Chemical Papers
https://doi.org/10.1007/s11696-025-04325-9

ORIGINAL PAPER

Electrochemical study of tartrazine on a diethylcarbamazine modified carbon paste electrode surface for enhancing food safety

Kailash S. Chadchan[1] · **B. Mehboob Basha**[1] · **Amit B. Teradale**[2] · **Swastika N. Das**[1]

Received: 8 April 2025 / Accepted: 17 August 2025

Abstract

Tartrazine (TZN), a synthetic azo dye, is extensively used in the food and beverage industry and has raised concerns owing to its potential health risks, necessitating the development of rapid, sensitive, and cost-effective detection methods. This study explored the development and application of a polydiethylcarbamazine modified carbon paste electrode (poly-DECZ/MCPE) for the electrochemical detection of TZN, offering an opportunity for a highly selective and efficient approach for its quantification. The electrode was fabricated through the electropolymerisation of diethylcarbamazine (DECZ) in a 0.2 M phosphate buffer solution (PBS, pH 7.4) using cyclic voltammetry (CV). The electrochemical behaviour of TZN was systematically investigated by considering the influences of the scan rate, pH, and concentration variations. The effect of scan rate variation suggests that the oxidation process of TZN is mainly diffusion-controlled, ensuring a reliable signal response. The lower limit of detection (LOD) of TZN was found to be 0.17 µM and the limit of quantification (LOQ) was found to be 0.567 µM using the differential pulse voltammetry (DPV) technique. In addition, the sensor demonstrated excellent selectivity for accurately detecting TZN in the presence of interfering components. To demonstrate its practical applicability, the modified electrode was successfully employed in the analysis of real samples, such as soft drink formulations. Owing to its high sensitivity, selectivity, and stability, poly-DECZ/MCPE is a promising approach for revealing the presence of tartrazine in different food items.

Keywords Tartrazine · Diethylcarbamazine · Electrochemical sensor · Carbon paste electrode · Food safety · Differential pulse voltammetry · Cyclic voltammetry · Azo dye detection

Abbreviations

TZN	Tartrazine
DECZ	Diethylcarbamazine
BCPE	Bare carbon paste electrode
MCPE	Modified carbon paste electrode
PBS	Phosphate buffer solution
CV	Cyclic voltammetry
DPV	Differential pulse voltammetry
LOD	Limit of detection
SCE	Saturated calomel electrode
CHI-619E	CH instruments-619E electrochemical workstation

Introduction

Synthetic dyes have revolutionized various industries owing to their remarkable properties and versatility. These dyes are widely used in textiles, food technology, cosmetics, pharmaceuticals, and agricultural research (Ghalkhani et al. 2022; Karimi-Maleh et al. 2022; Forgacs et al. 2004). Their cost-effectiveness, ease of production, and stability make them indispensable for applications that require vibrant, long-lasting colouration. In the food industry, synthetic dyes are preferred over natural dyes because they exhibit high stability to light, oxygen, and pH changes, ensuring a uniform colour and brightness of the products. Furthermore, synthetic dyes minimize microbiological contamination, offer a wide range of shades, and incur relatively low production costs, making

---

✉ Swastika N. Das
drswastika@yahoo.com; chem.swastika@bldeacet.ac.in

[1] Department of Chemistry, BLDEA's V. P. Dr. P. G. Halakatti College of Engineering and Technology (Affiliated to Visvesvaraya Technological University, Belagavi), Vijayapur, Karnataka 586103, India

[2] PG Department of Chemistry, BLDEA's S.B. Arts and K.C.P. Science College, Vijayapur, Karnataka 586103, India

them a practical choice for large-scale use (He et al. 2018; Mehmandoust et al. 2021).

Among synthetic dyes, tartrazine (E102) stands out for its vivid yellow colour, cost-effectiveness, and durability. It is extensively used in food products, beverages, pharmaceuticals, and cosmetics. Despite its widespread utility, the presence of the azo (–N = N–) group in tartrazine has raised significant public health concerns. Reports have linked tartrazine exposure to adverse biological effects, including allergic reactions, behavioural changes, anxiety, and potential carcinogenicity (Moulya et al. 2023; Amin et al. 2010; Abd-Elhakim et al. 2019; Amchovaet al. 2015). Consequently, regulatory authorities such as the Food and Agriculture Organization/World Health Organization (FAO/WHO) and the European Food Safety Authority (EFSA) have set an Acceptable Daily Intake (ADI) of 7.5 mg/kg body weight/day (Abd-Elhakim et al. 2019; Amchova et al. 2015; Wu et al. 2021). Despite these measures, the persistent use of the dye, especially in developing nations, underscores the necessity for reliable detection methods to ensure compliance with safety standards. Considering both the potential health effects and the need for knowledge of food components, detection of synthetic dyes in foodstuffs and beverages is an important issue (Gan et al. 2013). Numerous analytical techniques have been developed to quantify tartrazine (TZN) in food matrices, including High-Performance Liquid Chromatography (HPLC) (Ma et al.2006; Alves et al. 2008; Bonan et al. 2013; Chen et al. 1998), thin-layer chromatography (TLC) (Soponar et al. 2008), and spectrophotometry (Al-Degs and El-Sheikh 2013; Sahraei et al. 2013; Berzas et al. 1999), fluorescence emission spectrometry (Huang et al. 2012; Zhao et al. 2023) and capillary electrophoresis (Lee et al. 2008). These methods are effective, but are time-consuming, expensive, and often require extensive sample preparation involving organic solvents and extraction steps.

This backdrop sets the stage for exploring advanced detection techniques, particularly electrochemical methods such as cyclic voltammetry (CV) and differential pulse voltammetry (DPV), which offer promising alternatives to traditional analytical approaches. These methods aim to enhance operational simplicity, rapid response, accuracy, sensitivity, and feasibility for on-site testing (Majidi et al. 2013; Teradale et al. 2023). Among the electrochemical techniques, carbon paste electrodes (CPEs) have emerged as versatile platforms because of their easy modification, low background current, fast regenerative surface, low ohmic resistance, and low cost (Darabi and Shabani-Nooshabadi 2021; Mahale et al. 2022; Ghoreishi et al. 2011; Georgescu et al. 2022).

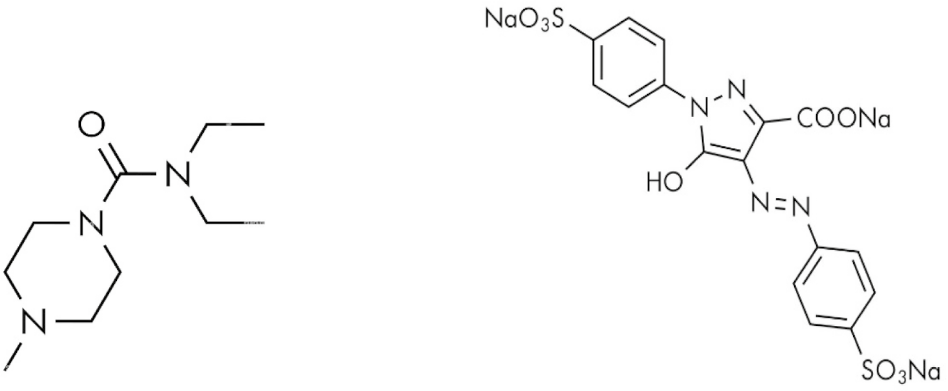
Recently, there has been a surge in the development of modified carbon-based electrodes for tartrazine sensing. For example, the use of a Sr-doped ZnO-modified carbon paste electrode with an enhanced electrochemical response has been reported for the detection of tartrazine in sports drinks, achieving high selectivity in complex matrices (Dai et al. 2024). Similarly, an $Ag\text{-}La(OH)_3@Dy_2O_3$ composite was employed on laser-induced graphene for simultaneous detection of bisphenol A and tartrazine, demonstrating excellent electrocatalytic behaviour (Vignesh et al. 2024). Nanoengineered yttrium iron oxide on functionalized carbon nanofibers was developed for precise azo dye detection, showing potential for multiplexed and real-time food safety applications (Senthilkumar et al. 2025). A comprehensive review summarizes emerging strategies using polymer films, doped oxides, and hybrid nanocomposites to improve the sensitivity, limit of detection (LOD), and anti-interference properties (Anaji et al.2024).

