane and carbon to produce a low-cost, sensitive, selective, and environmental friendly of uric acid sensor. The membrane consist of arrowroot starch, uric acid, polyvinyl alcohol, and crosslinker.

EXPERIMENTAL SECTION

Materials

Uric acid standard (Sigma Aldrich), potassium chloride (Merck), acetatic acid (Merck), sodium hydroxide (Merck), arrowroot starch (local product), sodium tripolyphosphate (Sigma Aldrich), polyvinyl alcohol (Merck), citric acid (Merck), glutaraldehyde 50% (Sigma Aldrich), and , 1-methyl-2-pyrrolidinone (Sigma Aldrich).

Instruments

Voltametric method was carried out using Galvanostat Potentiostat (Autolab PGSTAT204) connected with computer, glassy carbon electrode (2 mm in diameter and 7 cm in length) as working electrode, reference electrode was Ag/AgCl, and the counter electrode was platina wire, pH meter (Senz TI-13MO597), oven (Yenaco YNC-OV-30L), and glassware.

Optimization of Membranes Composition

The membrane were made in different composition as in **Table 1**. The composition of membrane was 7 mL of arrowroot starch (2% w/v) added with 1 mL of uric acid and 1 mL of crosslinker. The crosslinker used were 2% (w/v) of citric acid, 2% (w/v) of sodium tripolyphosphate, and 2% (v/v) of glutaraldehyde. The mixture was stirred at 80°C for eight hours. Then 1 mL of polyvinyl alcohol (1% w/v) was added and stirred for 30 minutes. After that, the mixture was poured into petri dish and dried at 60°C for 2 hours.

Modification of Electrode

Dry membrane was weighed 0.05 g, added with 0.05 g of carbon and 0.35 mL of 1-methyl-2-pyrrolidinone. The mixture was stirred to form a membrane suspension. Glassy carbon electrode (GCE) was washed with ethanol and dried at 50°C for 30 minutes. Then, GCE was coated with the membrane suspension and dried at 50°C for 1 hour. Uric acid in membrane was removed using cyclic voltammetry. The potential applied was -1.2 – 1.0 V (vs. Ag/AgCl) at scan rate of 25 mV/s.

Electrochemical Measurements

The determination of uric acid was performed by differential pulse voltammetry (DPV) in acetate buffer solution at pH 5 containing 0.2 M KCl. The reference electrode were Ag/AgCl, Pt wire was used as counter electrode, and GCE modified with arrowroot starch membrane and carbon as working electrode. The potential applied was 0 - 1.0 V (vs. Ag/AgCl) at scan rate of 2.5 mV/s, modulation amplitude was 300 V, and modulation time was 10 ms.

Table 1. Composition of membranes for GCE modification

Membrane	Arrowroot starch		Uric acid		Polyvinyl alcohol		Crosslinker	
	Mass (mg)	Volume (mL)	Mass (mg)	Volume (mL)	Mass (mg)	Volume (mL)	Mass (mg)	Volume (mL)
UA1	140	7	1	1	10	1	20	1
UA2	140	7	2	1	10	1	20	1
UA3	140	7	3	1	10	1	20	1

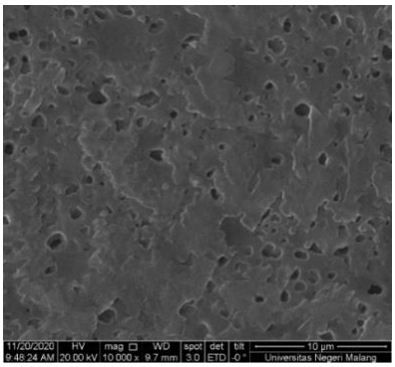

Figure 2. Scanning electron microscopy (SEM) image of arrowroot starch membrane

RESULTS AND DISCUSSION

Characterization of Modified Electrode

Membrane consist of arrowroot starch as polymer, uric acid, polyvinyl alcohol, and crosslinker. Uric acid that is added to the membrane was removed through cyclic voltammetry at scan rate 25 mV/s with range potential -1.2 – 1.0 V. Cyclic voltammetry done in ten cycles until there was no peak current appear in the voltammogram. The purpose of removing uric acid inside the membrane is to form cavity with shape and size that matches the target analyte, which is uric acid. The cavity formed can be seen in **Figure 2.**

