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Electrochemical Response of Ascorbic Acid Using Screen-Printed Carbon Electrode

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Electrochemical response of ascorbic acid (AA) has been studied using a screen-printed carbon electrode (SPCE). The electrochemical response was measured using cyclic voltammetry (CV) in 0.1 M phosphate buffer solution at various pH. The measurement was carried out at a potential of – 0.75 V to + 1.0 V at room temperature. The effect of scan rate was observed from 25 to 125 mV/s. The presence of interference compounds, i.e., glucose, uric acid and urea during AA measurement was also investigated. The electrochemical response of AA using SPCE was observed at around + 0.45 V in all pH variations without reduction peak. This indicated that AA can be detected by SPCE from its oxidation peak. It is in good agreement with the natural properties of AA, which is easily oxidized, tuning into dehydroascorbic acid (DHAA). No interference signal was found from interfering compounds during AA measurement at pH 7.0. The scan rate effect implied that the occurred process in SPCE was diffusion controlled. It was also shown that the anodic current peaks are linearly proportional to the scan rate, which means the electrocatalytic behavior of AA associated with the surface electron transfer. The results of this study proved that SPCE has good potential as a sensor for detecting AA.

Keywords: SPCE, Electrochemical response, Ascorbic acid, Innovation, Scientific research, Technology.

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1. INTRODUCTION

Ascorbic acid (AA), known as vitamin C, has an important role as an antioxidant and in the maintenance of collagen [1-3]. Lack of ascorbic acid intake in the body can cause muscle weakness and anemia [4]. In addition, a deficiency of ascorbic acid can also cause a decrease in the hydroxylation of proline and lysine, thereby affecting the synthesis of collagen [5]. In addition, AA is also largely used as an antioxidant additive in the food industry to prevent unwanted changes in the color or flavor of food and drinks [5-7]. Furthermore, the content of AA is used as an index of the health-related quality of fruits and vegetables [1]. Because of the important role of AA for humans, analytical methods for a quantitative determination of AA have been developed.

Spectroscopy [8], chemiluminescence [9], gas chromatography [10], and liquid chromatography [11] methods are the traditional methods for AA determination. Unfortunately, those methods are expensive, have a long duration of analysis, and relatively complicated sample preparation. An electrochemical type of sensor can be a promising solution to overcome this problem. This method has the advantages of being fast, inexpensive, easy sample preparation, and can be developed as a portable test device [12-16]. The electrochemical sensor uses the principle of reduction and oxidation reactions of the target on the electrodes [14, 16, 17]. Furthermore, the AA is easily oxidized, so that the electrochemical sensor is a suitable method to determine AA [1, 4, 5].

In this work, we studied the electrochemical response of AA using a screen-printed carbon electrode (SPCE). The SPCE has high selectivity and easily used in uncomfortable environments, and do not require special skills to operate. The AA electrochemical response from SPCE was evaluated using cyclic voltammetry (CV) in 0.1 M phosphate buffer solution at pH variations. The interference study was carried out in the presence of uric acid (UA), glucose, and urea. The effect of the scan rates was also evaluated.

2. MATERIALS AND EXPERIMENTS

The materials used in this work are the screen-printed carbon electrode (SPCE) was bought from POTEN. L(+)-Ascorbic acid (AA) [$C_6H_8O_6$], D(+)-Glucose [$C_6H_{12}O_6$], urea [$CO(NH_2)_2$], di-sodium hydrogen phosphate [Na_2HPO_4, Merck], and sodium dihydrogen phosphate [NaH_2PO_4] were purchased from Merck. Uric acid (UA) [$C_5H_4N_4O_3$] was purchased from Sigma Aldrich. Demineralized water from the local market was used for chemicals preparation and cleaning. A 0.1 M phosphate buffer solution with various pH of 5.0, 7.0, and 9.0 were made and prepared in the Laboratory of Instrumentation and Analytical Sciences, Chemistry Department, Faculty of Science and Data Analytics, Institut Teknologi Sepuluh Nopember.

The electrochemical measurement was carried out using a potentiostat from an electrochemical analyzer (model 700B, equipped with e-chem software version 2.1.13). Electrochemical experiments were performed by cyclic voltammetry (CV). The potential was swept from – 0.75 V to + 1.0 V with 20 seconds of rest time before measurement. The scan rates were 25, 50, 100, and 125 mV/s. The solution samples were made by dissolving AA, glucose, UA, and urea, each in 0.1 M phosphate buffer solutions with various pH (pH = 5.0, 7.0, and 9.0). The interference study of SPCE for AA detection by measuring 10 mM of AA, glucose, UA, and urea solutions. All experiments were performed at room temperature.