While these methods demonstrate progress, they often rely on multistep fabrication, expensive nanomaterials, or less accessible composites. In this context, our study introduces a novel, cost-effective electrochemical sensor that uses a polymerized diethylcarbamazine (poly-DECZ) film on a carbon paste electrode (CPE) to detect tartrazine. It has been reported that diethylcarbamazine citrate can boost the activation of voltage-activated potassium (SLO-1) currents in certain parasites, indirectly amplifying the efficacy of anthelmintic drugs (Buxton et al. 2014). Modification of the carbon paste electrode was achieved through electropolymerisation, which enhanced the surface area and conductivity of the electrode. Although no theoretical modelling was employed to confirm the interaction mechanism, it is presumed that functional groups such as tertiary amines and carbamate groups of DECZ may enable electrocatalytic enhancement through hydrogen bonding, π–π stacking, and electrostatic interactions with the sulfonate and azo groups of tartrazine. These interactions between the functional groups may improve the preconcentration of TZN near the electrode surface and facilitate its oxidation during voltammetric analysis. The approach of this study was to develop a simple, sensitive, and selective electrochemical sensor utilizing the interactions between TZN and functional groups present in the DECZ structures (Fig. 1), leading to an innovative and practical solution to ensure food safety and compliance with regulatory standards.

Experimental

Apparatus

An advanced CH Instruments electrochemical workstation (CHI-619E) was used for the electrochemical experiments. The system incorporated a conventional ideal three-electrode arrangement comprising a platinum wire as the counter electrode, a saturated calomel electrode (SCE) as the reference electrode, and either a bare carbon paste electrode (BCPE)



Diethyl Carbamazine (DECZ)

Tartrazine (TZN)

Fig. 1 Chemical structures of DECZ (left) and TZN (right)

or a poly DECZ-modified carbon paste electrode (poly-DECZ/MCPE) as the working electrode. This configuration formed the electrochemical cell.

Reagents and materials

Tartrazine (TZN) and diethyl carbamazine (DECZ) were acquired from Sigma-Aldrich Ltd. Stock solutions of TZN and DECZ ($C_{\mathrm{TZN}} = 0.001$ M and $C_{\mathrm{DECZ}} = 0.01$ M) were prepared by dissolving the calculated amounts in double-distilled water. The electrochemical study was performed in 0.2 M phosphate buffer solution (PBS). The desired pH was achieved by adjusting the quantities of the $NaH_2PO_4 \cdot H_2O$ and Na_2HPO_4 solutions. All experiments were performed at room temperature, and freshly prepared solutions were used to maintain consistency and reliability.

Fabrication of working electrodes (BCPE and MCPE)

Graphite powder was combined with silicone oil in a 70:30 weight ratio to prepare carbon paste electrodes. The blending process continued for approximately an hour until a consistent paste was obtained. This mixture was subsequently placed into a Teflon tube with an inner diameter of 3 mm to ensure proper contact with the electrical connector. Electropolymerization of DECZ on a bare carbon paste electrode (BCPE) surface was conducted through cyclic voltammetry, as previously described (Chadchan et al. 2022; Teradale et al. 2017). Following polymerization, the electrode was carefully rinsed with double-distilled water to eliminate any residual unreacted material. The electrode surface was renewed before each use following the same preparation procedure to maintain measurement consistency.

Interference study

The electrocatalytic response of 0.1 mM TZN in 0.2 M Phosphate Buffer Solution (pH 7.4) was investigated in the presence of various potentially interfering species commonly found in food matrices, including $CaCl_2$, KCl, $MgCl_2$, NH_4Cl, urea, and Zn $(NO_3)_2$. Each interferent was tested at a concentration ten times higher than that of TZN. For each test, the interferent solution was added to the TZN solution, and CV measurements were performed under identical conditions. The anodic peak current and potential of TZN in the absence and presence of each interferent were compared. The percentage change in peak potential values was calculated to assess tolerance levels.

Real sample analysis

The practical applicability of the fabricated poly(diethylcarbamazine)-modified carbon paste electrode (poly-DECZ/MCPE) was evaluated by determining tartrazine (TZN) levels in a locally available soft drink sample. The sample was first degassed using ultrasonication for approximately 10 min to remove dissolved gases. The sample was then diluted by mixing 10 mL of the sample solution with 90 mL of 0.2 M phosphate buffer solution (pH 7.4) to bring the TZN concentration within the working range of the sensor. This stock solution was tested by adding TZN in the concentration range of 0.1–0.9 mM using the CV technique. The recovery percentage was calculated to assess the accuracy and reliability of this method.

Result and discussion

Electro polymerization of DECZ on CPE

The fabrication of the poly-DECZ-modified carbon paste electrode (CPE) was achieved through electro-polymerization via cyclic voltammetry. This process involved repeated potential cycling between – 0.4 V and 1.4 V at a scan rate of 0.1 Vs^{-1} in 0.2 M phosphate-buffered saline at pH 7.4. Polymerization was continued until a consistent cyclic voltammogram was obtained, as shown in Fig. 2A. The gradual increase in the anodic peak currents indicated the development of an electroactive polymer layer on the BCPE surface. The thickness of the polymer coating was adjusted by changing the number of potential cycles applied to the bare CPE, which ranged from 10 to 30. Figure 2B shows that the anodic peak current response was Maximum at 25 cycles. Surpassing 25 cycles resulted in a reduction in peak currents, implying that an overly thick film hindered electron transfer and reduced the oxidation process (Teradale et al. 2024). Therefore, 25 cycles were chosen for the electropolymerisation of DECZ to modify the BCPE.

