

Full Paper

Stripping Voltammetric Determination of L-dopa using Poly Sulfacetamide Modified Glassy Carbon Electrode

Mahmoud A. A. Ghandour^a, Azza M. M. Ali^a, Hazim M. Ali^{*b} Abdelsatar H. Khedr^a

^a Department of Chemistry, Faculty of Science, Assiut University, Assiut, Egypt.

^b Department of Chemistry, Collage of Science, Aljouf University, Sakaka, Saudia Arabia.

Email: hmali@ju.edu.sa

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Abstract

The voltammetric behavior of L-dopa was studied at poly sulfacetamide modified glassy carbon electrode (SFA-modified GCE), based on electrochemical oxidation of sulfacetamide. The modified electrode exhibited good selectivity and strong electrocatalytic activity for electrochemical oxidation of L-dopa in Britton – Robinson buffer solution (pH 2). Under the chosen conditions, the oxidation peak currents showed a linear dependence on the L-dopa concentration in the range of 1×10^{-7} to 1.1×10^{-6} M with limit of detection of 0.3×10^{-9} M. This method was applied to the determination of L-dopa in human serum and urine with satisfactory results. In addition, L-dopa was determined in presence of ascorbic acid (AA), uric acid (UA) and glucose.

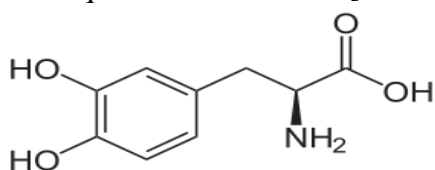
Keywords: Stripping voltammetry, L-dopa, Sulfacetamide, Ascorbic acid, Uric acid.

1. Introduction

L-dopa (3,4-dihydroxy-l-phenylalanine, Scheme (1)) is a chemical substance used in the treatment of patients with Parkinson's disease, acting efficiently in the ease of symptom. The substance is converted in dopamine by enzymatic reaction (dopa-decarboxilase) compensating the deficiency of dopamine

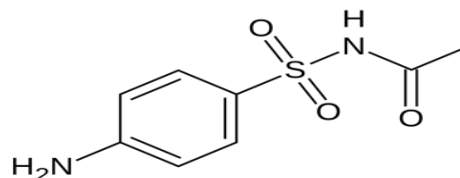
in organism [1,2]. L-dopa when used in long term run it causes serious side effects on the human health, example, Paranoia and dyskinesia [3, 4]. Several methods have been reported for the determination of L-dopa in pharmaceutical formulations and biological fluids such as spectrophotometry [5-11],

spectrofluorimetry [12], ion-selective electrode [13], NMR spectroscopy [14], high performance liquid chromatography (HPLC) [15-21] and capillary electrophoresis [22,23]. As with other catecholamines, L-dopa has electroactive groups. The oxidation process to quinone has been widely studied from an electrochemical point of view [24, 25]. The electrochemical oxidation process of L-dopa in neutral solution belongs to an EC mechanism. L-dopa is electrooxidized into dopaquinone and the dopaquinone cyclizes to cyclodopa and can be oxidized by dopaquinone quickly [2]. Unfortunately, most unmodified solid electrodes show a slow electron transfer for the electrochemical oxidation of L-dopa with a high overpotential. The oxidation product of L-dopa easily adsorbs at the bare electrode surface, leading to the poor reproducibility and repeatability of these unmodified electrodes. However, the major problem for voltammetric detection of L-dopa in real samples is the interference of the concomitant compounds, such as ascorbic acid (AA) and uric acid (UA), which generally results in overlapped voltammetric response due to their very similar oxidation peak potentials on unmodified carbon electrodes [26,27]. Nowadays, chemically-modified electrode surface has been proved to be a successful strategy to circumvent this problem, and various materials and techniques have been used [28-30].



