

Non-enzymatic detection of glucose in fruits using $\text{TiO}_2\text{-Mn}_3\text{O}_4$ hybrid nano interface

K. Jayanth Babu^{1,2,4} · Madhurantakam Sasya^{3,4} · Noel Nesakumar^{1,2,4} · Prabakaran Shankar^{1,2,4} · Manju Bhargavi Gumpu^{1,2,4} · Bhat Lakshmeshri Ramachandra^{1,2,4} · Arockia Jayalatha Kulandaisamy^{1,2,4} · John Bosco Balaguru Rayappan^{1,2,4}

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Abstract Consumption of fruits leads to increase in glucose level in blood for diabetic patients, which in turn leads to peripheral, vascular, ocular complications and cardiac diseases. In this context, a non-enzymatic hybrid glucose biosensor was fabricated for the first time to detect glucose by immobilizing titanium oxide–manganese oxide ($\text{TiO}_2\text{-Mn}_3\text{O}_4$) nanocomposite and chitosan membrane on to the surface of Pt working electrode ($\text{Pt/TiO}_2\text{-Mn}_3\text{O}_4/\text{chitosan}$). $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposite catalyzed the oxidation of glucose to gluconolactone in the absence of glucose oxidase enzyme with high electron transfer rate, good biocompatibility and large surface coverage. Electrochemical measurements revealed the excellent sensing response of the developed biosensor towards glucose with a high sensitivity of $7.073 \mu\text{A mM}^{-1}$, linearity of 0.01–0.1 mM, low detection limit of $0.01 \mu\text{M}$, reproducibility of 1.5% and stability of 98.8%. The electrochemical parameters estimated from the anodic process were subjected to linear regression models for the detection of unknown concentration of glucose in different fruit samples.

Keywords $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposites · Glucose · Linear sweep voltammetry · Sensor · Fruits

Introduction

Glucose, a monomer with the molecular weight of 180.16 g, is the most significant source of energy (Ameen et al. 2016) in living organisms. The blood glucose level in normal person ranges between 70 and 80 mg dL^{-1} (Gao et al. 2015; Heli and Amirizadeh 2016). The increase in the amount of glucose in blood results in type 1 and type 2 diabetes (Kim et al. 2015; Hsu et al. 2016; Li et al. 2016). The consumption of fruits raises blood glucose levels in diabetic patients, which in-turn leads to various complications including peripheral, vascular, ocular and cardiac diseases (Ameen et al. 2016; Chou et al. 2016). In this context, development of a biosensor for the quantification and detection of glucose in fruit samples will add a significant value to the field of biosensors.

Most of the electrochemical glucose biosensors are based on the glucose oxidase enzyme, which electrochemically catalyzes glucose into gluconic acid and hydrogen peroxide (H_2O_2) (Lu et al. 2016; Samdani et al. 2016; Vargas et al. 2016). The concentration of glucose in blood serum of patients with type I and type II diabetes can be calculated from the current density of enzymatically released H_2O_2 (Xia et al. 2014; Kim et al. 2015; Zhang et al. 2016). Compared to electrochemical glucose oxidase enzyme-based biosensors, non-enzymatic glucose biosensors based on metal oxide nanoparticles offer good stability against denaturation, easy to fabricate and facilitate effective glucose oxidase enzyme like catalysis over a wide temperature and pH ranges (Eguílaz et al. 2015; Heli and Amirizadeh 2016; Li et al. 2016). For these reasons, electrode materials showing enhanced catalytic activity are very important to attain extremely sensitive detection of glucose. Notably, $\text{NiCo}_2\text{O}_4\text{-polyaniline}$, Ag-CNT , Ni-CNT , graphene-CNT , $\text{graphene-polyppyrrrole}$, $\text{MnO}_2\text{-rGO}$,

✉ John Bosco Balaguru Rayappan
rjbosco@ece.sastra.edu

¹ Nanosensors Lab, SASTRA University, Thanjavur, Tamil Nadu 613 401, India
² School of Electrical & Electronics Engineering, SASTRA University, Thanjavur, Tamil Nadu 613 401, India
³ School of Chemical & Biotechnology, SASTRA University, Thanjavur, Tamil Nadu 613 401, India
⁴ Centre for Nanotechnology & Advanced Biomaterials, SASTRA University, Thanjavur, Tamil Nadu 613 401, India

