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RELATIONSHIP BETWEEN THE DIFFUSION COEFFICIENT AND VISCOSITY OF SOME ARTIFICIAL SWEETENER IN BLOOD MEDIUM BY CYCLIC VOLTAMMETRY USING NANO-SENSOR

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Abstract:

Different artificial sweeteners were studied in blood medium as electrolyte by cyclic voltammetric technique using modified glassy carbon electrode with carbon nanotubes to determine the diffusion coefficient for the redox current peaks of artificial sweetener by Randles-Sevcik equation. It was determined the viscosity of the blood medium after the addition of the artificial sweetener to find the relationship between the viscosity and the diffusion of sweetener ions in blood medium and reach to the electrode. The high viscosity of blood and addition of the sweetener compound which causes impedes of diffusion the ions for redox current of the reaction on the surface of the sensor. So, the results of diffusion coefficient values depended on the viscosity of blood medium. Sorbitol compound has a higher viscosity in blood medium with lower diffusion coefficient values of redox current peaks and mannitol has lower viscosity in the series of the sweetener compounds in blood medium with high values of diffusion coefficient for the redox current peaks.

1. Introduction

It is known in the subject of physical chemistry that the relationship of viscosity with the diffusion coefficient in the solution which depend on several factors, including temperature and radius of ion diffused in the solution, especially when studied by electrochemical analysis [1-7]. The relationship between the diffusion coefficient against to viscosity was studied for Cu in phosphoric acid, water and glycerin based baths using rotating disc electrode voltammetric technique to evaluate the model of Stokes–Einstein which shows an inverse relationship [8]. Diffusion coefficient of ferrocene was calculated from electrochemical parameters by rotating disk electrode voltammetry method using platinum and glassy carbon electrode. It was found that ferrocene derivatives have a good stability, a reversible reaction and an electronic attractor effect [9]. Iodine ions in aqueous media was studied by cyclic voltammetric technique to determine the diffusion coefficient value which shows the effect of fractal surface of electrode, this diffusion coefficient of iodine may be considered as a lower limit of species [10]. A liquid of Zr64Ni36 was determined each of diffusion coefficient, density and viscosity with high accuracy and precision using oscillating drop technique and quasielastic neutron scattering experiments at the same temperature. It was found that both viscosity and diffusion coefficient is depended on the temperature as in the relation of

Stokes-Einstein [11]. The redox current peaks of the process of Cu(II)/Cu(I) was studied at temperature 375K to estimate the diffusion coefficient by Randles-Ševcik equation and Nicholson's method, this reaction category as quasi-reversible [12]. A study of comparison of viscosity and diffusion coefficients was found fast moving ions unambiguously show that the product depends strongly on temperature (T). The temperature dependence of diffusion coefficient declines from that of viscosity [13].

Different artificial sweeteners in blood medium was studied at constant temperature the effect of viscosity of the electrolyte on the diffusion coefficient values for redox current peaks of the artificial sweeteners by cyclic voltammetry using nano-sensors (carbon nanotube on glassy carbon electrode CNT/GCE).

2. Experimental

2.1. Materials and method

Sodium saccharin (purity 99% from Sigma Aldrich company), Aspartame, Acesulfame Potassium and Xylitol (purity 99% BDH), Sorbitol (purity 99% from Sigma Aldrich company), Mannitol (purity 99%% BDH), carbon nanotubes (purity 99%) supplied from Fluka company (Germany). Healthy human blood samples were received from Iraqi Blood Bank in Baghdad City of Medicine, Deionized water was used for preparation of aqueous solutions. All solutions used in the cyclic voltammetric cell were treated with nitrogen gas for 10-15 minutes to remove the oxygen from the solutions.

2.2. Apparatus

2.2.1. Potentiostat

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) as shown in figure 1. Silver-silver chloride reference electrode (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.

