Electrochemical Enhancement: Titanium Dioxide-Modified Carbon Paste Electrodes Unlock Superior Glucose Oxidation Kinetics in Alkaline Medium

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Abstract
Electrochemical oxidation reaction of glucose in an alkaline medium was studied on carbon paste and titanium dioxide (TO_2)-modified carbon paste electrodes. The effect of titanium dioxide composition on the support was studied. Electrochemical methods used in this work were Cyclic Voltammetry, Electrochemical Impedance Spectroscopy and Tafel lines. It was confirmed that the addition of a TiO_2 composite catalyst significantly modified electro-oxidation of glucose.

Keywords: carbon paste electrode; Cyclic Voltammetry; titanium dioxide; Electrochemical Spectroscopy Impedance; glucose oxidation.

Introduction•

Due to the scarcity of fossil fuel reserves and the increasing severity of environmental legislation, scientific research has been directed towards alternative materials, such as the conversion of renewable biomass into fuels and high-value chemicals. Carbohydrates are renewable organic materials widely distributed in nature and constituting the majority of total biomass. More than 80% of the dry weight of herbaceous and woody biomass is carbohydrates [1]. However, despite their low cost and easy access, only 3–5% of carbohydrates are used industrially, with the vast majority remaining unutilized [2]. This has led to an intensification of research efforts focused on exploiting the potential of lignocellulosic biomass residues from forestry and agricultural activities [2-3]. Among carbohydrates, cellulose and glucose are of particular interest in green chemistry because they can generate a wide range of valuable compounds. Cellulose is a polysaccharide consisting of a linear chain of D-glucose units and

•The abbreviations list is in pages 687.

accounts for 45% of total annual biomass production [3]. Glucose is the monosaccharide obtained by depolymerization of this cellulose. Glucaric acid is one of the by-products obtained by oxidation of glucose, and subsequently derived from biomass [4]. Additionally, glucaric acid derivatives have also been studied in the pharmaceutical industry in applications related to cholesterol reduction and cancer chemotherapy [9-11]. Glutanic acid has shown high potential to be used in several processes as raw material for the development of metal complexing agents, biodegradable polymers and detergents, due to its non-harmful properties, since environmental regulations are beginning to limit the use of harmful chemicals [5-7]. In addition to its non-harmful properties, glutanic acid has carboxylic groups that can react selectively with different amines, alcohols and vinyl derivatives to form products with novel application profiles, such as aldonolactones, used in the preparation of N-alkyl aldonamide surfactants [8]. The production of glutanic acid mainly uses very complex chemical methods [12] which involve drastic synthesis conditions requiring high temperatures and pressures, in addition to the involvement of several synthesis steps.
Chemical oxidation of glucose using strong oxidants, such as nitric acid, is a non-selective and expensive process that, moreover, produces NOx emissions [12]. Contribution of electrochemistry in the synthesis of glutanic acid may present an alternative method of choice. Electrochemistry invests in simple, gentle mechanisms and limits the ejection steps without resorting to the use of oxidizing or reducing agents [13-15]. More importantly, selectivity can be controlled by adjusting operating voltage or current density. However, these methods use noble metal catalysts such as platinum or gold [16-30].
In this study, electrochemical oxidation of glucose was studied by cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS) and Tafel lines, in an alkaline medium using graphic carbon-based electrodes supported or not by varying amounts of titanium dioxide (TiO_2).

Experimental

Reagents and apparatus

All chemicals used were of analytical grade and employed without further purification. Solutions were prepared using double-distilled water. Glucose with 97% purity was sourced from Sigma-Aldrich (USA), while commercial graphite powder was obtained from Carbone. Lorraine, France (ref 9900). Electrochemical measurements were performed using a Voltalab potentiostat (PGSTAT 100 model, Ecochemie B.V., Utrecht, The Netherlands) controlled by Voltalab Master 4 software running on Windows 2007. The electrochemical cell setup included a modified carbon paste working electrode, a platinum counter electrode and Ag/AgCl as reference electrode.

Preparation of modified carbon paste electrode

Modified carbon paste was prepared by adding a specific amount of TiO_2 to a specific amount of graphite carbon powder (CP). The formed paste was

introduced into a cylindrical plastic cavity. This formed substance was attached to a carbon graphite rod to ensure the passage of the current. This electrode was rinsed with double-distilled water and then immersed in an electrolytic solution containing 0.1 M Sodium chloride (NaCl).