As shown on **Figure 2**. arrowroot starch membrane has cavities but the size of the imprinted uric acid is not the same. This is caused by adjacent and overlapping uric acid molecule. The cavity can catch uric acid molecules in the solution thereby accelerating the process of molecular diffusion from the solution to the electrode surface. The illustration of crosslinking between arrowroot starch and crosslinker on electrode surface can be seen in **Figure 3**. Uric acid in solution diffuse to electrode surface because of the difference of uric acid concentration in the solution and electrode surface. Electrode surface that has been coated with arrowroot starch membrane and carbon which has uric acid cavity can increase the diffusion process. Uric acid in solution that has been trapped by membrane in electrode surface will be oxidized. The oxidation happen because of the potential applied which generates current.

The modified electrode using arrowroot starch membrane and carbon was figured out using DPV for 0.5 mM of uric acid in acetate buffer solution at pH 5 containing 0.2 M KCl. The results are shown in **Figure 4.**

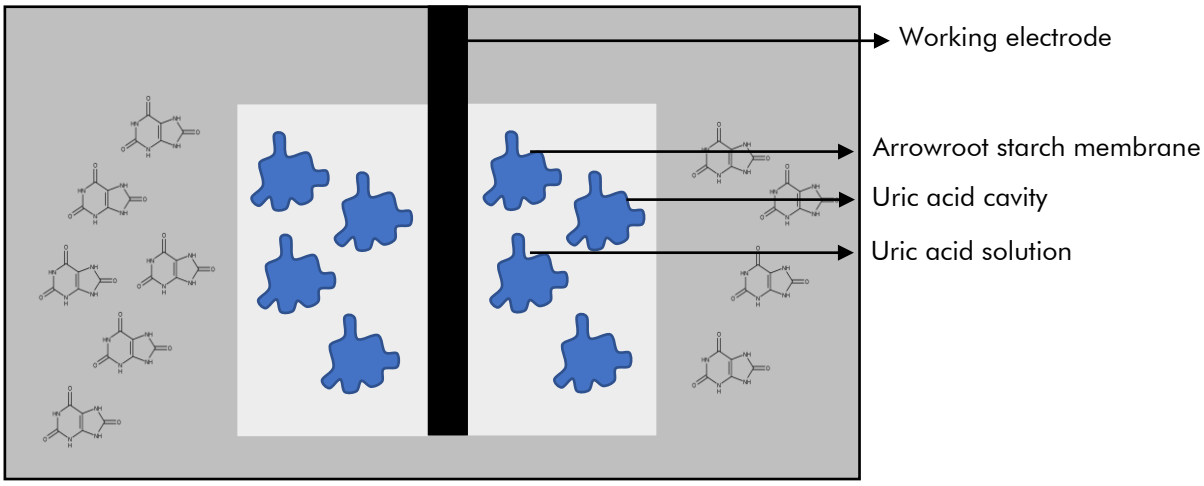

Figure 3. Illustration of electrode surface modified by arrowroot starch membrane