Scheme (1): Chemical structure of L-dopa

In the present work, sulfacetamide (SFA, Scheme (2)) is electro-polymerized on a glassy carbon electrode (GCE) with cyclic voltammetry, and the electrochemical behaviours of L-dopa are studied on the poly(sulfacetamide) modified GCE. The results show that the modified electrode has excellent properties for determination of L-dopa, and eliminating the interference of ascorbic acid (AA) and uric acid (UA). This method was also used to detect L-dopa in human serum and urine samples. Compared with other similar method, this method has advantages of wide linear range, low-cost, rapid and simple operation, and low detection limit.



Scheme (2): Chemical structure of sulfacetamide

2. Experimental

2.1. Reagents and solutions

L-dopa, Ascorbic acid (AA), Uric acid (UA), Glucose, Sulfacetamide (SFA), Sulfuric acid, Phosphoric acid, Acetic acid, Boric acid and Sodium hydroxide were purchased from Sigma - Aldrich Company and no further purification was performed. Stock solutions of L-dopa (1×10^{-3} M), AA (1×10^{-2} M), UA (1×10^{-3} M), Glucose (1×10^{-2} M), SFA (1×10^{-2} M) were prepared daily by using bidistilled water. Britton-Robinson buffer (B-R buffer) solution with different pH values were prepared by mixing 0.1M for

each of phosphoric acid, acetic acid and Boric acid with second distilled water.

2.2. Apparatus

All voltammetric measurements were recorded with an EG & G Princeton Applied Research Corp. (PAR; Princeton, N.J, USA) Model 264A stripping analyzer, coupled with a PAR303A cell and were carried out in a conventional three-electrode system with a sulfacetamide- modified glassy carbon electrode as a working electrode, a platinum wire as a counter electrode and a saturated Ag/AgCl as a reference electrode. A PAR 305 stirrer was connected to the 303A. A PAR Model RE 0089 X-Y recorder was used to collect experimental data. pH values were recorded with Hanna microprocessor pH model 211. Differential pulse measurements made using scan rate $10 \text{ mV}\cdot\text{s}^{-1}$ and pulse amplitude 25 mV. All electrochemical measurements were carried out at $25\pm 1^\circ\text{C}$.

3. Result and discussion.

3.1. Electrochemical polymerization of SFA on GCE

Sulfacetamide is an electroactive molecule, which was undergoing electro polymerization between the ranges of 0.4 to 1.4 V for 20 multiple cycles. The effect of supporting electrolyte and the effect of concentration of SFA were tested. The chosen working conditions are: 0.1 M of sulfuric acid is used as a suitable supporting electrolyte and 1×10^{-3} M SFA is appropriate concentration for film formation. **Fig. 1** shows the development of polymer film on the surface of GCE in 0.1 M H_2SO_4 solution.

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From this Fig., Sulfacetamide has only one anodic peak at +0.85 V and no cathodic peaks in this range refer to the irreversible nature of sulfacetamide. During the polymerization, an anodic peak corresponding to the oxidation of sulfacetamide descended gradually with cycles and tended to be stable after 20 cycles. This indicates that the poly sulfacetamide film was formed and deposited on the surface of the GCE. The possible reaction mechanism could be as follows (Scheme (3)), sulfacetamide (A) was first oxidized to free radical (B) by loses one electron and one proton; the free radical (B) combined together rapidly to form hydrazo compound (C) and finally the electrode surface was covered by the formed polymer (D).

3.2. Electrochemical oxidation of L-dopa on the SFA-modified GCE

Preliminary experiments were carried out to identify the general features, which characterize the behavior of L-dopa on the bare and SFA- modified GCE. **Fig.2** shows differential pulse stripping voltammograms (DPSV) of 1×10^{-6} M L-dopa in 0.01 M Britton-Robinson buffer (pH 2) at bare and SFA-modified GCE. A small anodic peak current was observed at the bare GCE while, an enhancement in the anodic peak current at $E_p=0.2\text{V}$ was observed at a SFA-modified GCE. The increase in anodic current at SFA-modified GCE is an indication of the important role of sulfacetamide in the accumulation process of L-dopa on the electrode surface.