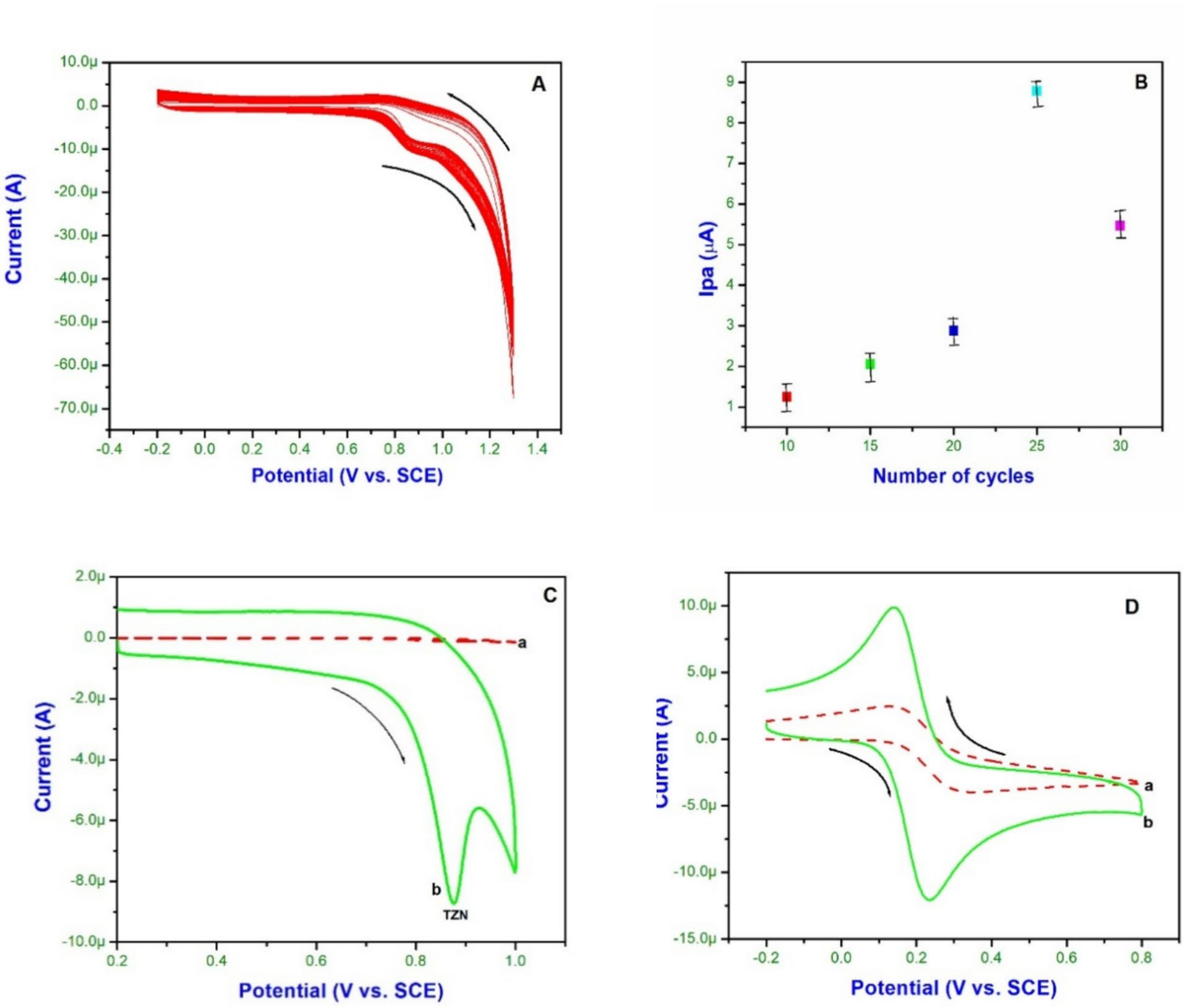


Fig. 2 **A** Electropolymerisation of poly-DECZ on CPE via cyclic voltammetry in 1.0 mM DECZ solution in 0.2 M PBS (pH 7.4) over 25 cycles at a 0.1 Vs^{-1} scan rate. **B** Plot of the anodic peak current of TZN and number of polymerization cycles of DECZ on BCPE. **C** Comparative anodic peak currents of 0.1 mM TZN at the unmodified CPE (curve a) and poly-DECZ/MCPE (curve b) in 0.2 M PBS (pH 7.4) at a scan rate of 0.05 Vs^{-1}. **D** Cyclic voltammograms of 1.0 mM potassium ferrocyanide with bare CPE (curve a) and poly-DECZ/MCPE (curve b) were recorded vs. SCE at a scan rate of 0.05 Vs.$^{-1}$

Electrochemical analysis of TZN at poly-DECZ/MCPE:

The electrochemical behaviour of 0.1 mM TZN was examined using the CV technique at both the bare carbon paste electrode (BCPE) and poly-DECZ/MCPE in 0.2 M PBS at pH 7.4 (Fig. 2C)**.** The BCPE (curve a) exhibited a weak oxidation response for TZN, with an oxidation peak at 0.826 V (vs. SCE). In contrast, poly-DECZ/MCPE (curve b) displays a notable increase in the current response, with oxidation occurring at a slightly lower potential of 0.786 V (vs. SCE) under the same conditions. These results indicate that poly-DECZ/MCPE facilitated the electrochemical oxidation of TZN.

Electrochemical behaviour of the standard potassium ferrocyanide system on the poly-DECZ/MCPE surface

A 0.1 mM potassium ferrocyanide solution in 1.0 M KCl was utilised to assess the electrochemical properties of the poly-DECZ/MCPE. The electro-oxidation of potassium ferrocyanide was evaluated at both BCPE (curve a) and poly-DECZ/MCPE (curve b), as depicted in Fig. 2D**.** The scan rate for all measurements was set at 0.05 Vs^{-1}.

The unmodified CPE exhibited relatively weak redox peak currents. In contrast, the poly-DECZ/MCPE exhibited markedly stronger redox peak currents under identical experimental conditions. These results indicate significant changes in the surface morphology of poly-DECZ/MCPE and confirm its electrocatalytic properties. The Randles–Sevcik Eq. (1) was employed to calculate the total active surface area of the MCPE available for the reaction of the electroactive species in the solution (Teradale et al. 2024). The electroactive surface area of poly-DECZ/MCPE was found to be 0.02436 cm^2, which is larger than that of the unmodified CPE (0.01537 cm^2).

$$Ip = 2.69 \times 105\, n^{3}/^{2} A\, D^{1/2} C_o \tag{1}$$

Influence of variation in scan rate on peak current of TZN

This study examined the effect of scan rate variation in the range of 0.04–0.40 Vs^{-1} on the oxidation of 0.1 mM TZN at the poly-DECZ/MCPE interface. As shown in Fig. 3A**,** increasing the scan rate resulted in a proportional increase in the anodic peak current. The absence of a cathodic peak in the cyclic voltammograms and the shift in the oxidation potential of TZN to more positive values with increasing scan rates indicated irreversible oxidation. The dependence of the peak current on the square root of the scan rate ($\upsilon^{1/2}$) and scan rate (υ) is shown in Fig. 3B and C, respectively. The plot of $\upsilon^{1/2}$ vs. current (Ipa) yielded good linearity which is expressed by Eq. (2):

$$Ip_{a},_{\mathrm{TZN}}\,(\mu\mathrm{A}) = 19.29\,\upsilon^{1/2} - 1.5119 \quad (r^2 = 0.9974) \tag{2}$$

These results indicate that the oxidation of TZN at the electrode is diffusion-controlled, which is in agreement with previously reported observations (Karim-Nezhad et al. 2017). The plot of υ vs. current (Ipa) yielded a graph with lower linearity, curved towards the x-axis, indicating the partial adsorption of the analyte on the sensor surface. This result is similar to that of a previous report (Tahtaisleyen et al. 2020). Based on the plot of Epa vs. log υ (Fig. 3D), an oxidation mechanism is proposed in Scheme 1**,** which is consistent with the previously reported mechanisms (He et al. 2018; Al-Refai et al. 2021; Ziyatdinova and Budnikov 2022). The number of electrons involved in the reaction can be calculated using the Laviron's equation for irreversible reactions (Moulya 2023; Al-Refai et al. 2021; Laviron 1974). The oxidation of TZN is commonly reported to be a one-electron, one-proton irreversible process, although the apparent electron transfer number may vary depending on the electrode surface properties and catalytic effects.