NiO–CNT, TiO₂–MWCNT, CdTe–CdS, graphene–CdS, PtM–CNT, Ni–carbon nanofiber and Pt-polypyrrole have been used as nanohybrid materials in the determination of glucose (Govindhan et al. 2015; Baghayeri et al. 2016; Yu et al. 2016). Recently, nanostructured TiO₂ and Mn₃O₄ have attracted enormous research interest in the design of electrochemical biosensors owing to their large electroactive surface area, electrocatalytic activity and enhanced electron transfer rate (Hu et al. 2011; Reza et al. 2014). Reza et al. (2014) developed xanthine biosensor by immobilizing Mn₃O₄–chitosan nanocomposites on indium tin oxide substrate in which Mn₃O₄ nanoparticles exhibited good biocompatibility, high carrier mobility and efficient catalytic activity. Similarly, Wang et al. (2015) developed hydrogen peroxide (H₂O₂) biosensor by immobilizing Ti₃C₂ MXene nanocomposite on glassy carbon electrode in which TiO₂ enhanced the electron transfer rate of hemoglobin and facilitated the electrocatalysis of H₂O₂. To enhance the electrocatalysis of glucose in the absence of glucose oxidase enzyme, a hybrid interface of TiO₂ and Mn₃O₄ was preferred as an electrocatalyst. To the best of our knowledge, electrochemical glucose biosensor based on TiO₂ and Mn₃O₄ hybrid interface has been reported for the first time, that too for glucose level detection in fruits. Hence, in the present work, a non-enzymatic hybrid interfaced electrochemical biosensor was developed for glucose detection in different fruits by modifying platinum (Pt) electrode with titanium oxide (TiO₂)–manganese oxide (Mn₃O₄) nano interface and chitosan membrane.

Experimental

Materials

Mannitol, xylose, sucrose, starch, maltose, galactose and fructose were purchased from HiMedia Laboratories, India. TiO₂ and Mn₃O₄ nanomaterials were procured from Sigma-Aldrich, USA. Chemicals, namely glucose, lactic acid, potassium hydroxide, sodium hydroxide 0.5 wt% chitosan in 1% acetic acid (degree of deacetylation of 82.5%, molecular weight 140,000 g mol⁻¹), dibasic sodium phosphate dihydrate, ascorbic acid, and monobasic sodium phosphate monohydrate were purchased from Merck India Ltd., India. Cadmium acetate dihydrate was procured from Loba Chemie Pvt. Ltd., India. All other chemicals, namely cupric acetate, nickel chloride, urea were procured from Thermo Fisher Scientific Pvt. Ltd., India. Pt wire which was used as counter electrode (CHI115, 0.5 mm diameter), KCl saturated Ag/AgCl which was used as reference electrode (CHI111, 0.5 mm

diameter) and Pt used as working electrode (CHI102, 2 mm diameter) were procured from CH Instruments, Inc. Deionized water was used to prepare all solutions and reagents (AQUA Purifications Systems, India).

Fabrication of Pt/TiO₂–Mn₃O₄/chitosan modified working electrode

TiO₂ and Mn₃O₄ nanoparticles were taken in the ratio of 1:1 and ground into fine powder in a mortar and pestle. Later, a novel composite of TiO₂ and Mn₃O₄ nanoparticles was prepared by ultrasonically mixing 1:1 ratio of TiO₂ and Mn₃O₄ nanoparticles in 100 mL PBS containing 10 μL of chitosan for 1 h. The Pt/TiO₂–Mn₃O₄/chitosan modified bioelectrode was fabricated by drop casting 3 μL of this suspension on to the exposed surface of Pt working electrode.

Characterization techniques

The morphologies of TiO₂, Mn₃O₄ and TiO₂–Mn₃O₄ nanocomposites were observed using field emission scanning electron microscope (FE-SEM, Model JSM 6701F, JEOL, Japan). Image J 1.48q software was used to study the size distribution of TiO₂, Mn₃O₄ and TiO₂–Mn₃O₄ nanocomposites. All linear sweep voltammetric experiments were carried out at ambient temperature with a conventional three-electrode system comprising a Pt/TiO₂–Mn₃O₄/chitosan, a Pt wire and Ag/AgCl saturated in 0.1 M KCl was taken as working, counter and reference electrodes, respectively.