E-mail: president@aun.edu.eg

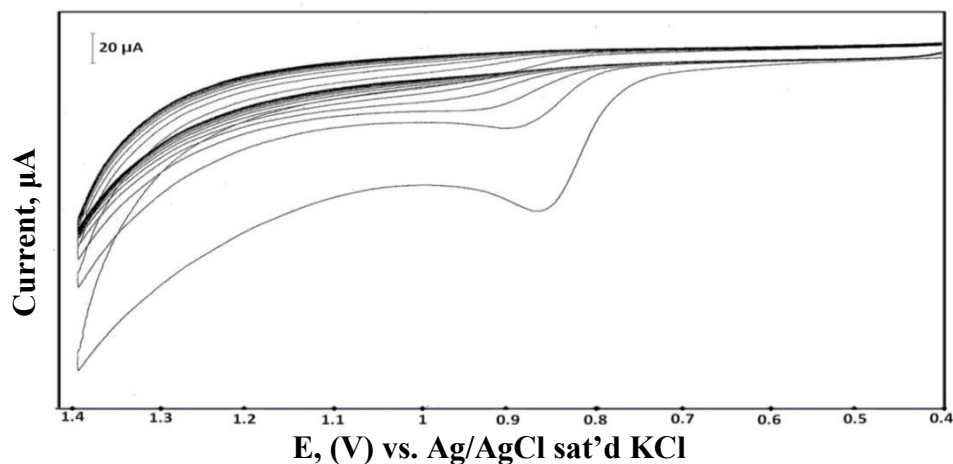


Fig 1. Repetitive cyclic voltammograms of sulfacetamide at a bare glassy carbon electrode in 0.1 M H₂SO₄ solution containing 1×10⁻³ M sulfacetamide; scan potential from 0.4 to 1.4 V; scan rate 100 mVs⁻¹.

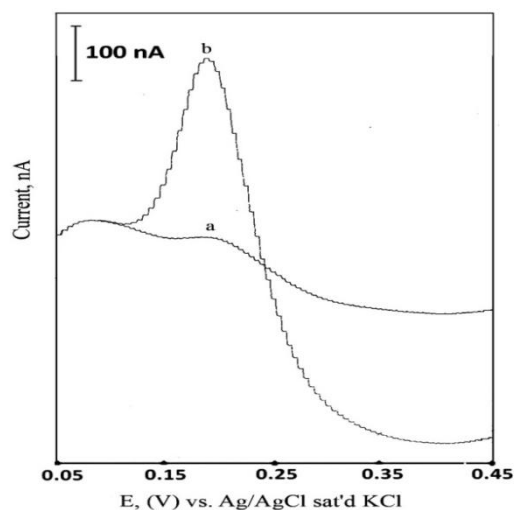
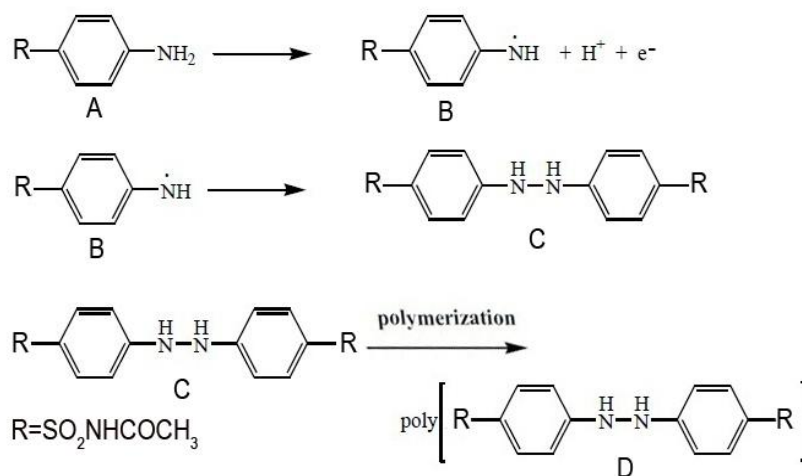


Fig 2. DPS Voltammograms of 1×10⁻⁶ M of L-dopa in 0.01 M B-R buffer solution (pH 2), accumulation time 30 second and scan rate 10 mVs⁻¹ at (a) bare electrode and (b) SFA-modified GCE electrode.