Influence of pH variation on TZN oxidation

The pH of an aqueous solution significantly influences its electrochemical behaviour, particularly affecting the peak potential and peak current. The effect of pH ranging from 5.5 to 8.0 on the electro-oxidation of 0.1 mM TZN at the poly-DECZ/MCPE was examined through cyclic voltammetry (Fig. 4A). An increase in the peak current was observed in the pH range of 5.5–6.5, and with a further increase in pH from 6.5 to 8.0, a gradual decrease in the peak current was observed. An increase in pH resulted in a negative shift in the peak potential, as illustrated in Fig. 4A, indicating the association of protons with the oxidation process of TZN (Teradale et al. 2024; Karim-Nezhad et al.2017). A linear relationship (Fig. 4B) was observed between Epa and pH, as expressed in Eq. (3).

$$\mathrm{Epa}\,(\mathrm{V}) = 1.136 - 0.03407(\mathrm{pH}) \tag{3}$$

Effect of TZN concentration on poly-DECZ/MCPE

The electrocatalytic oxidation of TZN at the poly DECZ/MCPE electrode was investigated using differential pulse voltammetry (DPV). TZN concentrations were varied in the range of 0.05–0.5 mM at a solution pH of 7.4. A progressive increase in the anodic peak current (Ipa) was

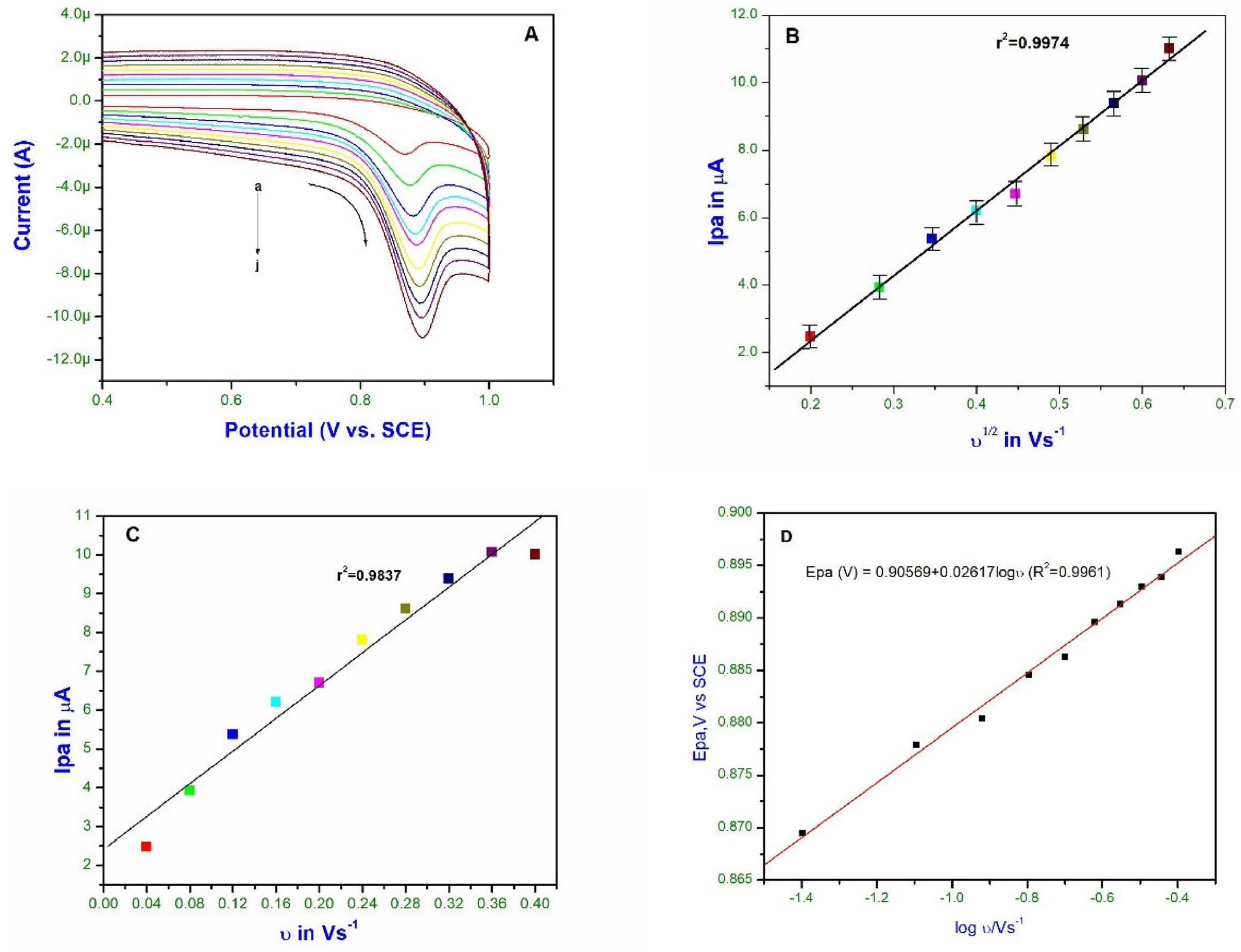
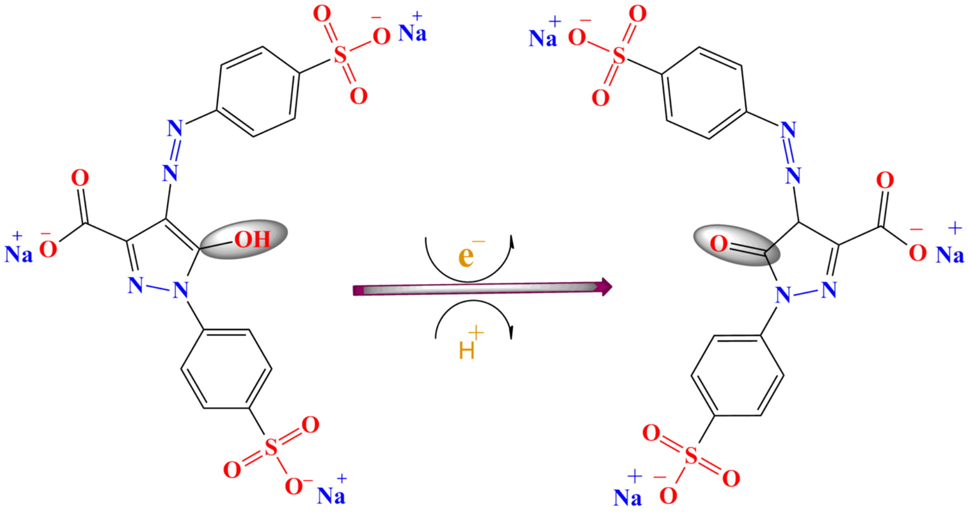


Fig. 3 **A** The CV curves for 0.1 mM TZN at poly-DECZ/MCPE at different scan rates (a-j; 0.04 Vs^{-1}to 0.40 Vs^{-1}at an increment of 0.04 Vs^{-1}). **B** Plot of Ipa versus **υ$^{1/2}$** for the TZN. **C** Plot of Ipa versus υ for the TZN. **D** Plot of Epa versus log υ

Scheme 1 Proposed electro-oxidation mechanism of TZN in poly-DECZ/MCPE



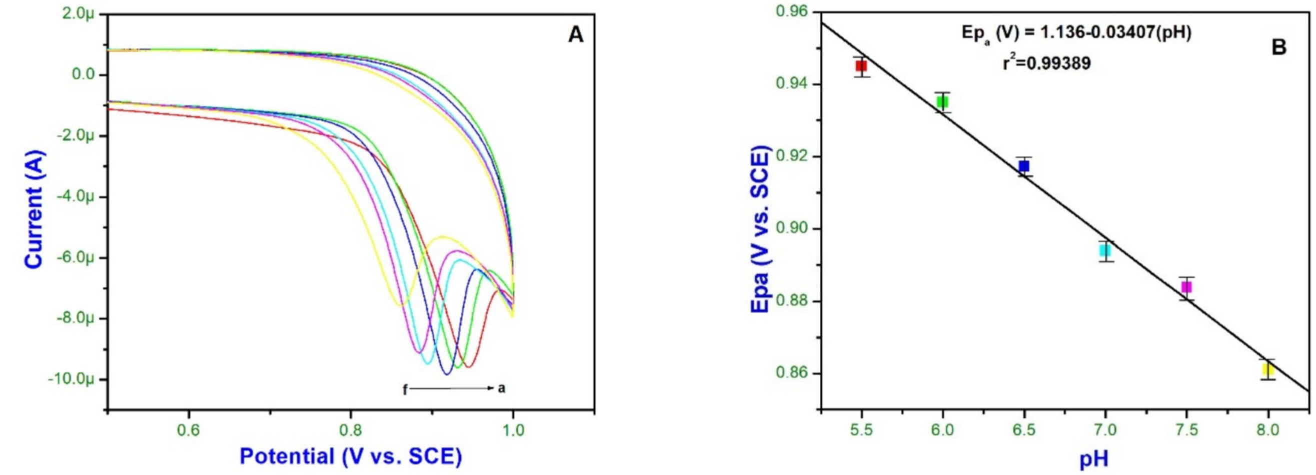


Fig. 4 **A** Cyclic voltammograms of TZN at the poly-DECZ/MCPE in 0.2 M PBS across varying pH levels (a-f: 5.5–8.0; a- 5.5, b-6.0, c-6.5, d-7.0, e-7.5, f-8.0) at a scan rate of 0.05 Vs^{-1}. **B** Plot of anodic peak potential (Epa) as a function of pH

