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Voltammetric behavior of dopamine at a glassy carbon electrode modified with $NiFe_2O_4$ magnetic nanoparticles decorated with multiwall carbon nanotubes

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ABSTRACT

Voltammetric behavior of dopamine was studied on a glassy carbon electrode (GCE) modified-$NiFe_2O_4$ magnetic nanoparticles decorated with multiwall carbon nanotubes. Impedance spectroscopy and cyclic voltammetry were used to characterize the behavior of dopamine at the surface of modified-GCE. The modified electrode showed a synergic effect toward the oxidation of dopamine. The oxidation peak current is increased linearly with the dopamine concentration (at pH 7.0) in wide dynamic ranges of 0.05–6.0 and 6.0–100 μmol L^{-1} with a detection limit of 0.02 μmol L^{-1}, using differential pulse voltammetry. The selectivity of the method was studied and the results showed that the modified electrode is free from interference of organic compounds especially ascorbic acid, uric acid, cysteine and urea. Its applicability in the determination of dopamine in pharmaceutical, urine samples and human blood serum was also evaluated. The proposed electrochemical sensor has appropriate properties such as high selectivity, low detection limit and wide linear dynamic range when compared with that of the previous reported papers for dopamine detection.

1. Introduction

Dopamine is a catecholamine neurotransmitter that helps control the brain's reward and pleasure centers [1]. This catecholamine is widely distributed in the brain for message transfer in the mammalian central nervous system [2]. Parkinson's disease and schizophrenia are two disorders that appear with dysfunctions of the dopamine production in the brain. People with low dopamine activity may be more susceptible to addiction [3,4]. Dopamine is also used as a medication. It affects the sympathetic nervous system. Dopamine increases heart rate and blood pressure. High doses of dopamine can lead to serious side effects such as heart arrhythmias that can be life-threatening and kidney damage [5]. So it is necessary to develop a rapid, selective and sensitive method with simple sample preparation and determination steps for dopamine analysis.

Recently, several analytical methods have been reported for the determination of dopamine including electrochemistry, high performance liquid chromatography (HPLC) [6,7] and chemiluminescence method [8,9]. Electrochemical techniques based on various chemically modified electrodes have been used to detect dopamine [10–14]. Common modifiers are organic polymers [15–18], metal complexes [19–21], enzymes [22], nanoparticles and carbon nanotubes [23–26], surfactants [27–29] and organic molecules [10–12,30,31,38–63].

Multiwall carbon nanotubes (MWCNTs) attract high attention as a prospective material due to their electrical and thermal conductivity, strength, stiffness, toughness and chemical stability. One of the most interesting ways of application of MWCNTs is their usage for the modification of the surface of electrodes in electrochemistry [32].

Magnetic nanoparticles provide significant levels of new functionality for electrochemistry due to their high surface area, effective mass transport, catalysis and control over the local microenvironment [33,34]. In the present study, we apply a magnetic nanocomposite of MWCNTs decorated with spinel $NiFe_2O_4$ as a modifier to fabricate a modified glassy carbon electrode (GCE) using a citrate sol–gel method. $NiFe_2O_4$-nanocomposites were used in electrochemical methods to detect guanine and adenine [35], sotalol [36] and cefixime [37]. The $NiFe_2O_4$ nanoparticle incorporated MWCNT modified GCE as a working electrode was utilized as a sensitive and selective electrochemical sensor for the determination of dopamine. The results of our studied showed that the proposed method is simple, rapid, sensitive and selective for the quantitative determination of dopamine at the $NiFe_2O_4$–MWCNT modified-GCE surface, using differential pulse voltammetry techniques. Its applicability in the determination of dopamine in pharmaceutical, urine samples and human blood serum was evaluated too.

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