Scheme (3): Electrochemical polymerization of Sulfacetamide

3.2.1. Effect of pH on the voltammetric response of L-dopa

The oxidation of L-dopa on the SFA-modified GCE surface is dependent on pH value. **Fig.3a** shows the effect of pH values on the peak current studied by recording DPS voltammograms of L-dopa in a series of B-R buffer solution with the pH values range 2.0-6.0. It was found that the oxidation peak current of L-dopa decreases with an increase in solution pH. Maximum anodic peak currents for L-dopa at pH 2.0. Hence, pH 2.0 solution was selected to use in the following experiments. On increasing the pH the anodic peak potential of L-dopa shifted toward negative potential as can

be seen in **Fig.3b**. The relationship between the anodic peak potential and the solution pH value could be fit to the regression equation of E_p / V (pH 2.0-6.0) = $-0.054 \text{ pH} + 0.325$, with a correlation coefficient of $R^2 = 0.984$. This demonstrates that the electrode process involves equal proton-electron transfer. The slope of the equation is in close agreement with $59/n$ mV. So the electrochemical redox reaction of L-dopa in the proposed electrode is a two-electron coupled two-proton transfer mechanism [31]. The electrochemical redox process of L-dopa to give dopaquinone is described in scheme (4).

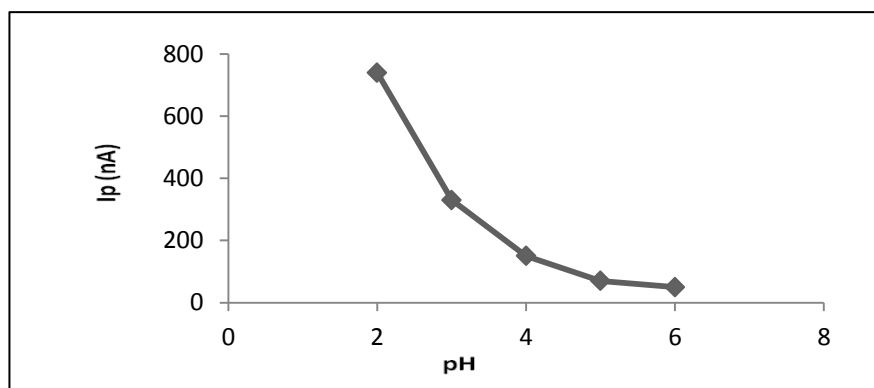


Fig 3a: Effect of pH on the i_p for 5×10^{-6} M of L-dopa in 0.01 M B-R buffer, accumulation time 60 second and scan rate 10 mVs^{-1} .