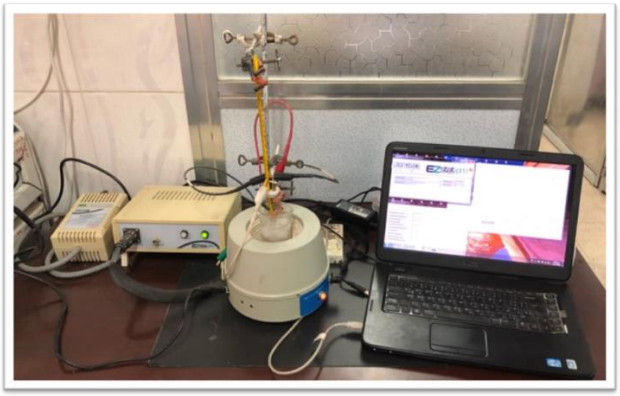

Figure 1. Cyclic voltammetry device

2.2.2. Viscosity

A viscometer type 1831 (0.4 mm) as shown in Figure 2 was used in the experiments at constant temperature to determine the viscosity of blood samples with different artificial sweeteners (aspartame, acesulfame potassium, xylitol, sorbitol, mannitol, and sodium saccharin).

Figure 2. Viscometer type 1831 (0.4 mm)

2.3. Preparing the modification of GCE with CNT (CNT/GCE)

Mechanical attachment technical method was employed to prepare the CNT/GCE working electrode as a nano-sensor [14,15] as shown in figure 3. The method of the modification of GCE included abrasive application of multiwall carbon nanotubes (MWCNT) on the clean surface of GCE,

forming an array of MWCNT as modified working electrode MWCNT/GCE and replaced in 10 ml of electrolyte in the cyclic voltammetric cell, then connected all electrodes (working electrode, reference electrode and counter electrode) with the potentio-stat.

Figure 3. Mechanical attachment method

3. Results and Discussion

3.1. Effect artificial sweeteners on the blood component

Different artificial sweeteners such as aspartame, acesulfame potassium, xylitol, sorbitol, mannitol, and sodium saccharin were studied in blood medium using cyclic voltammetric technique by nano-sensor (MWCNT/GCE) to determine the diffusion coefficient values for redox current peaks of each of artificial sweeteners from the study of different scan rate by Randles-Sevcik equation [16,17]:

$$I_p = (2.69 \times 10^5)\, n^{3/2}\, AC\, D_f^{1/2}\, v^{1/2} \quad (1)$$

where:

Ip is the current of the artificial sweetener.

n is the number of moles of electrons transferred in the reaction (1 electron).

A is the area of the electrode (0.07 cm^2).

D_f is the diffusion coefficient of the artificial sweetener (cm^2/sec).

v is the scan rate of the applied potential (0.1 $Vsec^{-1}$).

Table 1. illustrated the average values of diffusion coefficient of both oxidation-reduction current peaks of each of artificial sweeteners in blood medium. Figure 4, 5, 6, 7, 8 and 9 show the cyclic voltammogram of redox current peaks of Aspartame, Acesulfame Potassium, Xylitol, Sorbitol, Mannitol, and Sodium saccharin, respectively [18]. It was seen that diffusion coefficient values of oxidation and reduction current peaks nearly are equal, the reaction of these compounds in blood medium was reversible, but the diffusion coefficient of each sweetener compound in blood medium are different in the values because the other factors which affected these values, many factors were influenced the transmission and access the electrons to the electrode such as viscosity of the electrolyte [19].

Sample	Viscosity	$D_{f,pc}$ (cm^2/sec)	Ipc (uA)	$D_{f,pa}$ (cm^2/sec)	Ipa (uA)
blood	1.488661	-	-	-	-
sorbitol in blood	1.602782	5.29×10^{-6}	21.94	2.132×10^{-6}	34.36
xylitol in blood	1.468196	7.076×10^{-6}	24.45	2.657×10^{-6}	39.89
sodium saccharin in blood	1.464626	6.44×10^{-7}	16.91	1.28×10^{-6}	12.01
acesulfame potassium in blood	1.441716	6.445×10^{-7}	15.44	1.065×10^{-6}	18.88
aspartame in blood	1.335741	8.585×10^{-6}	24.09	2.592×10^{-6}	43.8
mannitol in blood	1.328111	1.303×10^{-5}	21.75	2.114×10^{-6}	54.05

