Impact viscosity of blood on the diffusion coefficient in the presence of ascorbic acid using cyclic voltammetry

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ABSTRACT

A new study for the effect the viscosity of human blood samples on the diffusion coefficient value was used by cyclic voltammetry method. The oxidation current peak of ascorbic acid (AA) was studied in blood medium at different viscosity by mixing with normal saline (NS) at different ratio. Randles-Seveik equation was used to determine the diffusion coefficient values of AA ions from scan rate of the anodic current peak which transfer through the blood medium to the electrodes at different ratio with normal saline. It was found that diffusion coefficient values of the oxidation current peak of AA were increased against to decreasing the ratio of blood in NS, means that diffusion coefficient depended on the degree of the blood viscosity.

Key words: PCV, blood, cyclic voltammetry, ascorbic acid, diffusion coefficient

INTRODUCTION

The diffusion coefficient factor of ascorbic acid was studied in previous research by electrochemical scientists at different electrolytes [1-5]. Ascorbic acid, or vitamin C, is an important nutrient and the structure shows in the scheme 1 [6].

A modified form of Fick’s second law that takes into account dimensional changes of the hydrogels during drug release is used here to evaluate the diffusion coefficient of the ascorbic acid into the gels [7]. Cyclic voltammetry and viscosity measurement techniques were used for (Z)-4-(4-cyanophenylamino)-4-oxobut-2-enoic acid (LH) and its new triphenyltin (IV) derivative (Ph3SnL). Voltammetric responses of both compounds before and after the addition of DNA indicated that diffusion controlled processes are involved. Complex Ph3SnL exhibited the best antitumor activity [8]. The modified carbon paste electrode shows excellent electrocatalytic activity toward the oxidation of dopamine (DA) in a phosphate buffer solution (pH=6.0). The rate constant k′, transfer coefficient α for the catalytic reaction and the diffusion coefficient of DA in the solution, D, were found to be 6.92×10−2 cm s−1, 0.71 and 1.41×10−5 cm2 s−1, respectively. The interference of
Ascorbic acid was investigated and greatly reduced using sodium tetraphenylborate incorporated modified carbon paste electrodes [9].

At glassy carbon, gold, and boron-doped diamond electrodes, the introduction of the coupled electrocatalytic reaction, while producing significantly enhanced dc currents, does not affect the ac harmonics. Cyclic voltammetry are predicted to be highly sensitive to the homogeneous kinetics when an electrocatalytic reaction is coupled to a quasi-reversible electron-transfer process [10]. MWCNT modified electrode exhibited obvious enhancing and electrocatalyzing effects to the oxidation of ascorbic acid using cyclic voltammetry technique. This also proposed MWCNT modified BPPG electrode possessed advantages such as low detection limit, high stability, low cost and simplicity in fabrication [11]. Voltammetric techniques have been considered as important methods among the analytical techniques used for the identification and determination of trace concentrations of many biological molecules such as L-ascorbic acid (AA) with calibration curve was linear over the range 1-175 μg/mL ($r^2 = 0.9977$, $p < 0.001$) [12]. The diffusion coefficients of aqueous L-ascorbic acid solutions at 298.15K-328.15K were determined. Results show that diffusion coefficients of aqueous L-ascorbic acid solutions decrease with the concentration increase at the same temperature and increase with the temperature increase at the same concentration. The data of density and viscosity of aqueous L-ascorbic acid solutions were measured and correlated with the concentration of the solution [13]. The diffusion coefficients were calculated based on the Einstein equation for vitamin C (VC) in water solution with molecular dynamics simulation. It is expected that this study can provide a theoretical direction for the experiments on the mass transfer of VC in water solution [14].

In this study, the oxidation current peak of ascorbic acid was affected by the viscosity of blood medium which act the diffusion coefficient at different values.

**MATERIALS AND METHOD**

Ascorbic acid was received from Technicon chemicals Co. (Oreq, Tournai Belgique), Normal saline from Adwic Pharmaceuticals Division (Egypt), Healthy human blood samples from Iraqi Blood Bank in Baghdad City of Medicine, and deionized water was used for preparation of aqueous solutions. All solutions were used in the cyclic voltammetric cell which treated with nitrogen gas for 10-15 minutes to remove the oxygen from the solutions.

**Apparatus**

Potentio-stat: An instrument of EZstat series (Potentiostat/Galvanostat) NuVant Systems Inc. (USA) was used in the experiments. The Electrochemical Bio-analytical cell was connected to a potentio-stat device and was monitored by special software to perform cyclic voltammetry (CV). Silver-silver chloride r (Ag/AgCl in 3M NaCl) and Platinum wire (1 mm diameter) were used as a reference and counter electrodes, respectively. The glassy carbon working electrode (GCE) modified with CNT was used in this study after cleaning with alumina solution and treated with ultrasonic path water for ten minutes.

Viscosity: a viscometer type 1831 (0.4 mm) as shown in Figure 1 was used in the experiments at constant temperature to determine the viscosity of blood samples with ascorbic acid.