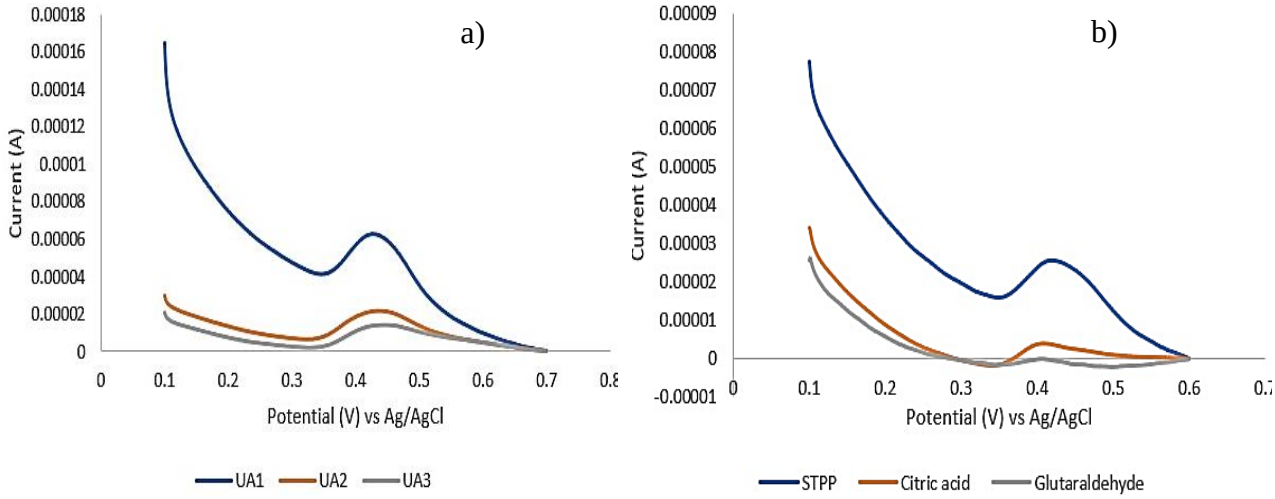

Figure 4. Differential pulse voltammetry (DPV) voltammogram of modified electrode (a) different concentration of uric acid inside the membrane and (b) different crosslinker in arrowroot starch membrane. All voltammogram were measured at scan rate 2.5 mV/s in acetate buffer pH 5 and KCl 0.2 M

Table 2. Peak potential and peak current for oxidation of uric acid using GCE modified with arrowroot starch membrane and carbon with different composition membranes

Membrane	Peak potential (V)	Peak current (μA)
UA1	0.43	21.46
UA2	0.44	16.29
UA3	0.44	12.27

Table 3. Peak potential and peak current for oxidation of uric acid using GCE modified with UA1 membrane and carbon with different crosslinker used in membranes

Type of crosslinker	Peak potential (V)	Peak current (μA)
STPP	0.42	9.68
Citric acid	0.41	5.75
Glutaraldehyde	0.41	1.76

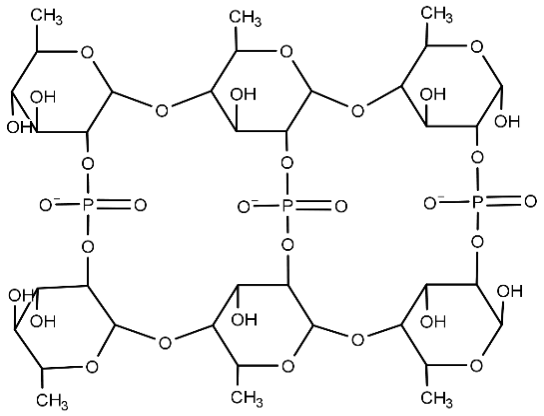

Figure 5. Crosslinking between arrowroot starch and STPP (Polnaya, Haryadi, Marseno, Cahyanto, 2013)