Results and discussion

Characterization of elaborated electrodes

CV in Fig. 1 show the electrochemical behavior of four electrodes with different proportions of carbon paste electrodes (CPE) and TiO_2 in an alkaline solution. Unmodified CPE (100%) curve shows minimal electrocatalytic activity. Current density remained close to zero over a wide potential range, indicating poor performance for redox reactions. All modified CPE-TiO_2 electrodes showed a significant increase in electrochemical activity compared to the unmodified electrode. CPE50% TiO_2 50% exhibited highest anodic current density (>3 mA/cm²), indicating superior catalytic performance. Electrocatalytic activity did not increase linearly with TiO_2 content. The electrode containing 75% TiO_2 showed lower performance than those containing 25 and 50% TiO_2. This suggests there is an optimal proportion of TiO_2 (~50%) that maximizes catalytic activity. Increased separation between anodic and cathodic branches for modified electrodes indicates a higher electrical double layer capacity, in accordance with Eq. (1):

$$I_c = v.\ C_{dl} \qquad (1)$$

where I_c is capacitive current, v is scan rate, and C_{dl} is double layer capacitance. This analysis suggests that 50% CPE/50% TiO_2 electrode would be the optimal choice for applications such as glucose sensors or glucose fuel cells.

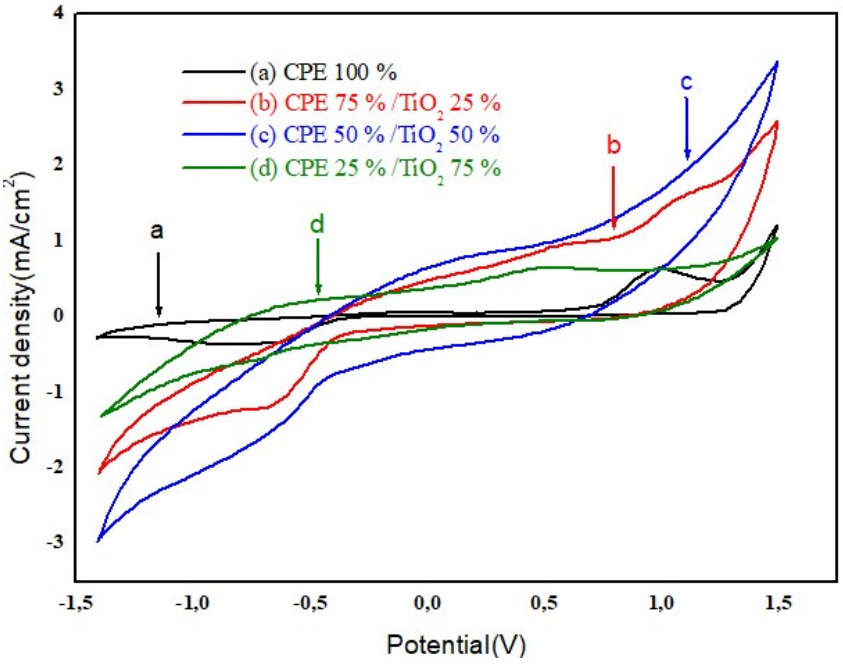

Figure 1: CV recorded in 0.1 M NaCl alkalin medium at- **(a)** CPE 100%, **(b)** CPE 75%/TiO_2 25%, **(c)** CPE 50%/TiO_2 50% and **(d)** CPE 25%/TiO_2 75%.

Fig. 2 shows the impedance behavior of the four electrode compositions in the alkaline electrolyte. EIS data can be interpreted using a modified Randles equivalent circuit:

$$Z = R_s + \frac{R_{ct}}{1 + (j\omega R_{ct} C_{dl})^{\alpha}} + \frac{1}{j\omega C_{ps}} \quad (2)$$

where R_s represents solution resistance, R_{ct} is charge transfer resistance, C_{dl} is double layer capacitance, C^{ps} is pseudocapacitance and α is constant phase element factor (0<α<1).