![Viscometer type 1831 (0.4 mm)](image1)
RESULTS AND DISCUSSION

Determination of PCV
Hematocrit test is performed on a sample of blood to measure the level of Packed Cell Volume (PCV) in the blood [15], it is known as a viscosity of blood samples at different conditions. It was studied sample of normal human blood with different addition of ascorbic acid to find the effect of ascorbic acid on the component of blood which changes the viscosity as PCV of the blood sample. Table 1 illustrated the PCV values of blood samples in different ratio with normal saline (NS) at room temperature 25 °C. The proportional of increasing blood ratio with normal saline is direct relationship with increasing PCV% values which depended with blood component of its viscosity [13]. It was found that ratio of blood: NS at 1: 9 has 10% of PCV while, the ratio of 10: 0 has 97% of PCV, the viscosity of blood (PCV) was depended on the concentration of blood.

Table 1: effect different ratio of blood in NS on the PCV and Dfa of AA in blood medium

<table>
<thead>
<tr>
<th>Blood: NS (Ratio)</th>
<th>PCV (%)</th>
<th>I_{pa}, AA, uA</th>
<th>Dfa, cm^2sec^{-1}, 10^5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:9</td>
<td>10</td>
<td>76</td>
<td>2.5</td>
</tr>
<tr>
<td>2:8</td>
<td>19</td>
<td>77</td>
<td>2.65</td>
</tr>
<tr>
<td>3:7</td>
<td>20</td>
<td>75</td>
<td>2.51</td>
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<td>4:6</td>
<td>26</td>
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<td>2.2</td>
</tr>
<tr>
<td>5:5</td>
<td>29</td>
<td>75.6</td>
<td>2.55</td>
</tr>
<tr>
<td>6:4</td>
<td>47</td>
<td>72.8</td>
<td>2.37</td>
</tr>
<tr>
<td>7:3</td>
<td>52</td>
<td>70.2</td>
<td>2.12</td>
</tr>
<tr>
<td>8:4</td>
<td>74</td>
<td>66.1</td>
<td>1.95</td>
</tr>
<tr>
<td>9:1</td>
<td>89</td>
<td>63</td>
<td>1.77</td>
</tr>
<tr>
<td>10:0</td>
<td>97</td>
<td>50</td>
<td>1.11</td>
</tr>
</tbody>
</table>

Effect PCV on oxidation current peak of ascorbic acid
The other study is the effect of ascorbic acid on the PCV of mixture of blood with NS via the finding of oxidation current peak by cyclic voltammetry. Figure 2 illustrated the voltammogram of oxidation peak of ascorbic acid which shows the effect of the ratio of blood: NS on this peak by decreasing the peak with increasing the blood concentration. In another meaning, the oxidation current peak of ascorbic acid was increased with decreasing PCV% as shown in figure 3.

Figure 2: Voltammogram of oxidation current peak for AA in different ratio of blood in NS on GCE versus Ag/AgCl and 100 mV sec^{-1}.
3.4. Effect of PCV on diffusion coefficient (Df) value

The usual of mathematical method can be used in finding the diffusion coefficient of the redox process for the saffron compound in the KCl solution from the Randles-Sevsk equation described reversible redox couple and the peak current [16,17].

\[ I_p = (2.69 \times 10^5)^n^{3/2} A D_f^{1/2} v^{1/2} \]  

Where:
- \( I_p \) is the current peak.
- \( n \) is the number of moles of electrons transferred in the reaction.
- \( A \) is the area of the electrode.
- \( D_f \) is the diffusion coefficient.
- \( v \) is the scan rate of the applied potential.

It was found the diffusion coefficient of oxidation – reduction process of saffron in KCl solution is 1.87x10^{-5} and 1.12x10^{-5} cm²/sec respectively [18].

3.5. Relationship between diffusion coefficient and PCV

Table 1 illustrated the relationship between the PCV of different concentration of blood ratio with NS and the different factors of AA such as anodic current peak and diffusion coefficient values. Figure 4 shows the relationship between diffusion coefficient of the AA ions in blood medium against to the percentage of blood in NS which has a linear line with high sensitivity \( R^2=0.7621 \). The relationship explain that diffusion coefficient of the AA ions in blood medium was linked with the concentration of blood medium [19].
The other relationship shows in figure 5 between the diffusion coefficient of AA ions in blood medium at different viscosity by diluted with NS which has good straight line with high sensitivity $R^2 = 0.8341$. The measurement of the effect diffusion coefficient of ascorbic acid ions in blood medium is based on the extent of the resistance which shown by the electrolyte to the high rate to arrive of these ions to the electrode, especially that the electrolyte is blood with has a high viscosity [20,21].

Also, the same relationship was shown in figure 6 which explain the anodic current peak of AA in blood medium with their different PCV values confirmed the electrochemical properties and give the support to the results in this way [22].

![Figure 5: Relationship between $D_{fa}$ of AA and PCV of blood in NS.](image)

![Figure 6: Relationship between oxidation current of $D_{fa}$ for AA and PCV of blood in NS.](image)

**CONCLUSION**

The relationship between the viscosity of the electrolyte (blood) and diffusion coefficient of the ions was studied by electrochemical analysis method by cyclic voltammetric technique. It was found that the chemical compound in blood medium such as oxidation current peak of ascorbic acid was diffused slowly to the working electrode in
concentrated blood because the high viscosity was reduced the movement of AA ions and reach to electrodes in potentiostate. So, the viscosity of the blood is the main factor for the transfer of ions to different parts of the body as the current in the cyclic voltammetric technique as a diffusion coefficient which find from the value of the scan rate.

REFERENCES