UA1, UA2, and UA3 were made using STPP as crosslinker and have different ratio of arrowroot starch and uric acid inside the membrane. The ratio of arrowroot starch:uric acid in UA1, UA2, and UA3 were 82:1, 81:1, and 41:1 respectively. According to Zheng et al (2018), the amount of uric acid added in the membrane affect the bonding affinity and the peak current in voltammetry. As can be seen on **Figure 4a**. the composition which has the highest peak current is UA1 which the concentration of uric acid added in arrowroot starch membrane was 0.1% and the ratio of arrowroot starch and uric acid was 82:1. UA1 had peak potential at 0.43 V and the peak current was 21.46 μA (**Table 2**). The peak current of UA2 and UA3 was 16.29 μA and 12.27 μA respectively. The concentration of uric acid added in UA2 and UA3 was 0.2% and 0.3% respectively. When the concentration of uric acid added is more than 0.1%, the current responses decrease. This is due to high crosslinking degree. So, the structure of uric acid imprinted in the membrane changes which cause the membrane is not selective and sensitive to detect uric acid. Moreover, using higher amount of arrowroot starch than uric acid in membrane would increase the non-covalent interaction during the polymerization process so that it can increase the binding capacity. Excess polymer in solution during the polymerization process can optimize the interaction between starch and uric acid. However, if the amount of arrowroot starch is too excessive then the interaction between polymers will possible to occur so that can decrease the interaction between arrowroot starch and uric acid. Thus, the optimum concentration of uric acid is 0.1% in UA1 membrane.

The hydroxyl group in arrowroot starch can be crosslinked with carboxylic group in covalent bond. The crosslinker used in this study are STPP, citric acid, and glutaraldehyde. The membrane were made with three different crosslinker and the ratio of arrowroot starch and uric acid was 82:1 (UA1) in three membranes. As shown in **Figure 4b**. the type of crosslinker that showed the best voltammogram is STPP. Peak potential using STPP as crosslinker was 0.42 V and the peak current was 9.68 μA (**Table 3**). The hydroxyl group in arrowroot starch substituted with STPP so the arrowroot starch can have both hydrophobic and hydrophilic properties. Crosslinking between arrowroot starch and STPP is showed in **Figure 5**.

Structure of arrowroot starch after crosslinking with STPP can be seen in FTIR spectrum in **Figure 6**. As can be seen on FTIR spectrum of arrowroot starch membrane, there was new peak in wave number 1050 cm^{-1} which correspond to P-O-C bonding. This peak indicates crosslinking between hydroxyl group of arrowroot starch and phosphate in STPP

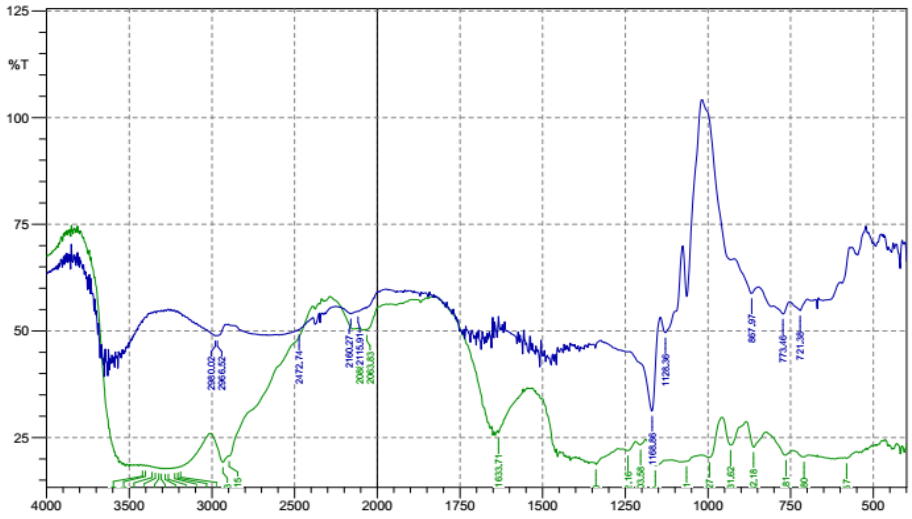

Figure 6. Fourier transform Infrared Spectroscopy (FTIR) spectrum of arrowroot starch (green line) and arrowroot starch membrane with STPP as crosslinker (blue line)