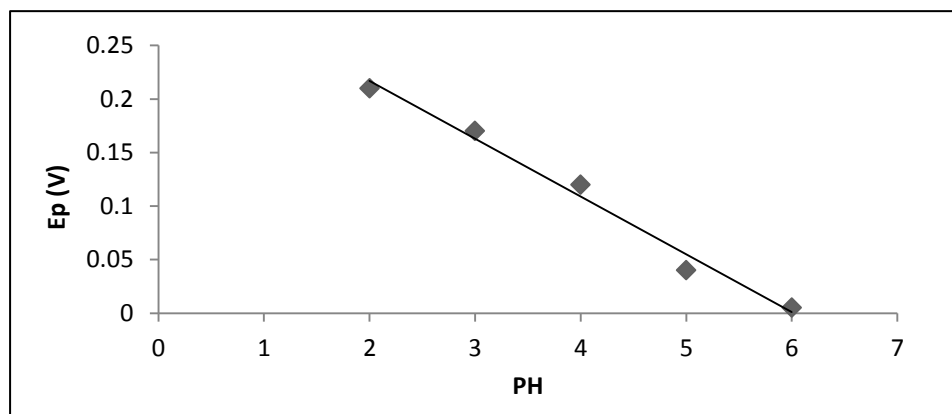
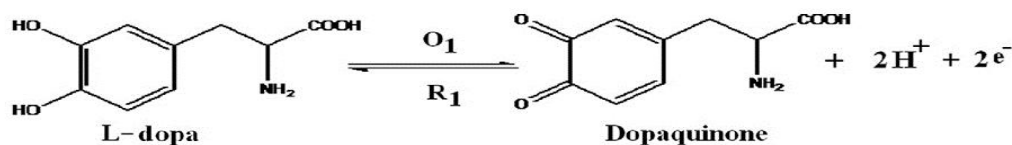


Fig 3b: Effect of pH on E_p for 5×10^{-6} M L-dopa in 0.01 M B-R buffers, accumulation time 60 second and scan rate 10 mVs^{-1} .



Scheme (4): The electrochemical mechanism of L-dopa.

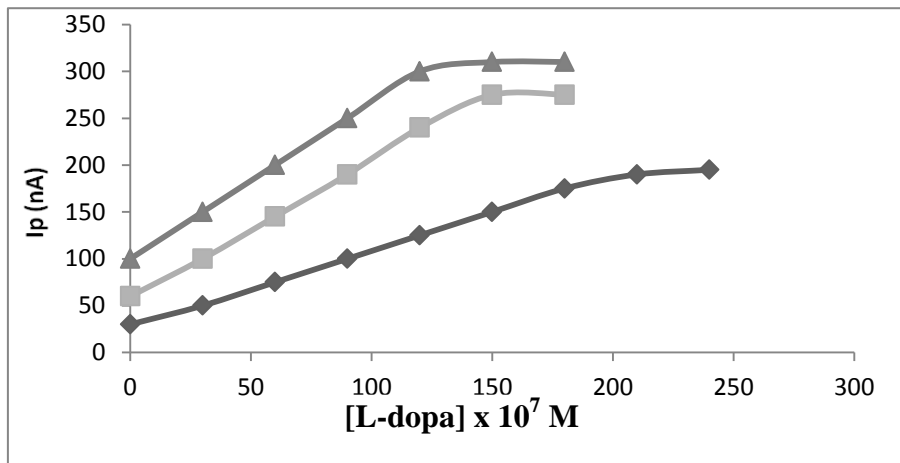


Fig.4 : Effect of accumulation time on i_p (a) of L-dopa in 0.01M B-R buffer (pH 2) , scan rate 10 mVs^{-1} at different concentration:

(a) 1×10^{-7} (b) 3×10^{-7} and (c) 5×10^{-7} M of L-dopa

3.2.2. Effect of accumulation potential

The effect of accumulation potential on the DPSV current response for L-dopa was studied on the SFA- modified GCE surface. It was found that the peak current of L-dopa was the highest at 0.05V as the accumulation potential so, accumulation potential of 0.05V was therefore chosen in all subsequent experiments.

3.2.3. Effect of accumulation time of L-dopa

The effect of accumulation time on the response current of different concentrations of L-dopa was investigated by DPSV on the SFA-modified GCE surface as shown in **Fig.4**. The peak current was found to increase with increasing the pre-concentration time and then remained constant, due to the surface saturation.