Table 1. Viscosity and diffusion coefficient values of different artificial sweeteners in blood medium

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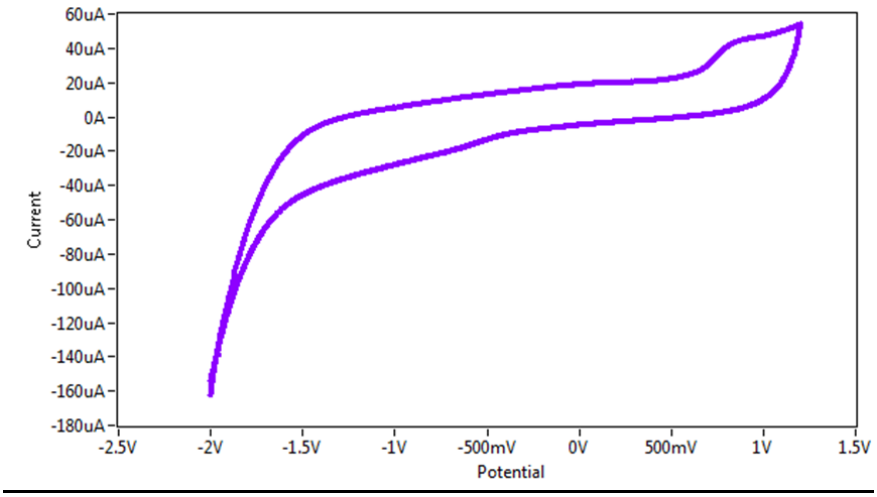

Figure 4 Cyclic voltammogram of oxidation - reduction current peaks of 1 mM aspartame in blood medium on CNT/GCE and scan rate 100 mVsec^{-1} versus Ag/AgCl as reference electrode

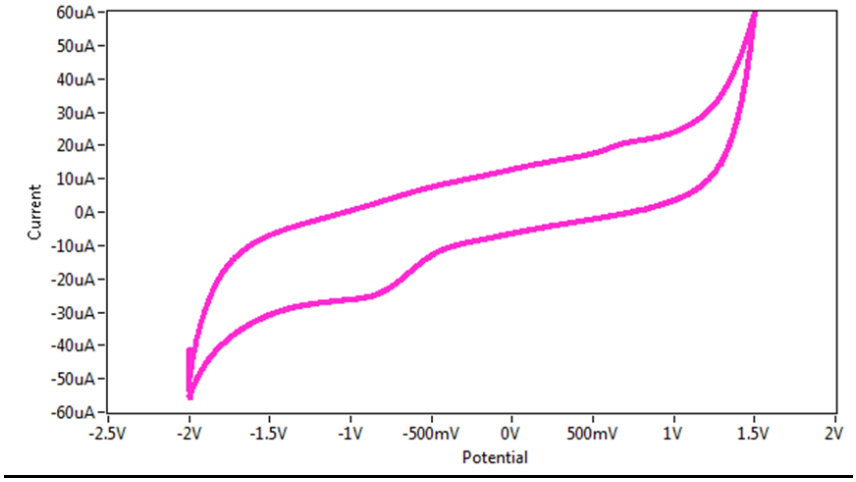

Figure 5 Cyclic voltammogram of oxidation and reduction current peaks of 1 mM acesulfame potassium in blood medium on CNT/GCE and scan rate 100 mVsec^{-1} versus Ag/AgCl as reference electrode