Preparation of real samples

For the estimation of glucose in banana (*Musa acuminata*), strawberry (*Fragaria ananassa*), apple (*Malus domestica*), grape (*Vitis vinifera*) and pomegranate (*Punica granatum*), samples are as follows: (1) initially, the flesh of fruit samples was ground using mortar and pestle. (2) 20 mg flesh of each sample was dispersed in 100 mL PBS solution and kept for centrifugation at 6000 rpm for 1 h. Later, 100 mL of deionized water was added to 0.4 mL of the supernatant for dilution. To investigate the performance of the Pt/TiO₂–Mn₃O₄/chitosan bioelectrode in fruit samples, Pt/TiO₂–Mn₃O₄/chitosan bioelectrode was exposed to recovery experiments by spiking various concentrations of glucose in 0.1 M PBS. Later, a calibration curve was plotted using the known concentration of glucose vs current density. Finally, the unknown glucose concentration in the flesh of fruit samples can be estimated by comparing the measured current density with the calibration curve.

Results and discussion

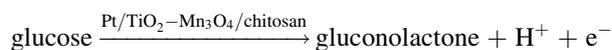
Morphological studies

The morphologies of TiO_2 , Mn_3O_4 and $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposites were characterized using FE-SEM (Fig. 1a–c). The spherical-like morphologies of TiO_2 and Mn_3O_4 nanoparticles were observed from FE-SEM studies. From the FE-SEM image of $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposite, it was confirmed that TiO_2 nanospheres were closely anchored and uniformly distributed on the surface of Mn_3O_4 nanospheres. The average diameters of TiO_2 , Mn_3O_4 and $\text{TiO}_2\text{-Mn}_3\text{O}_4$ were estimated to be 275 ± 4.7 , 325 ± 2.4 and 342 ± 3.7 nm, respectively.

Electrochemical characterization of various modified Pt electrodes

Linear sweep voltammetric response of bare Pt, Pt/ TiO_2 /chitosan, Pt/ Mn_3O_4 /chitosan and Pt/ $\text{TiO}_2\text{-Mn}_3\text{O}_4$ /chitosan electrodes in pH 7.4 PBS (0.1 M) having 0.01 mM glucose was executed at a scan rate of 0.1 V s^{-1} are shown in Fig. 2a. Comparison of electrochemical parameters for various modified Pt electrodes is shown in Table 1. The bare Pt electrode showed no anodic peak current. On adding Mn_3O_4 and TiO_2 nanospheres individually to the surface of Pt electrode, an anodic peak current was observed indicating oxidation of glucose to

gluconolactone. The Pt/ $\text{TiO}_2\text{-Mn}_3\text{O}_4$ /chitosan electrode exhibited increased peak current in the anodic process when compared with Pt/ Mn_3O_4 /chitosan and Pt/ TiO_2 /chitosan electrodes. This can be ascribed to the synergic effect of TiO_2 and Mn_3O_4 nanospheres in $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposite. It also depicted that the $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposite was well immobilized on to the surface of Platinum working electrode and provided necessary electron conduction pathways between Platinum working electrode and surface confined glucose biomolecules.