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3. RESULTS AND DISCUSSION

The cyclic voltammogram of AA in phosphate buffer solution at various pH using SPCE is shown in Fig. 1(a-c). In the absence of AA, there was no peak during measurement within the potential sweep from – 0.75 V to + 1 V. AA's oxidation peak was at around + 0.45 V in all pH variations without the reduction peak. It indicates that the electrochemical response of AA can be detected by SPCE from its oxidation peak appeared. The result is in good agreement with the natural properties of AA that easily oxidized become dehydroascorbic acid (DHAA) [1]. The oxidation reaction of AA was shown in Fig. 2.

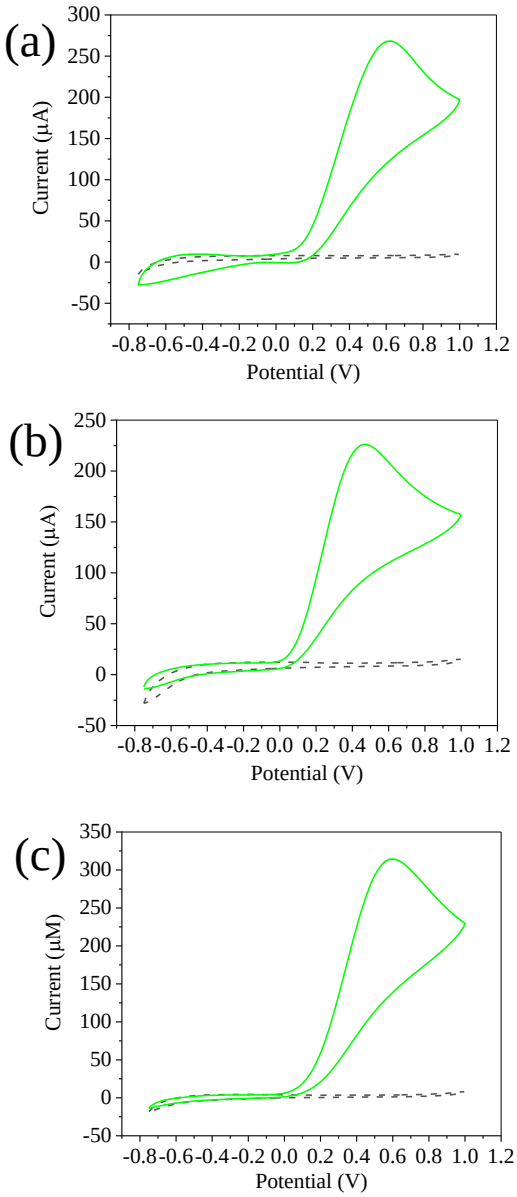

Fig. 1 – Cyclic voltammograms of 10 mM ascorbic acid (AA) solution in 0.1 M phosphate buffer at pH 5.0 (a), pH 7.0 (b), and pH 9.0 (c) using SPCE. Black dash is blank (0.1 M phosphate buffer) and green line is AA solution. The measurement was done at room temperature with scan rate of 100 mV/s