3.2.4. Effect of the scan rate on the determination of L-dopa

The adsorptive character of 1×10^{-6} M L-dopa was identified by measuring the peak current (i_p) at various scan rates v ($5\text{-}100 \text{ mVs}^{-1}$) by LSSV on the SFA-modified GCE surface as shown in **Fig.5a**. The results of linear sweep voltammetric studies for L-dopa showed that the peak current i_p , is linear with the scan rate (v). The linear relation can be represented by the equation $i_p \text{ (nA)} = 2.673 v \text{ (mVs}^{-1}\text{)} + 4.093$, with a correlation coefficient of $R^2 = 0.999$. furthermore, by plotting $\log i_p$ vs $\log (v)$ for 1×10^{-6} M of L-dopa in 0.01M B-R buffer (pH 2) as shown in **Fig.5b**, a straight line was obtained over the rang $5\text{-}100 \text{ mVs}^{-1}$ with a slope of 0.965 and a correlation coefficient 0.999 which is in close proximity to a slope of 1.0 that is expected for an ideal reaction of surface species [32-34].

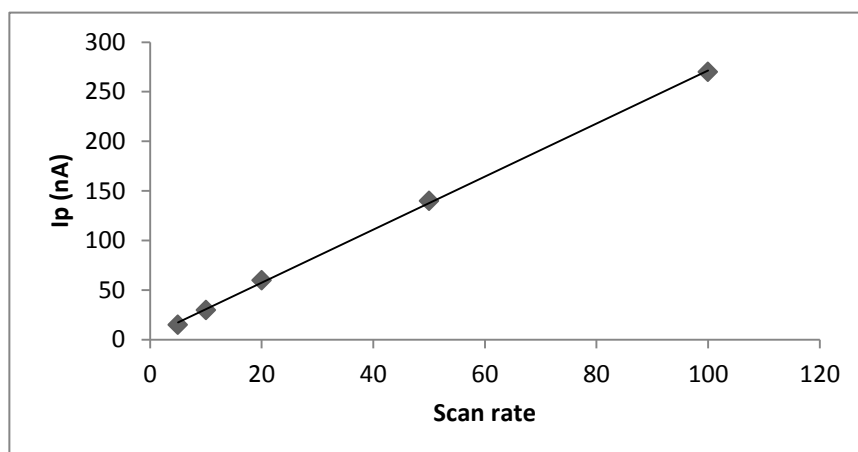


Fig.5a: Dependence of i_p on the scan rate for 1×10^{-6} M of L-dopa in 0.01 M B-R buffers (pH 2), accumulation time 30 second, using Linear sweep voltammetry.

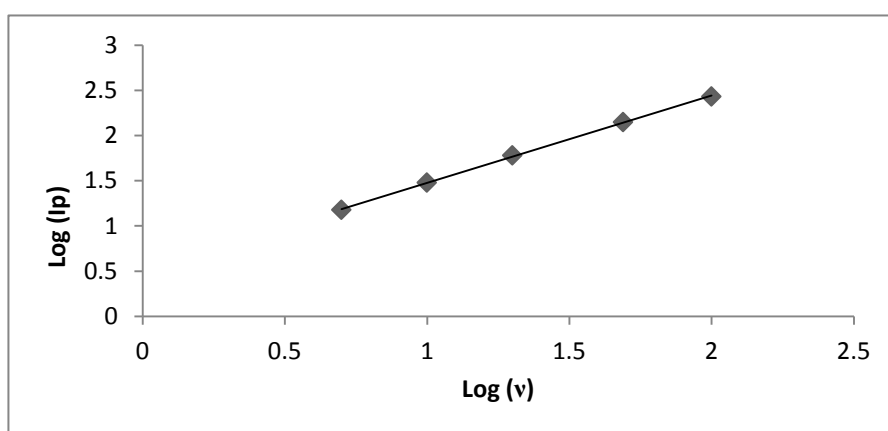


Fig.5b: Dependence of $\log i_p$ on $\log (v)$ for 1×10^{-6} M of L-dopa in 0.01 M B-R buffer (pH 2), accumulation time 30 second, using Linear sweep voltammetry.