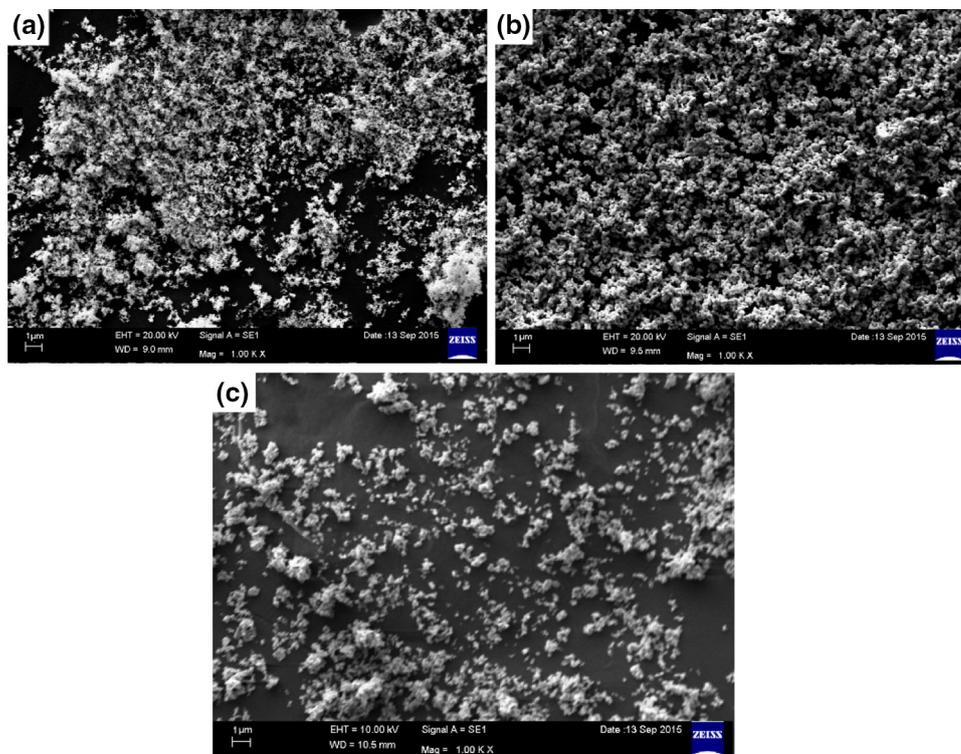
The anodic peak potential (E_{pa}) of Pt/ $\text{TiO}_2\text{-Mn}_3\text{O}_4$ /chitosan electrode (117 mV) was lesser than the E_{pa} values of Pt/ TiO_2 /chitosan (130 mV) and Pt/ Mn_3O_4 /chitosan (153 mV) electrodes. The lower E_{pa} value signified that the $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposites decreased the working potential needed for the oxidation of glucose to gluconolactone.

The electron transfer rate constant of different modified Pt electrodes was calculated using Eq. (1):

$$K_s = \frac{I_{\text{pa}}}{Q} \quad (1)$$

where I_{pa} is the anodic peak current and Q is the amount of charge consumed. The electron transfer rate constant of $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposites immobilized on the surface of Platinum working electrode in the anodic process was

Fig. 1 FE-SEM images of **a** TiO_2 , **b** Mn_3O_4 and **c** $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposites