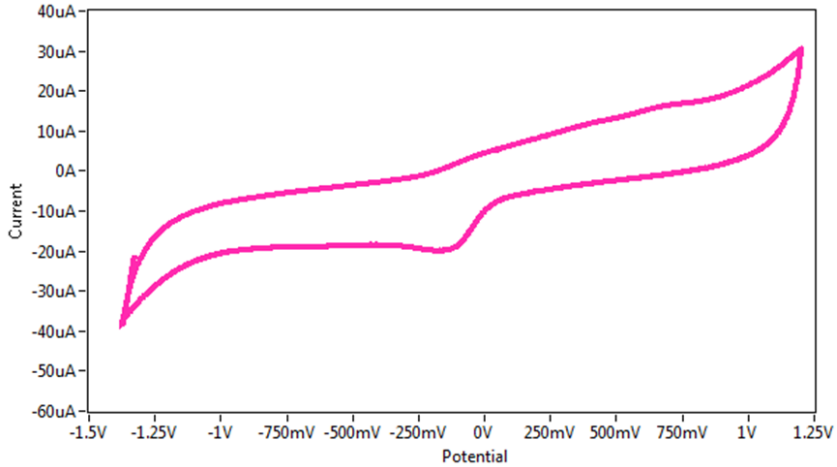

Figure 6 Cyclic voltammogram of oxidation - reduction current peaks of 0.1 mM xylitol in blood medium on CNT/GCE and scan rate 100 mVsec^{-1} versus Ag/AgCl as reference electrode

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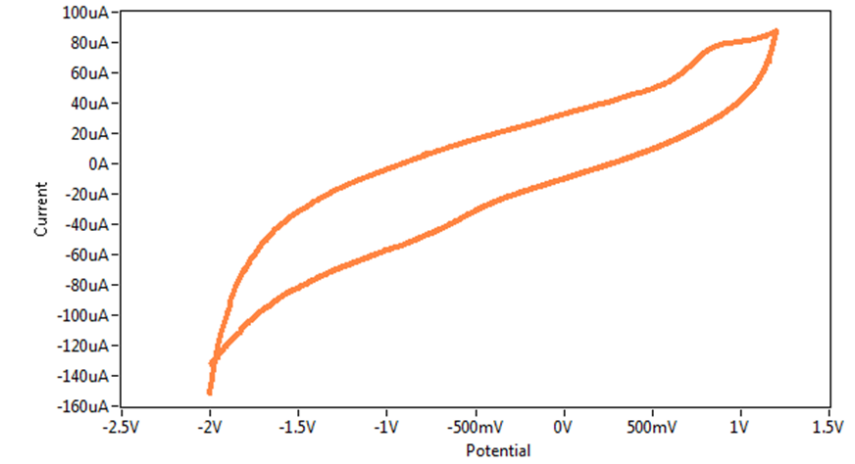

Figure 7 Cyclic voltammogram of oxidation - reduction current peaks of 1 mM sorbitol in blood medium on CNT/GCE and scan rate 100 mVsec^{-1} versus Ag/AgCl as reference electrode

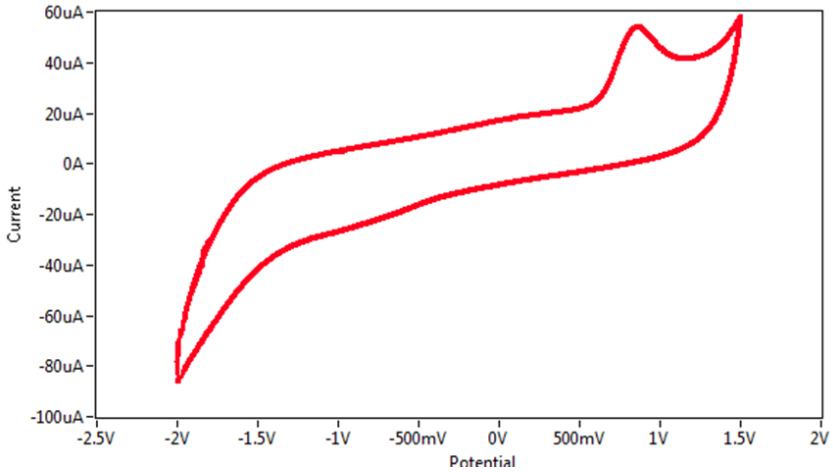

Figure 8 Cyclic voltammogram of oxidation and reduction current peaks of 0.1 mM mannitol in blood medium on CNT/GCE and scan rate 100 mVsec^{-1} versus Ag/AgCl as reference electrode