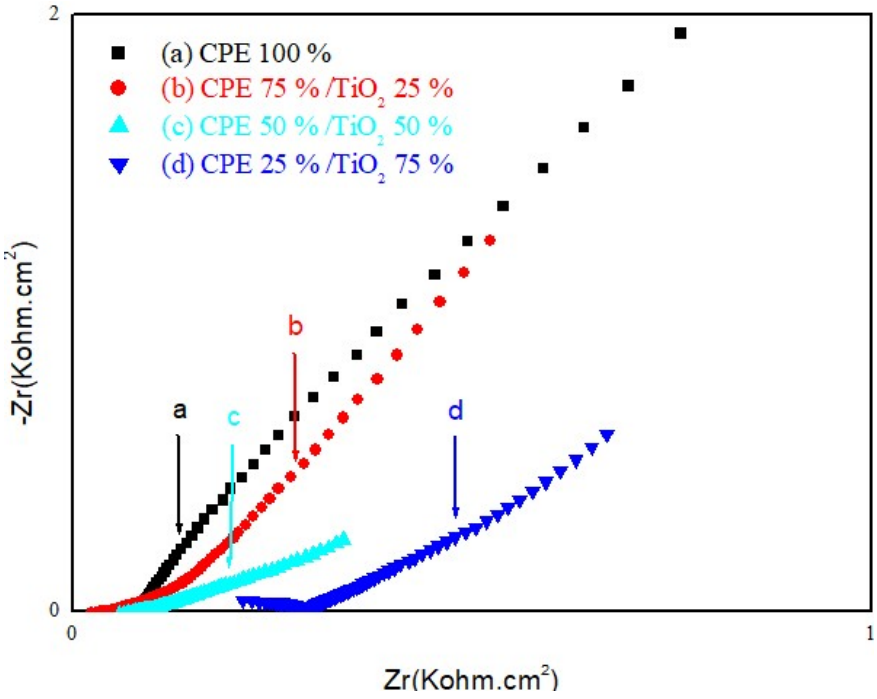

Figure 2: EIS diagrams recorded in 0.1 M NaCl alkalin medium at- **(a)** CPE 100%, **(b)** CPE 75%/TiO_2 25%, **(c)** CPE 50%/TiO_2 50% and **(d)** CPE 25%/TiO_2 75%.

Pure CPE (100%) shows the highest impedance values and steepest slope, indicating high charge transfer resistance. This suggests limited electron transfer kinetics at the unmodified CPE interface. TiO_2 Modifications show a clear decrease in impedance occurs with increasing TiO_2 content up to 50%, followed by a different behavior at 75% TiO_2. Optimal composition (50% TiO_2) (curve c) show the lowest impedance values and smallest semi-circle diameter, indicating minimum charge transfer resistance according to:

$$R_{ct} = \frac{RT}{nFi_0} \quad (3)$$

where i_0 is exchange current density, indicating superior interfacial electron transfer kinetics.

High TiO_2 content (75%) (curve d) show increased impedance compared to 50% TiO_2, suggesting a non-linear relationship between TiO_2 content and electrochemical performance. The slope of the linear region at low frequencies provides information about diffusion processes. 50% TiO_2 electrode shows the most ideal capacitive behavior with a slope closest to vertical. Warburg impedance (diffusion-controlled processes) can be modeled as:

$$Z_w = \sigma\omega^{-1/2}(1 - j) \quad (4)$$

Data suggests that 50% TiO_2 provides optimal double layer capacitance, likely due to increased surface area without compromising electronic conductivity. Finally, EIS data confirms that 50% TiO_2/50% CPE represents optimal composition for electrochemical performance in an alkaline medium, showing a lowest charge transfer resistance, enhanced capacitive behaviour and improved ion diffusion properties.

These properties make this composition particularly suitable for potential electroanalytical applications, offering an ideal balance between electronic conductivity, electroactive surface area and ion transport capabilities.

This graph (Fig. 3) presents a Tafel plot (Log I vs. Potential) comparing the electrochemical behavior of two electrode compositions in an alkaline electrolyte. Tafel plot provides critical information about the electrode kinetics, particularly exchange current density (i_0) and Tafel slope, which are essential parameters for evaluating catalytic activity. The fundamental relationship illustrated in this plot follows Tafel equation:

$$\eta = \alpha + b \log (i) \quad (5)$$

where η is overpotential, a is a constant related to standard electrode potential and exchange current density, b is Tafel slope and i is current density. From the plot, it is evident that CPE 50%/TiO_2 50% electrode (curve b) exhibits a different exchange current density compared to pure CPE electrode (curve a). Tafel slope provides insight into the rate-determining step of the electrode reaction:

$$b = \frac{2.303RT}{\alpha nF} \quad (6)$$

where R is gas constant, T is temperature, α is charge transfer coefficient, n is number of electrons involved and F is Faraday constant. Both electrodes show distinct Tafel slopes in cathodic branch, indicating different reaction mechanisms or rate-determining steps. Pure CPE (curve a) shows higher overall current densities across potential range, with log I values between approxim. 0 and 2 mA/cm², indicating less polarization resistance. TiO_2-modified electrode (curve b) displays lower current densities (log I between approxim. -2.2 and 0 mA/cm²), suggesting increased polarization resistance. The significant shift in current density for TiO_2-modified electrode indicates altered surface electrochemistry. In an alkaline medium, TiO_2 can undergo the following surface process:

$$Ti\text{-}OH + OH \rightleftharpoons Ti\text{-}O + H_2O \quad (7)$$

This creates negatively charged surface sites that can influence the double layer structure and electron transfer kinetics, explaining observed differences in Tafel behavior. Lower current density for TiO_2-modified electrode in this potential range suggests a higher polarization resistance, different reaction mechanism and altered surface energy and adsorption properties. These characteristics make TiO_2-modified electrode potentially advantageous for applications requiring controlled electron transfer rates and specific surface interactions with analytes. Tafel analysis confirms that incorporating 50% TiO_2 into CPE significantly modifies its fundamental electrochemical properties in an alkaline medium, consistent with previous CV and EIS findings.