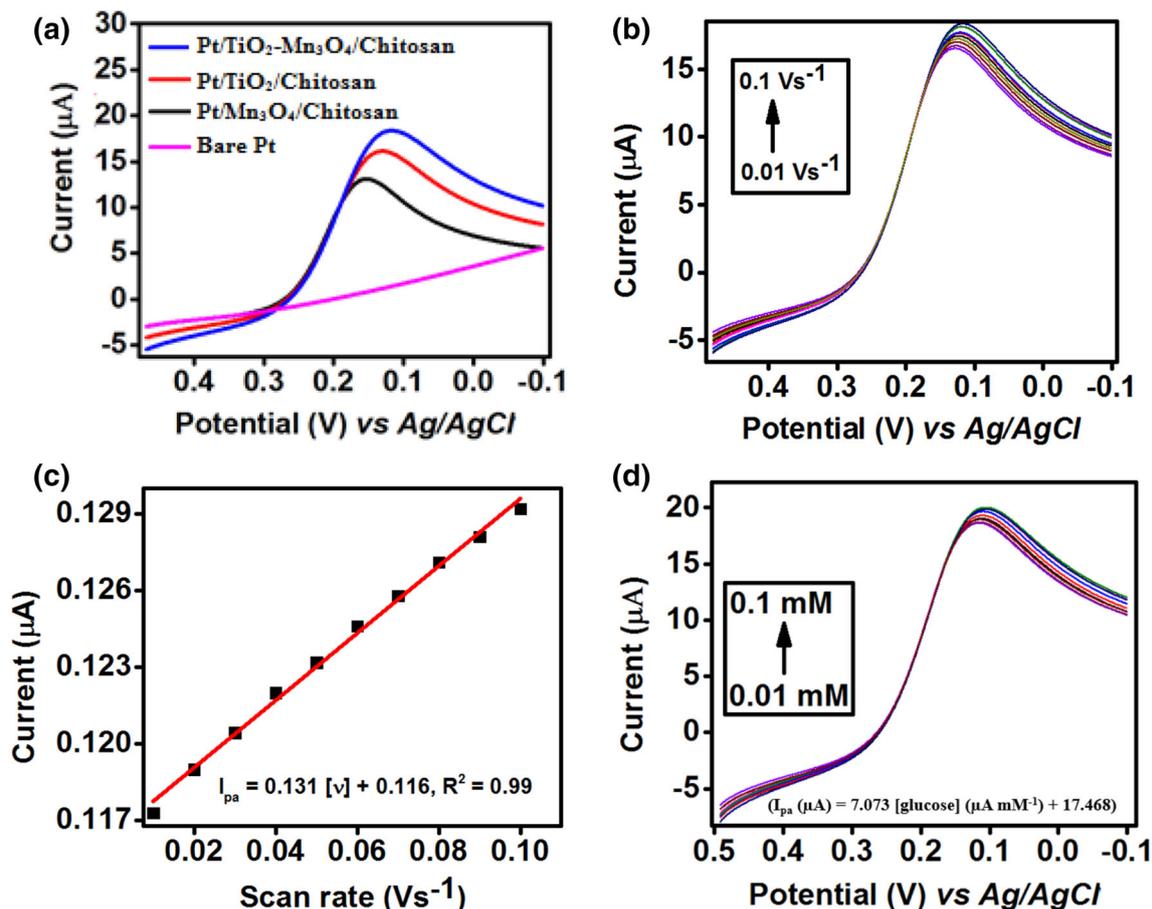


Fig. 2 **a** Linear sweep voltammetric response of various modified Pt electrodes in pH 7.4 PBS (0.1 M) containing 0.01 mM glucose at 0.1 V s⁻¹, **b** linear sweep voltammograms of Pt/TiO₂-Mn₃O₄/chitosan at different scan rates (0.01–0.1 V s⁻¹), **c** the plot of anodic peak current

vs scan rate and **d** linear sweep voltammetric curves of Pt/TiO₂-Mn₃O₄/chitosan electrode for increasing glucose concentration in PBS (pH 7.4, 0.1 M) at 0.1 V s⁻¹

Table 1 Comparison of electrochemical parameters for various modified Pt electrodes

Electrode	I_{pa} (μA)	E_{pa} (mV)	K_s (s ⁻¹)	Γ (×10 ⁻⁹ mol cm ⁻²)
Pt/Mn ₃ O ₄ /chitosan	13.4 ± 0.04	153 ± 0.02	1.4 ± 0.04	0.8 ± 0.05
Pt/TiO ₂ /chitosan	15.8 ± 0.08	130 ± 0.03	2.4 ± 0.02	1.0 ± 0.08
Pt/TiO ₂ -Mn ₃ O ₄ /chitosan	17.4 ± 0.01	117 ± 0.01	3.3 ± 0.05	1.5 ± 0.04

calculated as 3.35 s⁻¹, which was higher than the value reported for TiO₂ ($K_s = 2.42$ s⁻¹) and Mn₃O₄ nanospheres ($K_s = 1.44$ s⁻¹) immobilized on the surface of Platinum working electrode. The higher K_s value depicted the enhanced electron transfer rate by TiO₂-Mn₃O₄ nanocomposites during the anodic process.

The surface coverage of adsorbed electroactive glucose biomolecule on various modified Pt electrodes was calculated using Eq. (2):

$$\Gamma = \frac{I_p(\text{irrev.})2.718RT}{n\alpha n_a F^2 A\nu} \quad (2)$$

where n_a is the number of electrons involved in the charge transfer step, T is the room temperature, R is the gas constant, A is the area of Pt working electrode, Γ is the surface density of reactant species, $I_p(\text{irrev.})$ is the irreversible peak current, F is the Faraday's constant, n is the number of electrons in the redox reaction, α is the transfer coefficient and ν is the scan rate. The estimated surface coverage of electroactive glucose biomolecule on

Pt/TiO₂–Mn₃O₄/chitosan bioelectrode surface ($1.54 \times 10^{-1} \text{ mol cm}^{-2}$) was higher than those observed for other modified electrodes (Table 1). Owing to the enhanced electron transfer rate, high surface coverage of glucose and enhanced oxidation current, Pt/TiO₂–Mn₃O₄/chitosan electrode was chosen for further electrochemical analysis.

