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Quantitative Analysis of Caffeine in Pharmaceutical Formulations Using a Cost-Effective Electrochemical Sensor

Authors : Y. T. Gebreslassie, Abrha Tadesse, R. C. Saini, Rishi Pal

Abstract : Caffeine, known chemically as 3,7-dihydro-1,3,7-trimethyl-1H-purine-2,6-dione, is a naturally occurring alkaloid classified as an N-methyl derivative of xanthine. Given its widespread use in coffee and other caffeine-containing products, it is the most commonly consumed psychoactive substance in everyday human life. This research aimed to develop a cost-effective, sensitive, and easily manufacturable sensor for the detection of caffeine. Antraquinone-modified carbon paste electrode (AQMCPE) was fabricated, and the electrochemical behavior of caffeine on this electrode was investigated using cyclic voltammetry (CV) and square wave voltammetry (SWV) in a solution of 0.1M perchloric acid at pH 0.56. The modified electrode displayed enhanced electrocatalytic activity towards caffeine oxidation, exhibiting a two-fold increase in peak current and an 82 mV shift of the peak potential in the negative direction compared to an unmodified carbon paste electrode (UMCPE). Exploiting the electrocatalytic properties of the modified electrode, SWV was employed for the quantitative determination of caffeine. Under optimized experimental conditions, a linear relationship between peak current and concentration was observed within the range of 2.0 x 10^{-6} to 1.0× 10^{-4} M, with a correlation coefficient of 0.998 and a detection limit of 1.47× 10^{-7} M (signal-to-noise ratio = 3). Finally, the proposed method was successfully applied to the quantitative analysis of caffeine in pharmaceutical formulations, yielding recovery percentages ranging from 95.27% to 106.75%.

Keywords : antraquinone-modified carbon paste electrode, caffeine, detection, electrochemical sensor, quantitative analysis
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