3.3. Calibration curve and detection limit.

Under the optimum conditions, the effect of concentration of L-dopa on the anodic current response was performed by DPSV technique on the SFA-modified GCE surface. **Fig.6** shows the DPSV voltammograms at different concentrations L-dopa at the SFA-modified GCE. Clearly, the anodic peak current increases linearly with L-dopa concentration ranging from 0.1×10^{-6} to 1.1×10^{-6} M as shown in **Fig.6a**, the linear equation is $i_p(\text{nA}) = 45.25 \times 10^7 C(\text{M}) + 18.75$ with a correlation coefficient of 0.998. The limit of detection ($\text{LOD} = 3\text{S.D.}/a$ where “S.D.” is the

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standard deviation of the intercept and “a” is the slope of the calibration equation) of L-dopa was found to be 0.3×10^{-9} M, which is better than that of latest reports as shown in **Table 1**.

3.4. Study of interference.

Uric acid (UA), Ascorbic acid (AA) and glucose are the main interfering species in the determination of L-dopa in biological fluids. Therefore, the influence of UA, AA and glucose on the current response of L-dopa concentration was investigated individually. It was found that the current response decreased slightly in presence of these interferences but there is no any effect on the original concentration of L-dopa. This is confirm-

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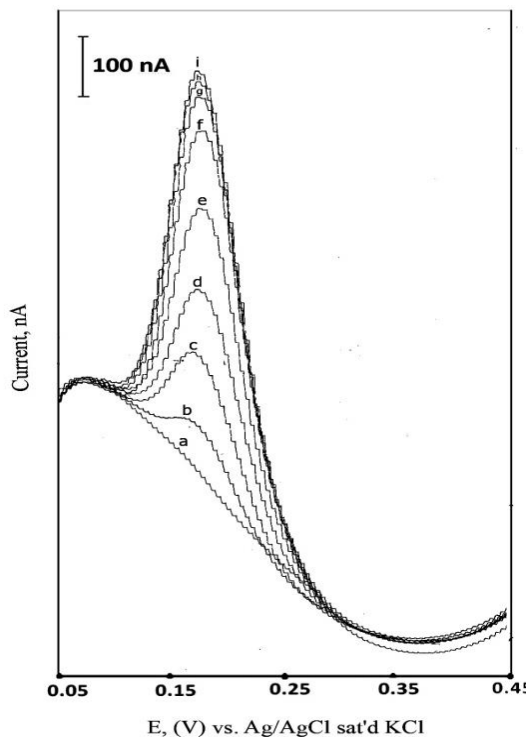


Fig.6. DPS Voltammograms of L-dopa in 0.01M B-R buffer (pH 2), accumulation time 30 second and scan rate 10 mVs^{-1} at different concentrations;
 a) Blank b) 1 c) 3 d) 5 e) 7 f) 9
 g) 11 h) 13 i) $15 \times 10^{-7} \text{ M}$ L-dopa