Effect of scan rate

The electrochemical response of Pt/TiO₂–Mn₃O₄/chitosan electrode in PBS (pH 7.4, 0.1 M) containing 0.01 mM glucose with the effect of scan rate is shown in Fig. 2b. From Fig. 2b, one can observe the applied scan rate-dependent anodic peak current. The anodic peak was shifted towards negative potential with the increased scan rate, which might be due to the electron transfer limitation of glucose at the surface of Pt/TiO₂–Mn₃O₄/chitosan electrode. The anodic current ($I_{\text{pa}} (\mu\text{A}) = 0.131 [v] (\mu\text{A}/\text{V s}^{-1}) + 0.116$) increased linearly with the scan rate from 0.01 to 0.1 V s⁻¹ (Fig. 2c). The linear dependency between scan rate and oxidation current indicated that electroactive glucose biomolecule adsorbed onto the surface of Pt/TiO₂–Mn₃O₄/chitosan electrode has experienced a surface confined electron transfer.

Effect of glucose

The electroanalytical performance of Pt/TiO₂–Mn₃O₄/chitosan electrode was investigated towards glucose by successive addition of glucose into electrochemical cell containing 0.1 M PBS (pH 7.4). The intensity of anodic current response increased with an increase of glucose concentration from 0.01 to 0.1 mM (Fig. 2d). The current response of the developed Pt/TiO₂–Mn₃O₄/chitosan electrode was linear ($I_{\text{pa}} (\mu\text{A}) = 7.073 [\text{glucose}] (\mu\text{A mM}^{-1}) + 17.468$) towards glucose in the concentration range between 0.01 and 0.1 mM with the correlation coefficient (r) of 0.99. Sensitivity and response time of the developed bioelectrode were estimated to be 7.073 $\mu\text{A mM}^{-1}$ and less than 5 s, respectively. The enhanced sensitivity can be attributed to the large specific surface area of the TiO₂–Mn₃O₄ nanocomposites, which allows the oxidation of substantial amount of glucose. The developed glucose biosensor displayed detection and quantification limits of 0.01 and 0.03 μM , respectively. The Michaelis–Menten constant estimated using Lineweaver–Burk plot was 32 μM , which indicated the good affinity between TiO₂–Mn₃O₄ nanocomposites and surface confined glucose biomolecules. From the Hill plot, the degree of cooperativity was calculated as 2.1. The estimated degree of cooperativity was greater than 1, which indicated that glucose bound on the surface of TiO₂–

Mn₃O₄ nanocomposites drives the other incoming glucose molecules to bind to the surface of the developed electrode.

Model fitting and validation

Table 2 shows the electrochemical parameters estimated from the anodic process for various glucose concentrations. Added glucose was considered as dependent variable and other electrochemical parameters as independent variables (K_s , I_{pa} , Γ , αn and Q). K_s vs [glucose], I_{pa} vs [glucose], Γ vs [glucose], αn vs [glucose] and Q vs [glucose] models exhibited linear behavior. Therefore, in this work, glucose quantification and detection in different fruit samples were performed using linear regression models.

Table 3 shows estimated parameters for various linear regression models. ANOVA results indicated the significance of the proposed linear regression models at 95% confidence limit. R^2 value obtained for the five linear regression models was greater than 99%, which proved the predictive ability of these five models. Root mean square error for cross validation (RMSECV), relative prediction error (RPE), % recovery and correlation (r) were compared for the predicted and added concentrations of glucose, to assess the accuracy of the five proposed linear regression models. Only the Q vs [glucose] model showed (RMSECV = 6.917×10^{-4} , $r = 0.99$ and % recovery = 99.283) best results in validation, whereas K_s vs [glucose], I_{pa} vs [glucose], Γ vs [glucose] and αn vs [glucose] models showed poor recovery, RMSECV and RPE. Based on the error analysis, Q vs [glucose] model was used for the estimation of glucose in fruit samples (Fig. 3a).