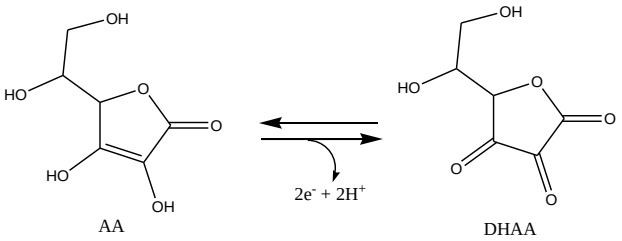

Fig. 2 – Oxidation reaction of AA

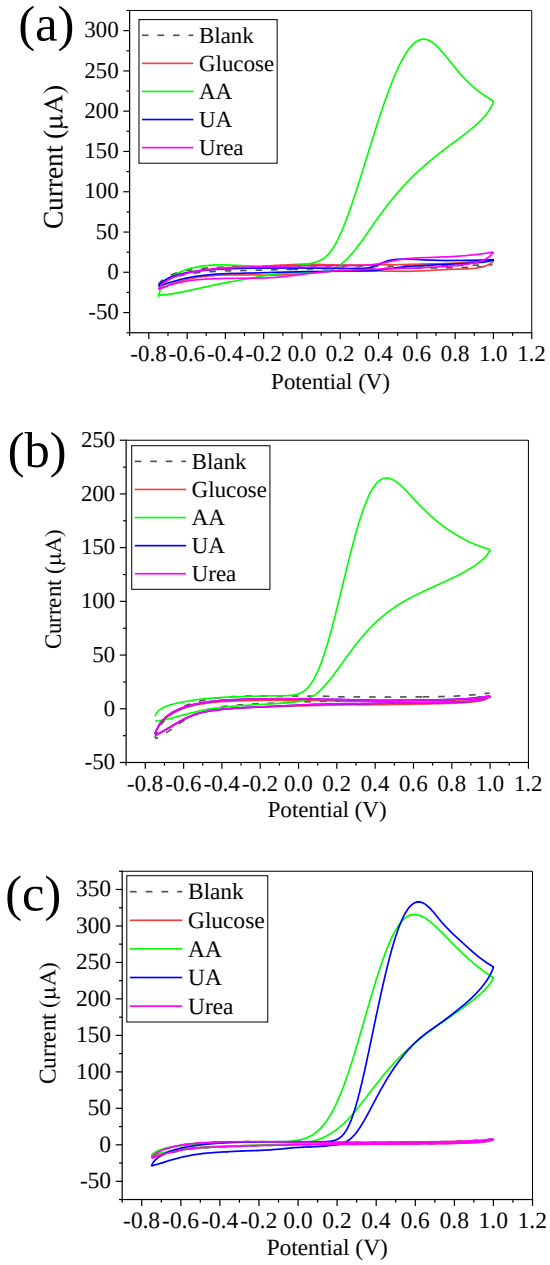

Fig. 3 – Cyclic voltammograms of 10 mM AA, 10 mM glucose, 10 mM UA, and 10 mM urea solutions in 0.1 M phosphate buffer at pH 5.0 (a), pH 7.0 (b), and pH 9.0 (c) using SPCE. The measurement was done at room temperature with scan rate of 100 mV/s

The electrochemical response of AA using SPCE in 0.1 M phosphate buffer with various pH was studied against glucose, UA, and urea. The cyclic voltammogram against glucose, UA, and urea. The cyclic voltammogram for phosphate buffer, AA, glucose, UA, and urea are shown in Fig. 3. The cyclic voltammogram shows that AA signals can be detected selectively in pH 7.0 (Fig. 3b), where there are no signals from glucose, UA, and urea. Unfortunately, the electrochemical response of AA in pH 5.0 is interfered with small signal of urea and glucose. Furthermore, in pH 9.0 (Fig. 3c), AA signal is interfered by urea. The result indicated that the best condition to detect ascorbic acid by SPCE is in pH 7.0.

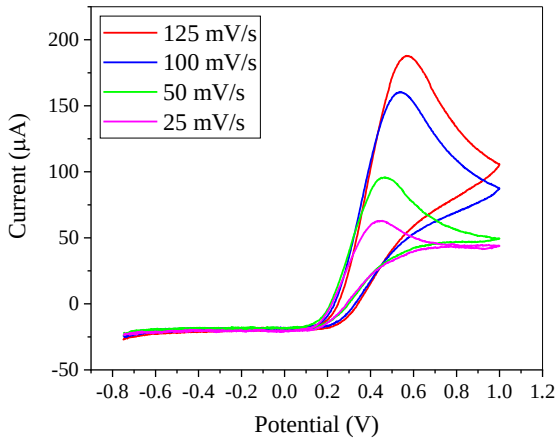

Fig. 4 – Cyclic voltammograms obtained from SPCE in 0.1 M phosphate buffer at pH 7.0, containing 10 mM AA solution with different scan rates (25, 50, 100, and 125 mV/s)

The effect of scan rates was done to assess whether the processes on the SPCE are controlled by diffusion or adsorption. Fig. 4 shows the cyclic voltammogram of 10 mM AA using SPCE at various scan rates. The increase in the scan rates shifted the Epa slightly to more positive potentials and increased the peak current. According to the Randles-Sevcik equation, the peak current for anodic oxidation is proportional to the square root of the scan rate (Fig. 5a) [12]. The linear regression equation for this work is i_{pa} (μA) = 20.479·$\upsilon^{1/2}$ (mV$^{1/2}$s$^{-1/2}$) – 43.541 with R^2 = 0.9946. The result implied that the process that occurred in the SPCE was diffusion controlled.