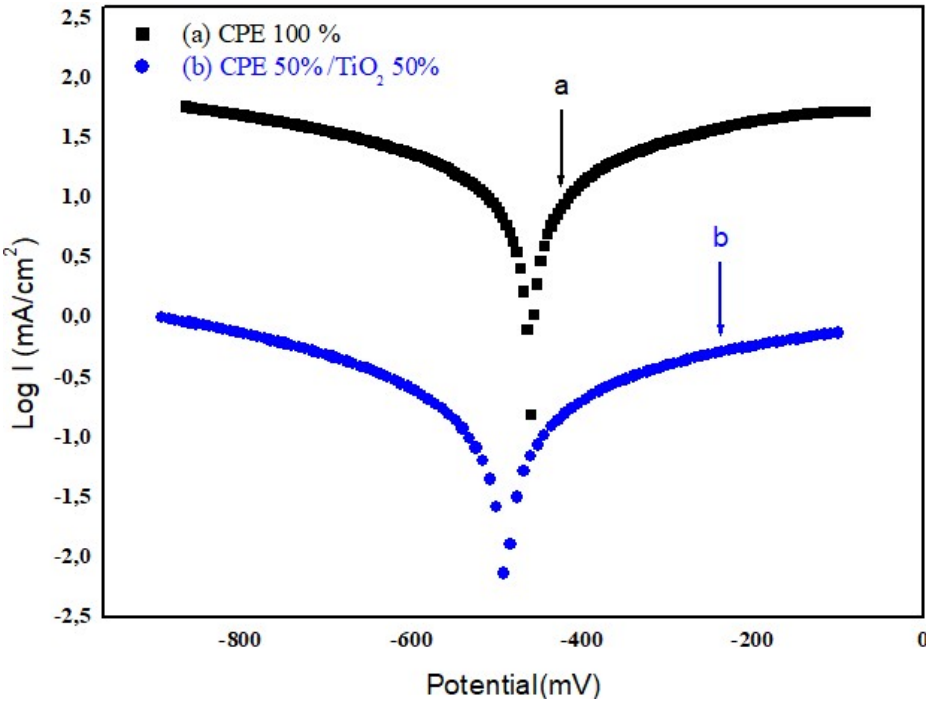

Figure 3: CV recorded in 0.1 M NaCl alkalin medium, respectively at - **(a)** CPE 100% and **(b)** CPE 50%/TiO_2 50% and **(d)** CPE 25%/TiO_2 75%.

Electrochemical oxidation of glucose at modified carbon paste electrodes in alkaline medium

This CV (Fig. 4) shows electrochemical behavior of glucose oxidation (0.08 M) at four different electrode compositions in an alkaline medium. Pure CPE (100%) curve (a) shows minimal electroactivity towards glucose oxidation, with very low current densities across potential range. This indicates poor catalytic activity of unmodified carbon paste for glucose oxidation. All TiO_2-modified electrodes demonstrate significantly enhanced electrocatalytic activity towards glucose oxidation, with the most pronounced effect observed for the 50% TiO_2 electrode (curve c). 50% TiO_2 electrode shows the highest anodic current density (~3.7 mA/cm²), indicating superior glucose oxidation kinetics. This composition appears to provide optimal balance

between conductivity and catalytic activity. In the alkaline medium, glucose oxidation proceeds via:

$$\text{Glucose} + 2OH^- \rightarrow \text{Gluconolactone} + H_2O + 2e^- \quad (8)$$

The reaction kinetics can be described by modified Butler-Volmer equation:

$$j = nFk_0 C_{\text{glucose}}^{\alpha} C_{OH^-}^{\beta} \exp\left(\frac{\alpha n F \eta}{RT}\right) \quad (9)$$

where k_0 is heterogeneous rate constant, α and β are reaction orders and η is overpotential. Onset potential for glucose oxidation shifts to less positive values with TiO_2 modification, indicating a reduction in activation energy barrier. This can be quantified by:

$$\Delta G^{\ddagger} = -nF(E_{onset} - E^0) \quad (10)$$

Onset potential decrease indicates that TiO_2 lowers energy barrier for glucose oxidation, enhancing the electrode's electrocatalytic efficiency. Superior performance of TiO_2-modified electrodes can be attributed to several factors, such as that they provide favorable adsorption sites for glucose molecules through interaction with hydroxyl groups:

$$Ti^{4+}\text{-O} + \text{Glucose-OH} \rightleftharpoons Ti^{4+}\text{-O- Glucose} + OH \quad (11)$$