Precision and accuracy studies

The repeatability and reproducibility of Pt/TiO₂–Mn₃O₄/chitosan electrode were studied by measuring anodic current in 0.1 mM of glucose using eight different Pt/TiO₂–Mn₃O₄/chitosan bioelectrodes. The relative standard deviation (RSD) of linear sweep voltammetric responses for intra-assay and inter-assay analysis was 1.2 and 1.5%, respectively. The observed results showed that the embedding between chitosan and TiO₂–Mn₃O₄ nanocomposite was good. The glucose concentration \pm relative error values for the assay of 0.01, 0.05 and 0.1 mM glucose added into 0.1 M PBS (pH 7.4) were $0.01 \pm 1.2 \times 10^{-4}$, $0.05 \pm 1.1 \times 10^{-4}$ and $0.01 \pm 1.2 \times 10^{-4}$ mM for five measurements, suggesting good accuracy of the glucose biosensor.

Interferent and stability studies

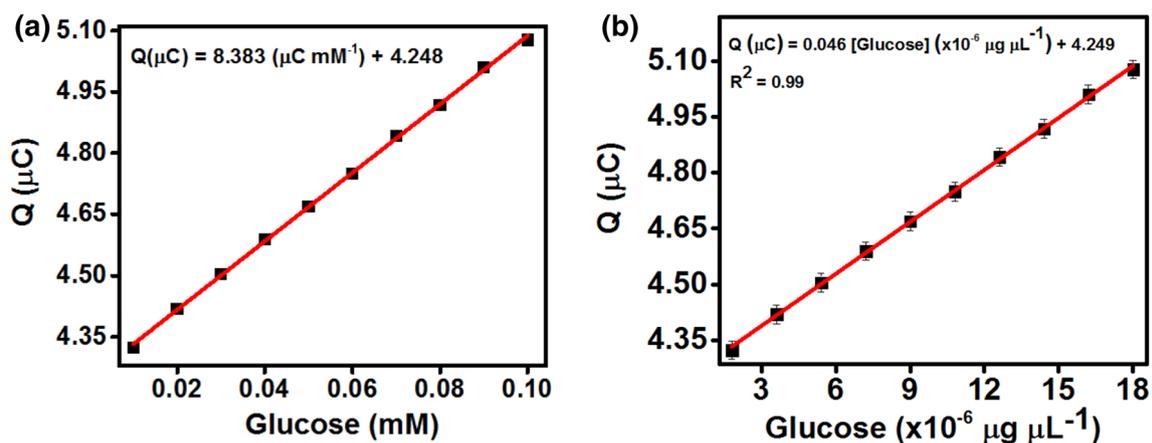
To investigate the interference of biomolecules with Pt/TiO₂–Mn₃O₄/chitosan electrode, interferents, namely mannitol,

Table 2 Electrochemical parameters estimated from the anodic process for various glucose concentrations

Glucose (mM)	I_{pa} (μA)	Q (μC)	αn	K_s (s^{-1})	Γ ($\times 10^{-9}$ mol cm^{-2})
0.01	17.5 ± 0.02	4.3 ± 0.02	0.5 ± 0.02	4.0 ± 0.05	7.0 ± 0.09
0.02	17.6 ± 0.01	4.4 ± 0.01	0.5 ± 0.03	3.9 ± 0.08	7.3 ± 0.01
0.03	17.6 ± 0.09	4.5 ± 0.01	0.5 ± 0.03	3.9 ± 0.03	7.4 ± 0.04
0.04	17.7 ± 0.06	4.5 ± 0.08	0.5 ± 0.04	3.8 ± 0.07	7.5 ± 0.07
0.05	17.8 ± 0.02	4.6 ± 0.06	0.5 ± 0.04	3.8 ± 0.01	7.7 ± 0.03
0.06	17.9 ± 0.01	4.7 ± 0.04	0.5 ± 0.05	3.7 ± 0.07	7.8 ± 0.08
0.07	17.9 ± 0.07	4.8 ± 0.04	0.5 ± 0.05	3.7 ± 0.01	8.0 ± 0.05
0.08	18.0 ± 0.03	4.9 ± 0.01	0.5 ± 0.06	3.6 ± 0.06	8.1 ± 0.08
0.09	18.0 ± 0.09	5.0 ± 0.01	0.5 ± 0.06	3.6 ± 0.01	8.3 ± 0.01
0.1	18.1 ± 0.06	5.0 ± 0.07	0.5 ± 0.07	3.5 ± 0.07	8.42 ± 0.02

Table 3 Parameters of linear response models for the determination of glucose in the anodic process