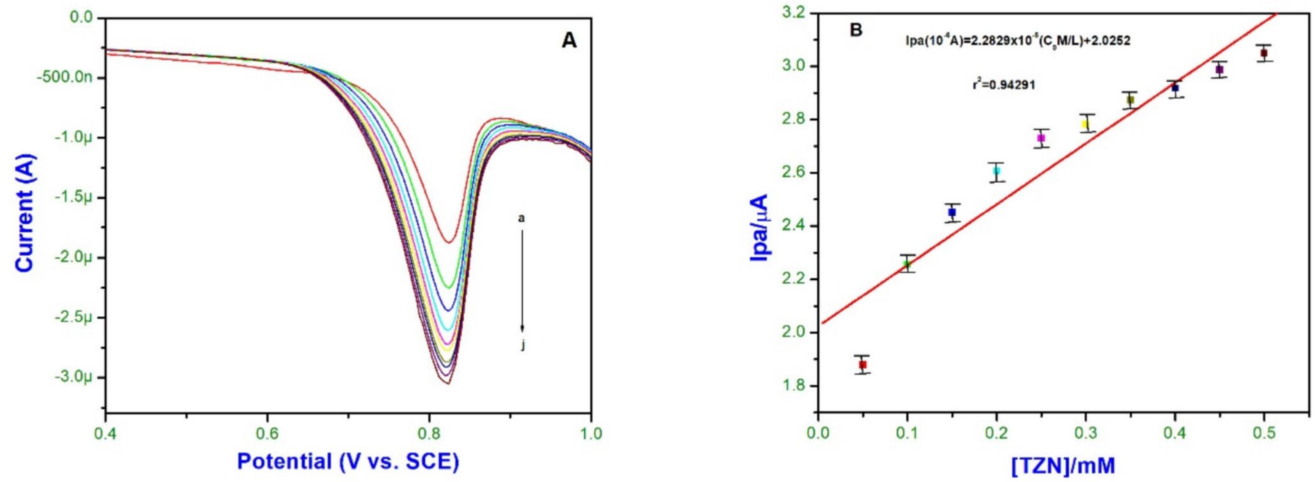


Fig. 5 **A** Differential pulse voltammograms (DPV) showing the effect of increasing TZN concentration (a = 0.05 mM to j = 0.5 mM) on the peak current**. B** Calibration plot of the anodic peak current (Ipa) as a function of TZN concentration

Table 1 LOD values for TZN at different electrode surfaces using different classical methods

Modified electrode	LOD(μM)	Technique	Citation
IL/AuTiO$_2$/GO/CPE	0.33	DPV	Georgescu et al. 2022
PTH/MWCNT	0.30	SWV	Al-Refai et al. 2021
CBPCE	0.02	LSV	Lipskikhet al. 2020
CHIT/GO/MWCNTs/AuNPs/GCE	1.45	CV	Rovina et al. 2019
(PEDOT@TbHCF)	0.03	DPV	Sakthivel et al. 2018
g-C$_3$N$_4$/graphite pencil electrode	0.21	DPV	Karimi et al. 2018
MWCNT/Pyrolyte/Graphite electrode	0.5	CV	Song et al. 2012
Cu/Fe/NiO/MCPE	0.01	CV	Kumari et al. 2024
ZnO/Cysteic acid/GCE	0.01	DPV	Dorraji and Jalali 2017
GO/MWCNT electrode	0.01	CV	Qiu et al. 2016
β-CD-PDDA-Gr GCE	0.014	DPV	Yeet al. 2013
PLA-ERGO/GCE	0.25	DPV	Wang 2020
poly-DECZ/MCPE	**0.17**	**DPV**	**Present work**

The bold signifies highlighting the present work

Table 2 Effect of different interfering molecules on TZN signals

Interferents	Concentration (mM)	Signal change (%) (ΔEpa)
Calcium chloride	1.0	0.0%
Potassium chloride	1.0	0.48%
Magnesium chloride	1.0	0.38%
Ammonium chloride	1.0	0.29%
Urea	1.0	0.18%
Zinc Nitrate	1.0	0.29%

observed with an increase in TZN concentration (Fig. 5A). A linear correlation (r2 = 0.94291) between Ipa and TZN concentration was established, as illustrated in Fig. 5B, yielding regression Eq. (4). It should be noted that the relatively high intercept observed in the linear regression (Eq. 4) arises from the non-faradaic or background current contributions introduced by surface polymer modification. Despite this, the bare carbon paste electrode (CPE) inherently provides a low background current compared with other electrode materials, which remains an advantage for sensitive electrochemical measurements.

$$\mathrm{Ipa}\left(10^{-6}\mathrm{A}\right) = 2.2829 \times 10^{-6}(\mathrm{Co}\ \mu\mathrm{M/L}) + 2.0252 \tag{4}$$

The limit of detection (LOD) and limit of quantification (LOQ) values were determined to be 0.17 µM and 0.567 µM, respectively, for TZN at poly-DECZ/MCPE surface. A comparative analysis of the LOD values for TZN on the different modified electrode surfaces is presented in Table 1

Interference study

The effect of the coexisting species on the electrochemical detection of TZN was systematically investigated, as described in Sect. "Interference study". It has been observed that the peak potential values of TZN remained consistent (Table 2) despite the presence of the interfering species. The peak current values for 0.1 mM TZN in the presence of different interferents are summarised in Fig. 6. Although the peak potential remained unaffected by interfering species (Table 2), the anodic peak current increased notably in some cases (Figs. 6 and 7). This may be due to ionic strength effects or the enhanced conductivity at the electrode surface. Importantly, this did not significantly compromise