Semiconductor properties of TiO_2 may create favorable electronic pathways, enhancing electron transfer kinetics according to Marcus theory:

$$k_{ET} = k_0 \exp\left(-\frac{\lambda}{4RT}\left(\frac{E - E^0}{\lambda}\right)^2\right) \quad (12)$$

where λ is reorganization energy. Electroactive surface area increases with TiO_2 addition up to 50%, enhancing the number of available reaction sites.
For the 50% TiO_2 electrode, peak current density can be related to glucose concentration according to:

$$i_p = nFAC_{\text{glucose}}\sqrt{\frac{nFvD}{RT}} \quad (13)$$

where A is electrode area, D is diffusion coefficient and v scan rate. Sensitivity can be expressed as:

$$\text{Sensitivity} = \frac{\Delta i_p}{\Delta C_{\text{glucose}}} \quad (14)$$

Superior performance of 50% TiO_2/50% CPE electrode for glucose oxidation makes it particularly promising for applications such as electrochemical glucose sensors, glucose fuel cells and electrochemical synthesis using glucose as renewable feedstock. Significant enhancement in current response with TiO_2 modification substantiates catalytic role of TiO_2 in facilitating glucose

electrooxidation in an alkaline medium, with 50% composition offering optimal balance between conductivity and catalytic surface area.

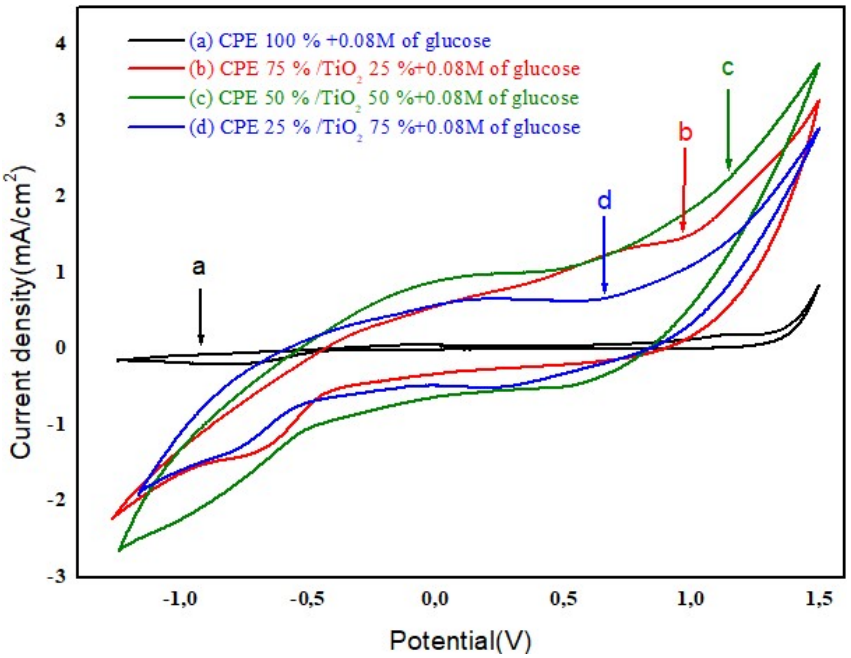

Figure 4: CV recorded in an 0.1 M NaCl alkalin medium containing 0.08 M glucose, respectively at - **(a)** CPE 100%, **(b)** CPE 75/TiO_2 25%, **(c)** CPE 50%/TiO_2 50% and **(d)** CPE 25%/TiO_2 75%.

Fig. 5 shows CV of glucose oxidation (0.08 M) at four different electrode compositions in an alkaline medium. Nyquist plots can be interpreted using modified Randles equivalent circuit incorporating R_s, R_{ct}, C_{dl} or CPE and Z_w: (Warburg impedance).

$$Z(\omega) = R_s + \frac{R_{ct}}{1 + j\omega C_{dl} R_{ct}} + \frac{\sigma}{\sqrt{\omega}}(1 - j) \qquad (15)$$

Pure CPE (100%) (curve a) show highest impedance values, with Rct estimated around 400 Ω·cm². This indicates poor electron transfer kinetics for glucose oxidation at unmodified CPE. All TiO_2-modified electrodes show significantly lower R_{ct} values, with a clear trend of decreasing it with increasing TiO_2 content up to 50%. 50% TiO_2 electrode (curve c) exhibits lowest R_{ct} (~170 Ω·cm²), indicating fastest electron transfer kinetics for glucose oxidation. R_{ct} is directly related to standard heterogeneous rate constant (k°) by:

$$R_{ct} = \frac{RT}{n^2 F^2 A k^\circ C} \qquad (16)$$

where A is electrode area, C is glucose concentration and n is number of electrons transferred. The slope of linear region at low frequencies (Warburg region) provides information about diffusion processes:

$$Zw = \sigma\omega\ ½(1 - j) \tag{17}$$

where σ is the Warburg coefficient:

$$\sigma = \frac{RT}{n^2F^2A\sqrt{2}}\left(\frac{1}{C_O\sqrt{D_O}} + \frac{1}{C_R\sqrt{D_R}}\right) \tag{18}$$