When the membrane was made using glutaraldehyde and citric acid as crosslinker, the current responses decrease. Peak current of citric acid and glutaraldehyde was 5.75 and 1.76 μA, respectively. Because of crosslinking between arrowroot starch and glutaraldehyde results a rigid membrane. Crosslinking between arrowroot starch and glutaraldehyde can decrease the hydrogen bonding of arrowroot starch and shorten the distance between polymer chains and form a rigid membrane. While crosslinking between arrowroot starch and citric acid r esults an elastic membrane. The use of citric acid as crosslinker of arrowroot starch decrease the membrane strength. This causes the resulting low current response when using glutaraldehyde and citric acid as crosslinker of arrowroot starch. According to Olsson (2013), molecular weight of crosslinker determine the characteristic of membrane produced. If the molecular weight is large, then it can produce hydrophobic membrane. The molecule of STPP is larger than citric acid and glutaraldehyde so that the membrane produce has high hydrophobicity than membrane from citric acid and glutaraldehyde. Therefore, the best composition of arrowroot starch membrane is UA1 with STPP as crosslinker.

Peak current produced from oxidation of uric acid influenced by solvent. In voltammetry, the solvent used must be conductive so that the current can form between the electrode and the solution. Conductivity can be increase by adding supporting electrolyte. Supporting electrolyte must be inert in order to not react with the target analyte in the range potential used during the measurement. Supporting electrolyte can be inorganic salt, mineral acid, or buffer. Supporting electrolyte can decrease the solution resistance, migration effects, and maintain the ionic strength. In this research, supporting electrolyte used was Britton-Robinson buffer pH 5, phosphate buffer pH 5, and acetate buffer pH 5. Moreover, 0.2 M KCl was added to each of the buffer solution. The result shows in **Figure 7**. As shown on anodic current in **Figure 7**, using acetate buffer and KCl shows better current response than others. Peak current results in buffer acetate is 84.59 μA at potential 0.29 V. The difference of current response caused by the conductivity of phosphate buffer, acetate buffer, and Britton- Robinson buffer. Oxidation of uric acid in Britton Robinson buffer pH 5 produced no current response because of the specific conductance is 0.008 mS/cm. Higher specific conductance can increase the conductivity. As can be seen in **Table 4**. while adding 0.2 M KCl shifts the oxidation potential to negative direction. KCl have ionic strength so it can increase the electron transfer kinetic and double layer capacitance. This is because KCl can reduce the barrier from the electron transfer process at the interface of the electrode and the electrolyte solution.

Linearity, Sensitivity, and Limit of Detection

In the optimal condition, determination of uric acid in acetate buffer pH 5 and 0.2 M KCl was performed using GCE modified by arrowroot starch membrane and carbon. Figure 8. shows the response of uric acid determination by differential pulse voltammetry at various concentration. As can be seen on voltammogram in **Figure 8a**. the peak current increases with increasing of uric acid concentration linearly. The linear range concentration was obtained in 100, 200, 300, 400, and 500 μM. The linear regression is shown as Ip (μA) = -2.7043 + 0.0509 $C_{uric\ acid}$ (μM) (R^2 = 0.981) with the limit of detection measured is 76 μM. Based on the linear regression, the sensitivity of electrode modified by arrowroot starch membrane and carbon is 0.0509 A/M. The comparison of GCE modified by arrowroot starch membrane and carbon with other modification to determine uric acid concentration shown in **Table 5**.

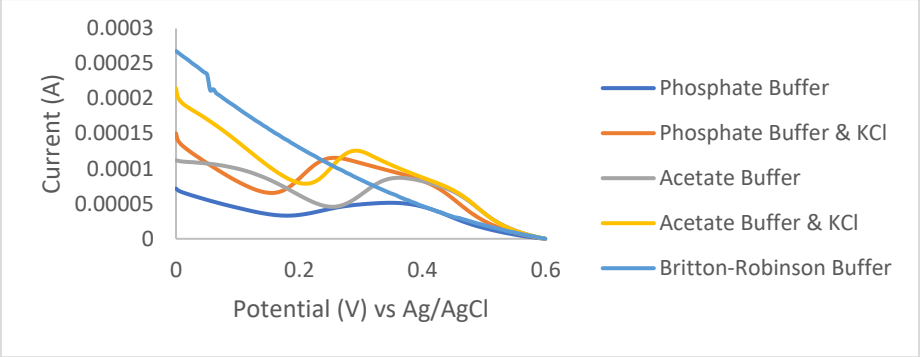

Figure 7. DPV voltammogram for oxidation of uric acid in different buffer solution