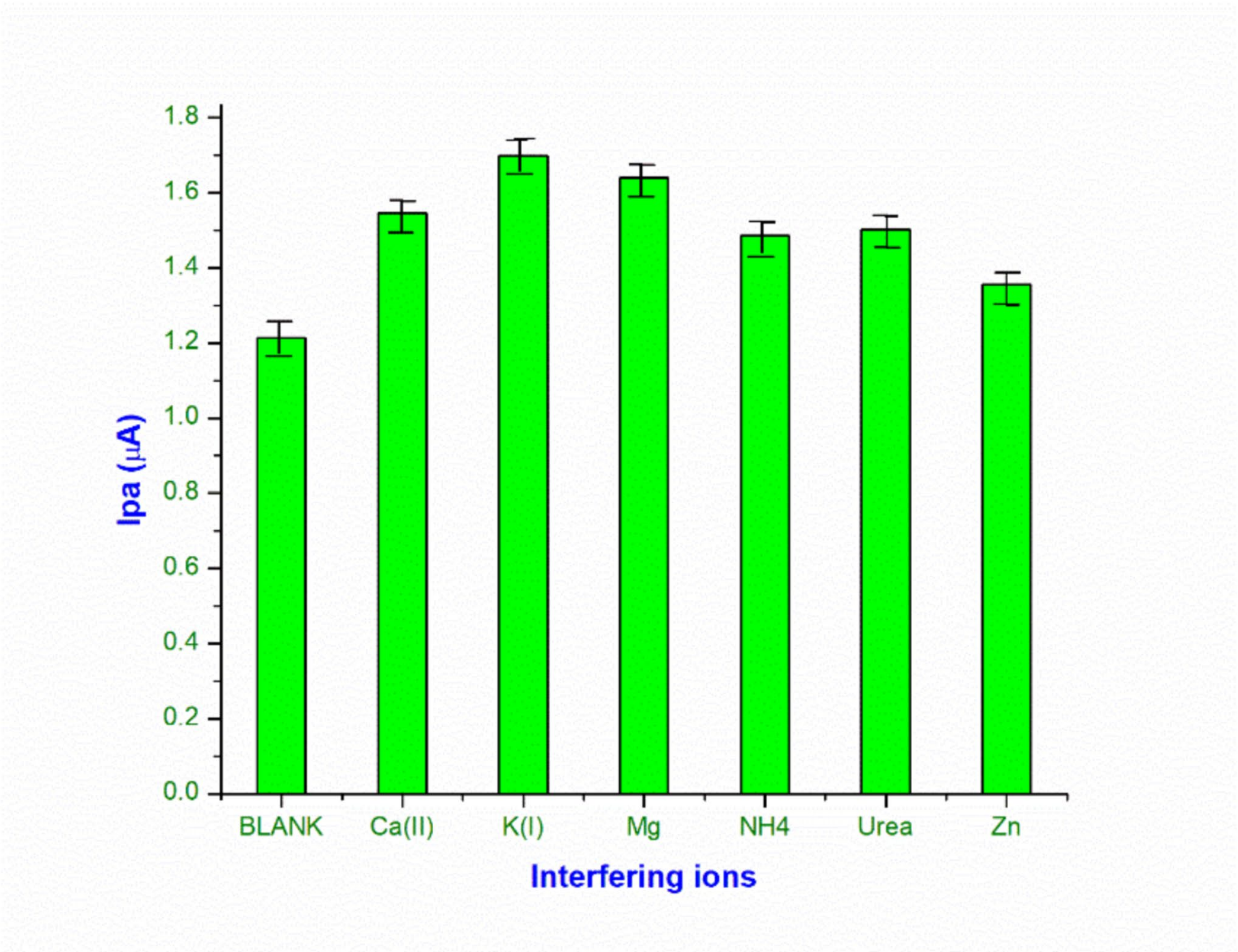


Fig. 6 Variation in Ipa with interfering ions in comparison with the blank

the quantification in real samples, as evidenced by the high recovery rates (Table 3).

Real sample analysis

TZN levels in a soft drink sample were measured using the standard addition method, as described in Sect. "Real sample analysis". Table 3 presents the findings of this study. The accuracy of the method was evaluated via a recovery test in which known quantities of tartrazine were added to the samples. The recovery rates, which ranged from 99.8 to 103%, confirmed the reliability of this method.

Conclusion

In this study, we developed and evaluated a novel electrochemical sensor based on a polydiethylcarbamazine-modified carbon-paste electrode (poly-DECZ/MCPE) for

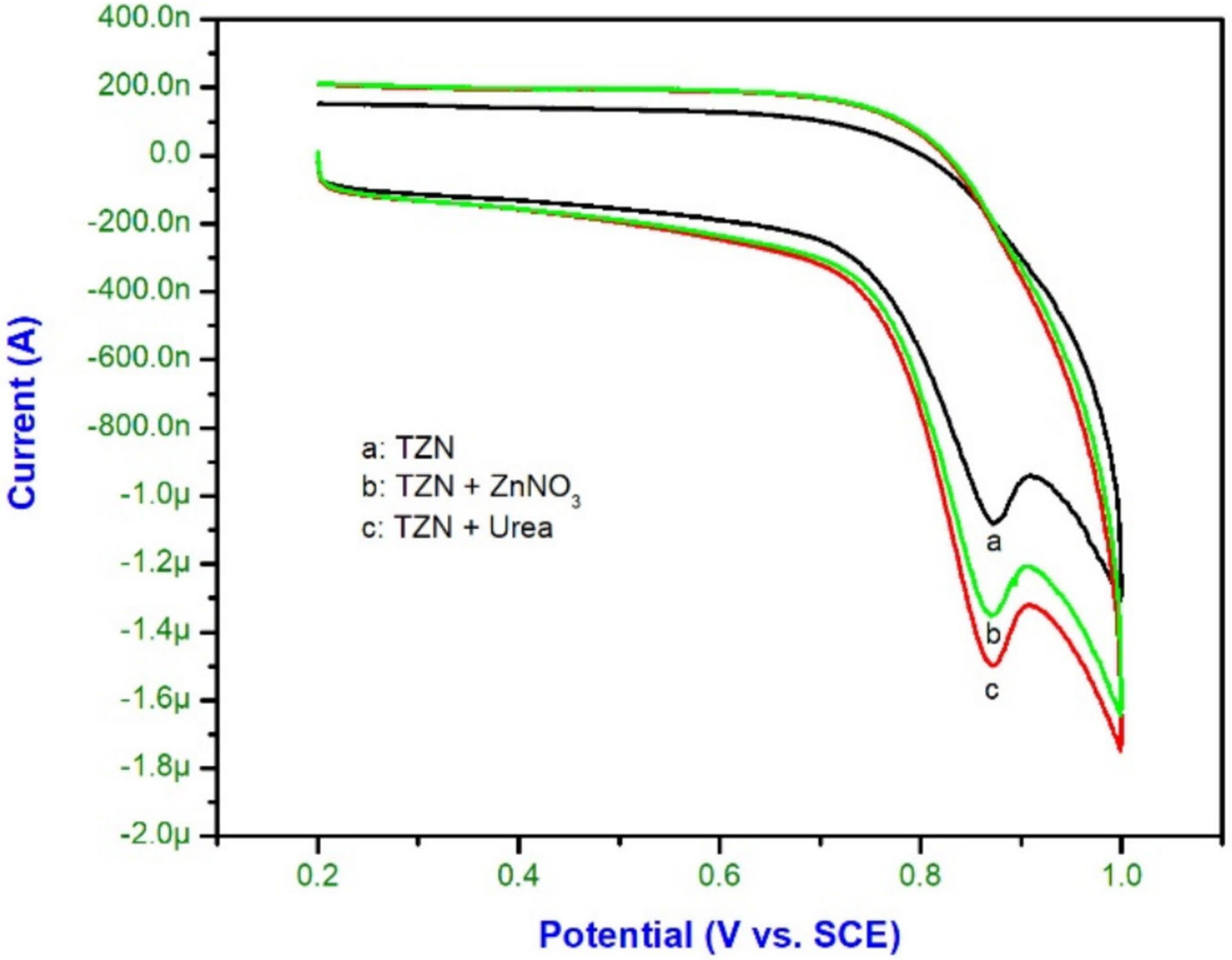


Fig. 7 Cyclic voltammograms of **a** TZN in the absence of interferents, **b** TZN in the presence of Zn(NO3)2, and **c** TZN in the presence of urea

the detection of tartrazine (TZN) at a physiological pH of 7.4. The sensor exhibited electrocatalytic activity with an improved peak current response and reduced oxidation potential compared to the bare electrode. The electrochemical oxidation of TZN is affected by crucial factors such as pH, TZN concentration, and scan rate. The oxidation process was found to be irreversible and primarily diffusion-controlled, with partial adsorption characteristics. Differential pulse voltammetry (DPV) revealed a low limit of detection (LOD) of 0.17 μM and a limit of quantification (LOQ) of 0.567 μM, underscoring the sensor's high sensitivity.