Steeper slopes for TiO_2-modified electrodes indicate more favorable diffusion characteristics for glucose oxidation. Significant decrease in R_{ct} with TiO_2 modification suggests that TiO_2 facilitates electron transfer process during glucose oxidation through several mechanisms: TiO_2 provides favorable adsorption sites for glucose molecules, enhancing pre-reaction complex formation:

$$TiO_2 + Glucose \rightleftharpoons TiO_2 - Glucose_{ads} \tag{19}$$

Semiconducting properties of TiO_2 create a favorable electronic environment for electron transfer, lowering activation energy:

$$\Delta G^{\ddagger} = \frac{\lambda}{4}\left(1 + \frac{\Delta G^0}{\lambda}\right)^2 \tag{20}$$

where λ is reorganization energy and ΔG^0 is standard free energy change. The interface between carbon and TiO_2 may create unique electronic states that enhance electrocatalytic activity.

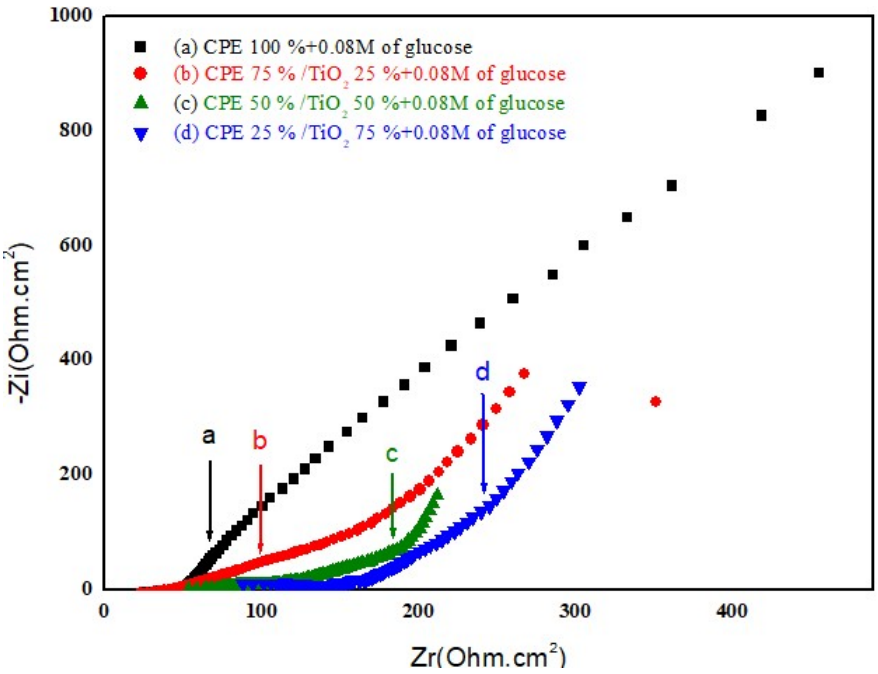

Figure 5: CV recorded in 0.1 M NaCl alkalin medium containing 0.08 M glucose at- **(a)** CPE 100%, **(b)** CPE 75%$TiO_2$25%, **(c)** CPE50%$TiO_2$50% and **(d)** CPE25%$TiO_2$75%.

EIS results corroborate CV findings, confirming that 50% TiO_2/50% CPE composition provides optimal balance of minimal charge transfer resistance,

enhanced electron transfer kinetics, favorable glucose adsorption properties and sufficient electronic conductivity.

EIS data provides compelling evidence for mechanistic role of TiO_2 in facilitating glucose electrooxidation, particularly at optimal 50% loading, making it the most promising composition for electroanalytical applications involving glucose detection or glucose-based energy conversion.

Conclusion

This comprehensive electrochemical investigation has elucidated the significant impact of TiO_2 modification on CPE for glucose oxidation in an alkaline medium. Key findings and conclusions are as follows:

50% CPE / 50% TiO_2 electrode consistently demonstrated superior electrochemical performance across all characterization techniques (CV, EIS and Tafel analysis). This composition provides optimal balance between electronic conductivity and electrocatalytic activity.