Table 4. Peak potential and peak current of uric acid oxidation using GCE modified arrowroot starch membrane and carbon in various supporting electrolyte

Supporting Electrolyte	Peak potential (V)	Peak current (μA)
Phosphate buffer	0.35	34.76
Acetate buffer	0.35	64.25
Britton-Robinson buffer	-	-
Phosphate buffer	0.25	81.77
Acetate buffer	0.29	84.59

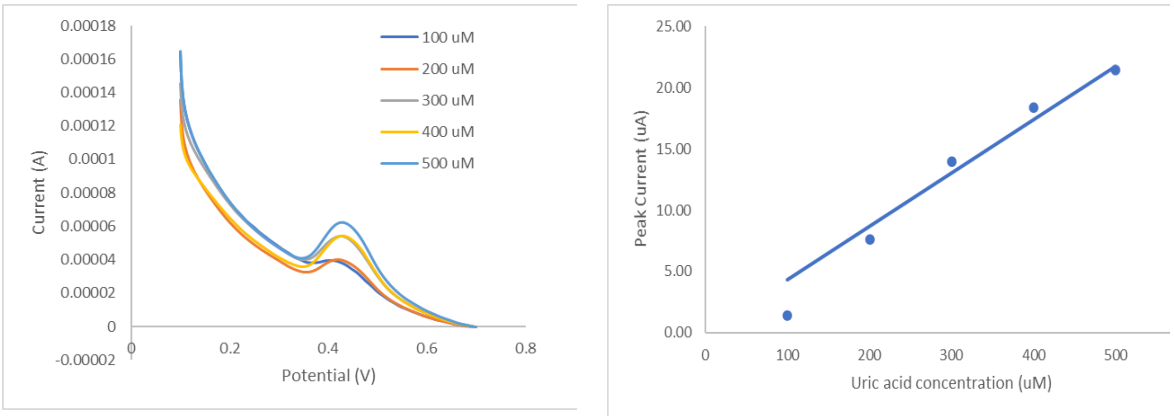

Figure 8. (**a**) DPV voltammogram of uric acid and (**b**) calibration curve of uric acid at 100-500 μM. Uric acid standard were measured at scan rate 2.5 mV/s in acetate buffer pH 5 and KCl 0.2 M

Table 5. Comparison of GCE modification using arrowroot starch membrane and other modification for uric acid determination

Modification	Method	Limit of Detection (μM)	Range concentration (μM)	Reference
Nitrogen-doped zinc oxide thin films	CV	40	50 - 1000	Jindal, Tomar, & Gupta, (2013)
poly(3,4-ethylenedioxythiophene) / reduced graphene oxide electrode (PrGO)	DPV	0.19	1 - 300	Tukimin et al. (2017)
MIP/reduced graphene oxide	DPV	0.0032	0.01 - 100	Zheng et al. (2018)
Graphene oxide	ASV	0.11	0.2 - 30	Soleh et al. (2019)
N,Co-doped porous carbon	DPV	0.83	2 - 110	Liu et al. (2019)
Arrowroot starch membrane and carbon	DPV	76	100 - 500	This work

CONCLUSIONS

A modified electrode by arrowroot starch membrane and carbon was developed for the determination of uric acid using differential pulse voltammetry. Membrane consist of arrowroot starch, polyvinyl alcohol, uric acid, and crosslinker. The arrowroot starch membrane is mixed with carbon and organic solvents and then coated on the surface of the electrode. The composition of membrane affects the sensitivity of the sensor. The best composition of arrowroot starch membrane which resulting higher peak current is UA1 with STPP as crosslinker and the ratio of arrowroot starch and uric acid is 82:1. The measurement was performed at scan rate 2.5 mV/s using acetate buffer pH 5 and 0.2 M KCl. In the optimal condition, the linearity, limit of detection, and sensitivity are 100-500 μM, 76 μM, and 0.0509 A/M respectively. This sensor can determine uric acid, providing alternative diagnostic tool of uric acid in the health sector.