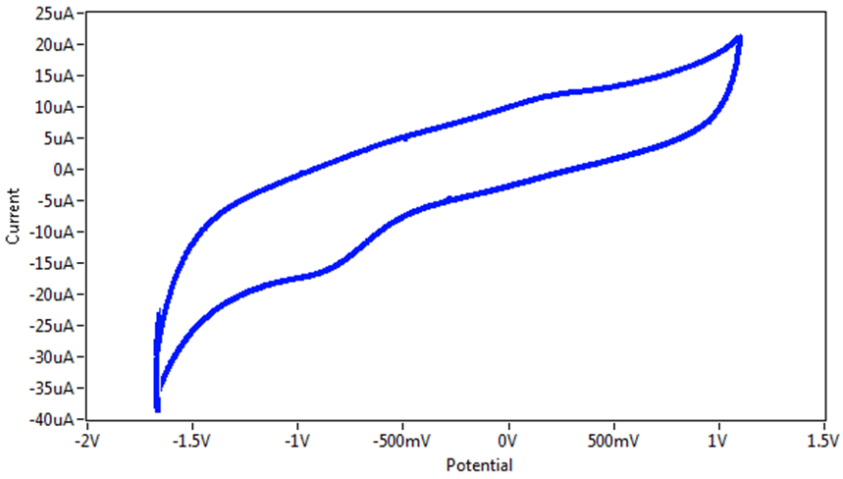

Figure 9 Cyclic voltammogram of redox current peaks of 1 mM sodium saccharin in blood medium on CNT/GCE and scan rate 100 mVsec^{-1} versus Ag/AgCl as reference electrode

3.2. Effect the viscosity factor on the diffusion coefficient value

The viscosity of blood medium without and with present of sweeteners compound were determined by viscometer using the following equation:

$$ŋ = \frac{p_s \, x \, t_s}{p_w \, x \, t_w} \quad (2)$$

ŋ: viscosity

P_s : density of sample g.ml^{-1}.

t_s : time of sample min.

P_w : density of water g.ml^{-1}.

t_w: time of water min.

Table 1 shows the viscosity values and their effect on the diffusion coefficient of redox current peaks for blood containing the sweeteners. The highest value of the viscosity was found in the blood alone (1.490), but viscosity was decreased after the addition of sweeteners compound at the range of 1.33-1.60 which affected on the diffusion coefficient value as shown in table 1. [20,21].

It was found the high value of viscosity for sorbitol in blood medium about 1.603 has been affected on the diffusion coefficient values of oxidation-reduction process in blood with lower values about 2.132x10^{-6} and 5.29 x10^{-6} cm^2 sec^{-1} respectively. So, sorbitol ions in blood medium diffused more slowly to the modified electrode (CNT/GCE) comparing with other ions in the studied serious of sweetener compounds such as mannitol which has low viscosity in blood about 1.33, the results of diffusion coefficient values for oxidation-reduction reaction of mannitol in blood have high about 2.114x10^{-6} and 1.303x10^{-5} cm^2 sec^{-1} respectively, the reason of enhancement the rate for diffuse the ions in to the electrode is the low value of viscosity for electrolyte and transfer of electron (current) is more easy in the compound with blood medium.

The viscosity of the artificial sweeteners compound in blood medium was at different values as in the following series:

Sorbitol > xylitol > sodium saccharin > acesulfame potassium > aspartame > mannitol

So, the different diffusion coefficient values were affected with viscosity factor of the sweetener compounds in blood medium as in the following series for both cathodic and anodic current peaks:

Cathodic current peaks: *mannitol > aspartame > xylitol > Sorbitol > acesulfame potassium > sodium saccharin*

Anodic current peaks: *xylitol > aspartame > Sorbitol > mannitol > sodium saccharin > acesulfame potassium*

Conclusion

The study of effect blood viscosity on the diffusion coefficient values was very important especially for different artificial sweetener using electrochemical method by cyclic voltammetric technique with nano-sensor (CNT/GCE). Blood has different components which affected on its viscosity and block passing of ions (current) through it to the electrodes, but the sweetener compounds allowed to follow the current in the blood medium. It means that the rate of current (diffusion coefficient) depend on the viscosity of electrolyte (blood) and the nature of the compounds (sweetener) with blood medium, so, increasing viscosity causes decrease the diffuse ions in the electrolyte as in the results of the research.

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