TiO_2 modification significantly decreases charge transfer resistance for glucose oxidation, with 50% TiO_2 electrode showing lowest R_{ct} values. This indicates faster electron transfer kinetics and more efficient glucose oxidation. Electrochemical data suggests that TiO_2 enhances glucose oxidation through multiple mechanisms, provision of favourable adsorption sites for glucose molecules, creation of a beneficial electronic environment for electron transfer and formation of active Ti-O^- surface species in an alkaline medium that facilitate glucose oxidation. The relationship between TiO_2 content and electrochemical performance is non-linear, with performance declining at 75% TiO_2 content. This indicates a trade-off between catalytic benefits of TiO_2 and CPE's conductive properties. Significantly enhanced electrocatalytic activity of 50% TiO_2-modified CPE towards glucose oxidation makes it a promising material for several applications: electrochemical glucose sensing- improved sensitivity and electrocatalytic activity could lead to more efficient non-enzymatic glucose sensors with lower detection limits and wider linear ranges; glucose fuel cells- enhanced electron transfer kinetics could improve efficiency of direct glucose fuel cells, offering potential for sustainable energy generation; electrochemical synthesis- modified electrodes could facilitate selective electrochemical conversion of glucose to value-added products.

Authors' contributions

M. Oukbab: conceptualization; experimental; investigation; original draft preparation and writing; review and editing data analysis. **M. Enasraouy**: conceptualization; investigation; original draft preparation and writing; review and editing; data analysis. **M. Oubaouz**: experimental; investigation. **M. Erradi**: investigation; conceptualization. **Rachida Najih**: methodology; review and editing. **A. Chtaini**: conceptualization; methodology; original draft preparation and writing; review and editing; supervision.

Abbreviations

C_{dl}: double layer capacitance
CP: carbon powder
CPE: carbon paste electrode
CPE/TiO_2: carbon paste electrode modified with titanium dioxide
CV: cyclic voltammetry
EIS: electrochemical impedance diagrams
NaCl: sodium chloride
R_{ct}: charge transfer resistance
R_s: solution resistance
TiO_2: Titanium dioxide
VL: linear voltammetry
Z_w: Warburg impendance

References

1. Huber GW, Chheda JN, Barrett CJ et al. Production of liquid alkanes by aqueous-phase processing of biomass-derived carbohydrates. Science. 2005;308(5727):1446-50. https://doi.org/10.1126/science.1111166
2. Lichtenthaler FW, Peters S. Comptes Rendus de l'Académie des Sciences and sugar chemistry. C R Chim. 2004;7(2):65-90. https://doi.org/10.1016/j.crci.2003.12.002
3. Song J, Fan H, Ma J et al. Conversion of glucose and cellulose into value-added products in water and ionic liquids. Green Chem. 2013;15(10):2619-35. https://doi.org/10.1039/c3gc41141a
4. Werpy T, Petersen G, editors. Top Value Added Chemicals from Biomass: Volume I - Results of Screening for Potential Candidates from Sugars and Synthesis Gas. Golden, CO: National Renewable Energy Laboratory; 2004. Report No.: NREL/TP-510-35523. https://doi.org/10.2172/15008859
5. Grand View Research. Glucaric Acid Market Size, Share & Trends Analysis Report By Application, By Region And Segment Forecasts, 2017-2025. San Francisco: Grand View Research; 2017. Available from: https://www.grandviewresearch.com/industry-analysis/glucaric-acid-market
6. Ragauskas AJ, Williams CK, Davison BH et al. The path forward for biofuels and biomaterials. Science. 2006;311(5760):484-89. https://doi.org/10.1126/science.1114736
7. Kiely DE, Chen L, Lin T. Synthetic applications of furan Diels-Alder chemistry. 1. Multifunctionalized building blocks for organic synthesis from carbohydrates. J Am Chem Soc. 1994;116(2):571-78. https://doi.org/10.1021/ja00081a026
8. Lichtenthaler FW. Carbohydrates as organic raw materials. In: Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. Weinheim: Wiley-VCH; 2010. p. 583-616. https://doi.org/10.1002/14356007.a05_345.pub2