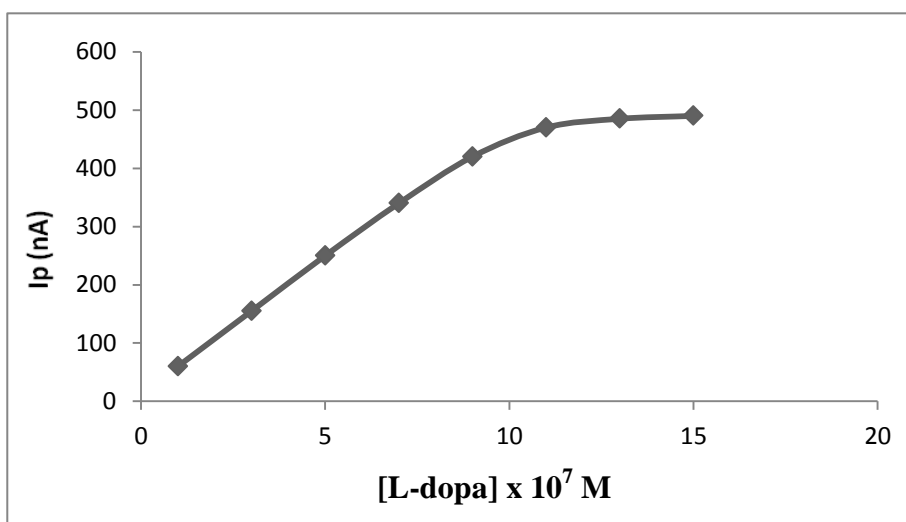


Fig.6a. Current-concentration plots of DPS Voltammograms of 1×10^{-7} to $15 \times 10^{-7} \text{ M}$ of L-dopa in 0.01M B-R buffer (pH 2), accumulation time 30 second and scan rate 10 mVs^{-1} .

Table 1: The LODs of L-dopa obtained using different modified electrode

Modified Electrode	LOD	Reference
Poly (methyl orange) film coated glassy carbon electrode	3.7×10^{-6} M	30
Single-wall carbon nanotube modified glassy carbon electrode	3×10^{-7} M	31
Nickel hexacyanoferrate film modified gold nanoparticle graphite composite electrode	5.3×10^{-7} M	35
Gold nanoparticle self-assembled carbon nanotube-modified pyrolytic graphite electrode	50×10^{-9} M	36
Cobalt hexacyanoferrate/large-mesopore carbon composite modified glassy carbon electrode	1.7×10^{-8} M	37
Nickel hydroxide nanoparticles/multi-walled carbon nanotubes composite modified glassy carbon electrode	2.1×10^{-7} M	38
Carbon paste electrode modified with the ionic liquid 1-butyl-4-methylpyridinium hexafluorophosphate	3.2×10^{-6} M	39

Table 2: Results of recoveries for determination of L-dopa in presence of 5×10^{-7} M of UA

Sample	Added (μ M)	Found (μ M)	Recovery (%)
1	0.1	0.105	105
2	0.2	0.194	97
3	0.3	0.293	97.66

Table 3: Results of recoveries for determination of L-dopa in presence of 2.5×10^{-7} M of AA and 2.5×10^{-7} M of glucose

Sample	Added (μ M)	Found (μ M)	Recovery (%)
1	0.1	0.095	95
2	0.2	0.205	102.5
3	0.3	0.307	102.33

-ed by the study of recovery. Good recoveries of the samples were obtained as can be seen in **Tables 2** and **3**.

3.5. Application of the method.

SFA – modified GCE was used to detect L-dopa in serum and urine samples of human by standard addition method. For each sample (10 μ l) was added to 10 ml of 0.01 M B – R buffer (pH 2). The results of recovery were shown in **Tables 4** and **5**. Satisfactory recoveries of the samples indicate that the proposed method will have promising prospects in clinical applications.

4. Conclusion

In this study, it is shown that the sulfacetamide modified glassy carbon electrode can be considered as a sensitive

and selective sensing element in voltammetric determination of L-dopa. The proposed modified electrode showed an effective novel electrocatalytic activity towards the anodic oxidation of L-dopa leading to significant increase in the peak currents. All the above investigations as well as other properties of proposed electrode showed an excellent reproducibility, good selectivity and stability and low detection limit. This charge discrimination towards AA, UA and glucose makes the modified electrode a very useful for electrochemical determination of L-dopa in pharmaceutical and clinical preparation.

Table 4: The results of L-dopa detection in human serum

Sample	Added (μ M)	Found (μ M)	Recovery (%)
1	0.1	0.098	98
2	0.2	0.195	97.5
3	0.3	0.293	97.66

Table 5: The results of L-dopa detection in human urine

Sample	Added (μ M)	Found (μ M)	Recovery (%)
1	0.1	0.093	93
2	0.2	0.194	97
3	0.3	0.295	98.33

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