Table 3 Determination of TZN content in soft drink samples

Sample	TZN added (mM)	Detected (mM)	Recovery (%)	SD ± RSD (%)
Soft drink	0.1	0.103	103	0.0022 ± 0.0015
	0.3	0.303	101	0.0212 ± 0.0151
	0.5	0.499	99.8	0.0070 ± 0.0050
	0.7	0.712	101.6	0.0819 ± 0.0585
	0.9	0.904	100.4	0.0311 ± 0.0222

The sensor demonstrated strong selectivity and maintained consistent electrochemical responses even in the presence of common interfering species at tenfold concentrations. Real sample analysis in commercial soft drink yielded high recovery rates (99.8–103%), confirming the method's accuracy and practical applicability. Furthermore, the electrode fabrication process is straightforward, cost-effective, and reproducible, making it suitable for the routine monitoring of synthetic dyes in food matrices.

Overall, the poly-DECZ/MCPE sensor offers a promising, low-cost, and efficient platform for selective detection of tartrazine in real-world samples, with potential applications in food safety regulation, quality control, and environmental monitoring. Furthermore, this work keeps the futuristic scope open, wherein diethylcarbamazine can be tested to develop electrochemical sensors to detect multiple analytes.

Authors contribution Kailash S. Chadchan: Methodology for the experiment, carried out experiment, Data analysis, manuscript preparation. B. Mehaboob Basha: Review of literature, methodology for the experiment, carried out experiment. Amit B. Teradale: Conceptualization, investigation, data analysis, manuscript preparation. Swastika. N. Das: Conceptualization, resources, supervision of the work, writing original draft, editing and correspondence.

Declarations

Conflict of interest The authors declare no conflicts of interest.

References

Abd-Elhakim YM, Moustafa GG, Hashem MM, Ali HA, Abo-El-Sooud K, El-Metwally AE (2019) Influence of the long-term exposure to tartrazine and chlorophyll on the fibrogenic signaling pathway in liver and kidney of rats: The expression patterns of collagen 1α, TGFβ-1, fibronectin, and caspase-3 genes. Environ Sci Pollut Res Int 26:12368–12378

Al-Degs YS, El-Sheikh AH (2013) Spectrophotometric determination of food dyes in soft drinks by second-order multivariate calibration of the absorbance spectra-pH data matrices. Dyes Pigments 97(2):330–339. https://doi.org/10.1016/j.dyepig.2012.12.019

Al-Refai HH, Ganash AA, Hussein MA (2021) Sensitive and selective voltammetric sensor based on polythiophene nanocomposite mixed MWCNT-G for the determination of tartrazine. Synth Met 280:116875. https://doi.org/10.1016/j.synthmet.2021.116875

Alves SP, Brum DM, Andrade ÉCB, Netto ADP (2008) Determination of synthetic dyes in selected foodstuffs by high-performance liquid chromatography with UV-DAD detection. Food Chem 107(1):489–496. https://doi.org/10.1016/j.foodchem.2007.07.054

Amchova P, Kotolova H, Ruda-Kucerova J (2015) Health safety issues of synthetic food colorants. Regul Toxicol Pharmacol 73:914–922

Amin KA, Abdel Hameid H, Abd Elsttar AH (2010) Effect of food azo dyes tartrazine and carmoisine on biochemical parameters related to renal, hepatic function, and oxidative stress biomarkers in young male rats. Food Chem Toxicol 48:2994–2999

Anaji N, Jayaprakash GK, Naik P, Tigri G (2024) Recent advances in developing modified electrode interface for sensing tartrazine in real samples: A brief review. J Electrochem Sci Eng 14(6):719-735 https://hrcak.srce.hr/file/467906

Berzas JJ, Rodríguez JJ, Llerena MV, Fariñas NR (1999) Spectrophotometric resolution of ternary mixtures of tartrazine, patent blue and indigo carmine in commercial products. Anal Chim Acta 391(3):353–364. https://doi.org/10.1016/s0003-2670(99)00215-9

Bonan S, Fedrizzi G, Menotta S, Caprai E (2013) Simultaneous determination of synthetic dyes in foodstuffs and beverages by high-performance liquid chromatography coupled with diode-array detector. Dyes Pigment 99(1):36–40. https://doi.org/10.1016/j.dyepig.2013.03.029

Buxton SK, Robertson AP, Martin RJ (2014) Diethylcarbamazine increases activation of voltage activated potassium (SLO-1) currents in *Ascaris suum* and potentiates effects of emodepside. PLoS Negl Trop Dis 8(11):e3276. https://doi.org/10.1371/journal.pntd.0003276

Chadchan KS, Teradale AB, Ganesh PS, Das S (2022) Simultaneous sensing of mesalazine and folic acid at poly(murexide) modified glassy carbon electrode surface. Mater Chem Phys 290:126538. https://doi.org/10.1016/j.matchemphys.2022.126538

Chen QC, Mou SF, Hou XP, Riviello JM, Ni ZM (1998) Determination of eight synthetic food colorants in drinks by high-performance ion chromatography. J Chromatogr A 827(1):73–81. https://doi.org/10.1016/S0021-9673(98)00759-6

Dai J, Liu Y, Jiang E (2024) Enhanced electrochemical performance of Sr-doped ZnO for tartrazine detection in sports drinks. Matéria (Rio J) 29(3) https://www.scielo.br/j/rmat/a/jsH5nx5wJZJfPBXpZMWJ3Jf/

Darabi R, Shabani-Nooshabadi M (2021) $NiFe_2O_4$-rGO/ionic liquid modified carbon paste electrode: an amplified electrochemical sensitive sensor for determination of sunset yellow in the presence of tartrazine and allura red. Food Chem 339:127841. https://doi.org/10.1016/j.foodchem.2020.127841

Dorraji PS, Jalali F (2017) Electrochemical fabrication of a novel ZnO/cysteic acid nanocomposite modified electrode and its application to simultaneous determination of sunset yellow and tartrazine. Food Chem 227:73–77

Forgacs E, Cserháti T, Oros G (2004) Removal of synthetic dyes from wastewater: a review. Environ Int 30(7):953–971. https://doi.org/10.1016/j.envint.2004.02.001

Gan T, Sun J, Meng W, Song L, Zhang Y (2013) Electrochemical sensor based on graphene and mesoporous TiO_2 for the simultaneous determination of trace colorants in food. Food Chem 141(4):3731–3737. https://doi.org/10.1016/j.foodchem.2013.06.084

Georgescu R, van Staden JF, State R, Papa F (2022) Rapid and sensitive electrochemical determination of tartrazine in commercial food samples using IL/AuTiO_2/GO composite modified carbon paste electrode. Food Chem 385:132616. https://doi.org/10.1016/j.foodchem.2022.132616

Ghalkhani M, Zare N, Karimi F, Karaman C, Alizadeh M, Vasseghian Y (2022) Recent advances in Ponceau dyes monitoring as food colorant substances by electrochemical sensors and developed procedures for their removal from real samples. Food Chem Toxicol 161:112830. https://doi.org/10.1016/j.fct.2022.112830

Ghoreishi SM, Behpour M, Golestaneh M (2011) Simultaneous voltammetric determination of brilliant blue and tartrazine in real samples at the surface of a multi-walled carbon nanotube paste electrode. Anal Methods 3(12):2842. https://doi.org/10.1039/c1ay05327b