REFERENCES

Detduangchan, N., Sridach, W., Wittaya, T. (2014). Enhancement of the properties of biodegradable rice starch films by using chemical crosslinking agents. *International Food Research Journal*, 21(3), 1225-1235.

Gadhave, R. V., Vineeth, S. K., Gadekar, P. T. (2020). Cross-linking of polyvinyl alcohol/starch blends by glutaraldehyde sodium bisulfite for improvement in thermal and mechanical properties. *Journal of Materials and Environmental Science*, 11, 5, 704-712.

Jindal, K., Tomar, M., Gupta, V. (2013). Nitrogen-doped zinc oxide thin films biosensor for determination of uric acid. *Analyst, 138*, 4353–4362. doi: https://doi.org/10.1039/C3AN36695B

Khan, A., Savi, P., Quaranta, S., Rovere, M., Giorcelli, M., Tagliaferro, A., Rosso, C., Jia, C. Q. (2017). Low-cost carbon fillers to improve mechanical properties and conductivity of epoxy composites. *Polymers*, 9. doi: 10.3390/polym9120642

Liu, L., Liu, L., Wang, Y., Ye, B. (2019). A novel electrochemical sensor based on bimetallic metal–organic framework-derived porous carbon for detection of uric acid. *Talanta,* 199, 478-484. doi: https://doi.org/10.1016/j.talanta.2019.03.008

Nugroho, F. G., Nizardo, N. M., Saepudin, E. (2020). Synthesis of Citric Acid Crosslinked PVA/Tapioca Starch Bioplastic Reinforced with Grafted Cellulose. *AIP Conference Proceedings*. doi: https://doi.org/10.1063/5.0010357

Olsson, E. (2013). Effects of Citric Acid on Starch-Based Barrier Coatings. *Dissertation*. Karlstad University Studies.

Polnaya, F. J., Haryadi, Marseno, D.W., Cahyanto, M. N. (2013). Effects of phosphorylation and cross-linking on the pasting properties and molecular structure of sago starch. *International Food Research Journal*, *20*(4), 1609-1615.

Ridi, R. E., and Tallima, H. (2017). Physiological functions and pathogenic potential of uric acid: A review. *Journal of Advanced Research*, *8*, 487-493. doi: http://dx.doi.org/10.1016/j.jare.2017.03.003

Soleh, A., Kanatharana, P., Thavarungkul, P. (2019). Novel electrochemical sensor using a dual-working electrode system for the simultaneous determination of glucose, uric acid and dopamine. *Microchemical Journal*. doi: https://doi.org/10.1016/j.microc.2019.104379

Sholichah, E., Purwono, B., Nugroho, P. (2017). Improving Properties of Arrowroot Starch *(Maranta arundinacea)*/PVA Blend Films by Using Citric Acid as Cross-linking Agent. *IOP Conf. Series: Earth and Environmental Science*, 101. doi: 10.1088/1755-1315/101/1/012018

Tukimin, N., Abdullah, J., Sulaiman, Y. (2017). Development of a PrGO-Modified Electrode for Uric Acid Determination in the Presence of Ascorbic Acid by an Electrochemical Technique. *Sensors*, *17*, 1539. doi: 10.3390/s17071539

Wang, J. (2000). *Analytical Electrochemistry 2nd Edition*, New York: John Wiley & Sons, Inc.

Zheng, W., Zhao, M., Liu, W., Yu, S., Niu, L., Li, G., Li, H., Liu, W. (2018). Electrochemical sensor based on molecularly imprinted polymer/reduced graphene oxide composite for simultaneous determination of uric acid and tyrosine. *Journal of Electroanalytical Chemistry*, *813*, 75-82. doi: https://doi.org/10.1016/j.jelechem.2018.02.022