The electrocatalytic behavior of AA using SPCE also has been determined. Fig. 5b shows the linear calibration curve between the peak currents and scan rates. The obtained linear equation is i_{pa} = 1.261·υ (mV/s) + 32.138 with R^2 = 0.9989. According to the linear equation, the anodic current peaks are linearly proportional to the scan rate. This indicated that the electrocatalytic behavior of AA involved surface electron transfer [12, 18].

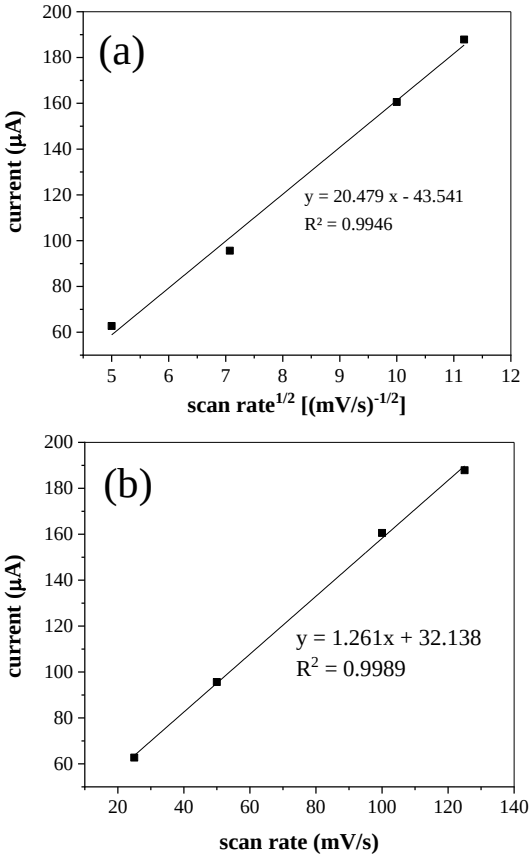

Fig. 5 – Plot of anodic current at + 0.45 V vs. square root of the scan rate (a) and plot of anodic current at + 0.45 V vs. scan rate (b)

4. CONCLUSIONS

The electrochemical response of ascorbic acid (AA) was detected using a screen-printed carbon electrode (SPCE) in 0.1 M phosphate buffer at various pH. The best response of AA has appeared in 0.1 M phosphate buffer at pH 7.0. The interference study showed that AA could be detected specifically from its oxidation peak in the presence of glucose, uric acid, and urea. The effect of scan rates indicated the AA detection process by SPCE is the diffusion controlled. In addition, AA detection also showed an electrocatalytic behavior in the SPCE surface.

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Електрохімічна реакція аскорбінової кислоти за допомогою вугільного електрода з трафаретним друком

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Електрохімічну реакцію аскорбінової кислоти (АА) реалізовували за допомогою вугільного електрода з трафаретним друком (SPCE). Електрохімічну реакцію вимірювали з використанням циклічної вольтамперометрії (CV) у 0,1 М фосфатному буферному розчині при різних значеннях pH. Вимірювання проводили при потенціалі від – 0,75 В до + 1,0 В при кімнатній температурі. Вплив швидкості сканування спостерігався від 25 до 125 мВ/с. Також було досліджено наявність інтерференційних сполук, тобто глюкози, сечової кислоти та сечовини під час вимірювання АА. Електрохімічну реакцію АА за допомогою SPCE спостерігали при близько + 0,45 В у всіх варіаціях pH без піку відновлення. Це вказує на те, що АА може бути виявлена SPCE з її піку окислення. Це добре узгоджується з природними властивостями АА, яка легко окислюється, перетворюючись на дегідроаскорбінову кислоту (DHAA). Під час вимірювання АА при pH 7,0 не було виявлено інтерференційного сигналу від інтерференційних сполук. Ефект швидкості сканування означав, що процес, який відбувався в SPCE, контролювався дифузією. Також показано, що піки анодного струму лінійно пропорційні швидкості сканування, що означає електрокаталітичну поведінку АА, пов'язану з поверхневим переносом електронів. Результати цього дослідження довели, що SPCE має хороший потенціал як датчик для виявлення АА.

Ключові слова: SPCE, Електрохімічна реакція, Аскорбінова кислота (АА), Інновація, Наукові дослідження, Технологія.