9. Aury S, Rubini P, Gerardin C. In M, Lamartine R. A glucaric acid-based bolaamphiphile: synthesis and studies of its Langmuir and Langmuir-Blodgett films. Chem Eur J. 2004;10(8):2057-66. https://doi.org/10.1002/chem.200305351
10. Weuste B, Jansen AK, inventors; Akzo Nobel NV, assignee. Process for preparing glucaric acid. US patent 5,741,897. 1998 Apr 21.
11. Okada DR, Johnson BG, Liu Z et al. Manganese-enhanced magnetic resonance imaging (MEMRI): imaging of ion uptake in heart. J Nucl Med. 2004;45(4):655-64. https://doi.org/10.2967/jnumed.103.032201
12. Smith TN, Hash K, Davey CL et al. Modifications in the nitric acid oxidation of D-glucose. Carbohydr Res. 2012;350:6-13. https://doi.org/10.1016/j.carres.2011.12.022
13. Bin D, Wang H, Li J et al. Controllable oxidation of glucose to gluconic acid and glucaric acid through electrocatalysis. Electrochim Acta. 2014;130:170-8. https://doi.org/10.1016/j.electacta.2014.03.008
14. Yoshida J, Kataoka K, Horcajada R et al. Modern strategies in electroorganic synthesis. Chem Rev. 2008;108(7):2265-99. https://doi.org/10.1021/cr0680843
15. Frontana-Uribe BA, Little RD, Ibanez JG et al. Organic electrosynthesis: a promising green methodology in organic chemistry. Green Chem. 2010;12(12):2099-19. https://doi.org/10.1039/c0gc00382d
16. Bae IT, Yeager E, Xing X et al. *In situ* Raman spectroscopic study of SO42-adsorption on gold in acidic solutions. J Electroanalyt Chem. 1991;309(1-2):131-45. https://doi.org/10.1016/0022-0728(91)87009-Z
17. Ben Aoun S, Taniguchi I. Electrooxidation of sugars on gold electrode in alkaline media: effect of modification of gold electrode with upd of copper. Chem Lett. 2008;37(9):936-7. https://doi.org/10.1246/cl.2008.936
18. Yei LHE, Beden B, Lamy C. Anodic oxidation of glucose on gold and silver electrodes in alkaline medium. J Electroanalyt Chem. 1988;246(2):349-62. https://doi.org/10.1016/0022-0728(88)80177-3
19. Nikolaeva NN, Khazova OA, Vasil'ev YB. Kinetics and mechanism of glucose electrooxidation on different electrode-catalysts: Part I. Adsorption and oxidation on platinum. Elektrokhimiya. 1983;19(11):1476-81.
20. Nikolaeva NN, Khazova OA, Vasil'ev YB. Kinetics and mechanism of glucose electrooxidation on different electrode-catalysts: Part II. Effect of the nature of the electrode and the medium on the oxidation of glucose. Elektrokhimiya. 1980;16(9):1227-30.
21. Beden B, Largeaud F, Kokoh KB et al. Fourier transform infrared reflectance spectroscopic investigation of the electrocatalytic oxidation of D-glucose: identification of reactive intermediates and reaction products. Electrochim Acta. 1996;41(5):701-9. https://doi.org/10.1016/0013-4686(95)00456-4

22. Corrigan DS, Leung LWH, Weaver MJ. Relationships between surface coordination chemistry and surface-enhanced Raman scattering for pyridine and related adsorbates at silver electrodes. Analyt Chem. 1987;59(21):2252-56. https://doi.org/10.1021/ac00146a024
23. Pons S, Davidson T, Bewick A. Vibrational spectroscopy of the electrode-electrolyte interface. J Electroanalyt Chem. 1984;160(1):63-71. https://doi.org/10.1016/S0022-0728(84)80114-X
24. Rao JR, Richter GJ, Von Sturm F et al. The electrochemical behaviour of glucose at platinum electrodes. Bioelectrochem Bioenerg. 1976;3(1):139-50. https://doi.org/10.1016/0302-4598(76)85014-9
25. Gebhardt U, Luft G, Richter GJ et al. Bioelectrochemical fuel cell with glucose oxidase-catalyzed anodic glucose oxidation. Bioelectrochem Bioenerg. 1978;5(4):607-24. https://doi.org/10.1016/0302-4598(78)85042-6
26. Tominaga M, Nagashima M, Nishiyama K et al. Surface poisoning during electrocatalytic monosaccharide oxidation reactions at gold electrodes in alkaline medium. Electrochem Commun. 2007;9(8):1892-98. https://doi.org/10.1016/j.elecom.2007.04.026
27. Pasta M. Electrocatalytic oxidation of organic molecules: mechanistic aspects and analytical applications [dissertation]. Milano: Università degli Studi di Milano; 2010.
28. Tominaga M, Shimazoe T, Nagashima M et al. Electrocatalytic oxidation of glucose at gold nanoparticle-modified carbon electrodes in alkaline and neutral solutions. J Electroanal Chem. 2006;590(1):37-46. https://doi.org/10.1016/j.jelechem.2006.02.022
29. Tominaga M, Shimazoe T, Nagashima M et al. Electrocatalytic oxidation of glucose at gold-silver alloy, silver and gold nanoparticles in an alkaline solution. Electrochem Commun. 2005;7(2):189-93. https://doi.org/10.1016/j.elecom.2004.12.006
30. Zhou YG, Yang S, Qian QY et al. Gold nanoparticles integrated in a nanotube array for electrochemical detection of glucose. Electrochem Commun. 2009;11(1):216-19. https://doi.org/10.1016/j.elecom.2008.11.010