Parameters	I_{pa} vs glucose	Q vs glucose	αn vs glucose	K_s vs glucose	Γ vs glucose
Slope (μA)	7.073	8.383	0.468	-5.280	14.729
Intercept (μA)	17.468	4.249	0.523	4.089	6.989
R^2 adjusted	0.99	0.99	0.99	0.99	0.99
Range (mM)	0.01–0.1	0.01–0.1	0.01–0.1	0.01–0.1	0.01–0.1
Recovery (%)	98.560	99.283	98.897	97.698	98.322
RMSECV	0.001	6.917×10^{-4}	0.001	0.028	0.001
RPE	0.018	0.011	0.022	0.001	0.025
R	0.99	0.99	0.99	0.99	0.99

**Fig. 3** a and b Calibration curves of the immobilized $\text{TiO}_2\text{-Mn}_3\text{O}_4$ nanocomposites-based Pt electrode showing the amount of charge consumed at various glucose concentrations

xylose, sucrose, starch, maltose, galactose, fructose, lactic acid, ascorbic acid, urea, Ca^{2+} , Zn^{2+} , Cd^{2+} and Ni^{2+} at a relatively high concentration of 0.1 mM were added to electrochemical cell containing 0.1 mM glucose. No significant change in current response was observed ($I(\%) \leq 2.15$) in the presence of interferents like mannitol ($I(\%) = 0.25$), xylose ($I(\%) = 1.32$), sucrose ($I(\%) = 2.15$), starch ($I(\%) = 1.58$), maltose ($I(\%) = 1.76$), galactose ($I(\%) = 0.74$), fructose

($I(\%) = 2.12$), lactic acid ($I(\%) = 1.14$), ascorbic acid ($I(\%) = 1.48$), urea ($I(\%) = 0.58$), Ca^{2+} ($I(\%) = 2.31$), Zn^{2+} ($I(\%) = 2.67$), Cd^{2+} ($I(\%) = 1.41$) and Ni^{2+} ($I(\%) = 1.54$) indicating the ability of developed electrode to overcome tested interferents. The $\text{Pt/TiO}_2\text{-Mn}_3\text{O}_4/\text{chitosan}$ electrode was preserved in PBS (0.1 M, pH 7.4) at room temperature after each linear sweep voltammetric measurement. It was observed that the oxidation current response

decreased by about 1.2% after 10 days. These results indicated the good stability and reproducibility of the Pt/TiO₂–Mn₃O₄/chitosan electrode. It also indicated that the fabrication technique and embedding between TiO₂–Mn₃O₄ nanocomposite and chitosan were good.

Glucose detection in different fruit samples

The concentration of glucose in the flesh of fruit samples was estimated using the calibrated Q vs [glucose] model (Fig. 3b) and Eq. (3),

$$\text{glucose concentration} \left(\frac{\mu\text{g}}{\mu\text{L}} \right) = \frac{Q(\mu\text{C}) \times \text{dilution factor}}{\text{slope} \left(\frac{\mu\text{C}}{\mu\text{g}} \right) \times \text{volume of diluted glucose used for the assay}(\mu\text{L})} \quad (3)$$

To examine the potential application of the developed Pt/TiO₂–Mn₃O₄/chitosan electrode in the flesh of fruit samples, the extract of flesh of different fruits was diluted in the ratio of 1:10, 1:100 and 1:1000. From the calibration curve, the amount of glucose present in the banana, strawberry, apple, grape and pomegranate samples was found to be 0.02, 0.03, 0.02, 0.04 and 0.03 mM. The observed results demonstrated that the TiO₂–Mn₃O₄ nanocomposites can be used as a novel sensing material for quantification of glucose in different fruit samples.

Conclusion

In the present work, an enzyme-free glucose biosensor was fabricated by immobilizing TiO₂–Mn₃O₄ nanocomposite on the surface of Pt working electrode. The TiO₂–Mn₃O₄ nanocomposites catalyzed the oxidation of glucose to gluconolactone in the absence of glucose oxidase enzyme. The TiO₂–Mn₃O₄ enhanced the electron transfer rate between adsorbed glucose and Pt working electrode and, thereby, minimized the working potential needed for the oxidation of glucose to gluconolactone. The observed results are encouraging; hence, in future, this sensor can also be implemented for the detection and quantification of wide range of glucose in different food samples, packaged food, beverages and also in blood serum.

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