He Q, Liu J, Liu X, Li G, Deng P, Liang J, Chen D (2018) Sensitive and selective detection of tartrazine based on TiO_2-electrochemically reduced graphene oxide composite-modified electrodes. Sensors. https://doi.org/10.3390/s18061911

Huang ST, Shi Y, Li NB, Luo HQ (2012) Sensitive turn-on fluorescent detection of tartrazine based on fluorescence resonance energy transfer. Chem Commun 48:747–749. https://doi.org/10.1039/C1CC15959C

Karimi MA, Aghaei VH, Nezhadali A (2018) Graphitic carbon nitride as a new sensitive material for electrochemical determination of trace amounts of tartrazine in food samples. Food Anal Methods 11:2907–2915. https://doi.org/10.1007/s12161-018-1264-4

Karimi-Maleh H, Beitollahi H, Kumar PS, Tajik S, Mohammadzadeh Jahani P, Karimi F, Karaman C, Vasseghian Y, Baghayeri M, Rouhi J, Show PL, Rajendran S, Fu L, Zare N (2022) Recent advances in carbon nanomaterials-based electrochemical sensors for food azo dyes detection. Food Chem Toxicol 164:112961. https://doi.org/10.1016/j.fct.2022.112961

Karim-Nezhad G, Khorablou Z, Zamani M, Dorraji PS, Alamgholiloo M (2017) Voltammetric sensor for tartrazine determination in soft drinks using poly(p-aminobenzenesulfonic acid)/zinc oxide nanoparticles in carbon paste electrode. J Food Drug Anal 25(2):293–301. https://doi.org/10.1016/j.jfda.2016.10.016

Kumari R, Kumar H, Sharma R, Kumar G, Tundwal A, Dhayal A, Yadav A, Khatkar A (2024) Highly efficient and reliable voltammetry food sensor for tartrazine dye using a nanocomposite reformed electrode. Microchem J 196:109583. https://doi.org/10.1016/j.microc.2023.109583

Laviron E (1974) Adsorption, autoinhibition and autocatalysis in polarography and in linear potential sweep voltammetry. J Electroanal Chem 52(3):355–393. https://doi.org/10.1016/S0022-0728(74)80448-1

Lee KS, Shiddiky MJ, Park SH, Park DS, Shim YB (2008) Electrophoretic analysis of food dyes using a miniaturized microfluidic system. Electrophoresis 29(9):1910–1917. https://doi.org/10.1002/elps.200700556

Lipskikh OI, Korotkova EI, Bareka J, Vyskocil V, Khristunova EP (2020) Simultaneous voltammetric determination of Brilliant Blue FCF and Tartrazine for food quality control. Talanta 218:121136. https://doi.org/10.1016/j.talanta.2020.121136

Ma M, Luo X, Chen B, Su S, Yao S (2006) Simultaneous determination of water-soluble and fat-soluble synthetic colorants in foodstuff by high-performance liquid chromatography-diode array detection-electrospray mass spectrometry. J Chromatogr A 1103:170–176. https://doi.org/10.1016/j.chroma.2005.11.061

Mahale RS, Shashanka R, Vasanth S, Vinaykumar R (2022) Voltammetric determination of various food azo dyes using different modified carbon paste electrodes. Biointerface Res Appl Chem 4(12):4557–4566. https://doi.org/10.33263/BRIAC124.45574566

Majidi MR, Fadakar Bajeh Baj R, Naseri A (2013) Carbon nanotube–ionic liquid (CNT–IL) nanocomposite modified sol-gel derived carbon-ceramic electrode for simultaneous determination of sunset yellow and tartrazine in food samples. Food Anal Methods 6:1388–1397. https://doi.org/10.1007/s12161-012-9556-6

Mehmandoust M, Erk N, Karaman O, Karimi F, Bijad M, Karaman C (2021) Three-dimensional porous reduced graphene oxide decorated with carbon quantum dots and platinum nanoparticles for highly selective determination of azo dye compound tartrazine. Food Chem Toxicol 158:112698. https://doi.org/10.1016/j.fct.2021.112698

Moulya KP, Manjunatha JG, Aljuwayid AM, Habila MA (2023) Polymer-modified carbon paste electrode for electrochemical analysis of tartrazine. Results Chem 5:100809. https://doi.org/10.1016/j.rechem.2023.100809

Qiu X, Lu L, Leng J, Yu Y, Wang W, Jiang M, Bai L (2016) An enhanced electrochemical platform based on graphene oxide and multi-walled carbon nanotubes nanocomposite for sensitive determination of sunset yellow and tartrazine. Food Chem 190:889–895. https://doi.org/10.1016/j.foodchem.2015.06.045

Rovina K, Siddiquee S, Shaarani SM (2019) An electrochemical sensor for the determination of tartrazine based on CHIT/GO/MWCNTs/AuNPs composite film modified glassy carbon electrode. Drug Chem Toxicol 44:447–457

Sahraei R, Farmany A, Mortazavi SS (2013) A nanosilver-based spectrophotometry method for sensitive determination of tartrazine in food samples. Food Chem 138:1239–1242. https://doi.org/10.1016/j.foodchem.2012.11.029

Sakthivel M, Sivakumar M, Chen SM, Pandi K (2018) Electrochemical synthesis of poly(3,4-ethylenedioxythiophene) on terbium hexacyanoferrate for sensitive determination of tartrazine. Sens Actuators B Chem 256:195–203

Senthilkumar D, Kuo CY, Aldossari SA (2025) Advanced highly precise simultaneous electrochemical detection of toxic azo dyes with nanoengineered yttrium iron oxide decorated functionalized carbon nanofibers. Food Chem. https://doi.org/10.1016/j.foodchem.2025.135858

Song YZ, Xu JM, Lv JS, Zhong H, Ye Y, Xie JM (2012) Electrochemical reduction of tartrazine at multi-walled carbon nanotube-modified pyrolytic graphite electrode. Russ J Phys Chem A 86(2):303–310. https://doi.org/10.1134/S0036024412020306

Soponar F, Moţ AC, Sârbu C (2008) Quantitative determination of some food dyes using digital processing of images obtained by thin-layer chromatography. J Chromatogr A 1188(2):295–300. https://doi.org/10.1016/j.chroma.2008.02.077

Tahtaisleyen S, Gorduk O, Sahin Y (2020) Electrochemical determination of tartrazine using a graphene/poly(L-phenylalanine) modified pencil graphite electrode. Anal Lett 53(11):1683–1703. https://doi.org/10.1080/00032719.2020.1716242

Teradale AB, Lamani SD, Ganesh PS, Swamy BK, Das S (2017) CTAB immobilized carbon paste electrode for the determination of mesalazine: a cyclic voltammetric method. Sens Bio Sens Res 15:53–59. https://doi.org/10.1016/j.sbsr.2017.08.001

Teradale AB, Chadchan KS, Ganesh P, Das S, Ebenso EE (2023) Synergetic effects of a poly-tartrazine/CTAB modified carbon paste electrode sensor towards simultaneous and interference-free determination of benzenediol isomers. React Chem Eng 8(12):3071–3081. https://doi.org/10.1039/d3re00318c

Teradale AB, Unki SN, Ganesh PS, Das KK, Das SN (2024) Development of a diethylcarbamazine citrate-based electrochemical sensor for quick and affordable detection of sulfadiazine and uric acid in environmental monitoring. Chem Sel 9(22):e202401047. https://doi.org/10.1002/slct.v9.22

Vignesh K, Kumar AS, Napoleon AA (2024) Ag-La(OH)$_3$@Dy$_2$O$_3$ hybrid composite modified laser-induced graphene surface for simultaneous electrochemical detection of bisphenol A and tartrazine. Appl Surf Sci. https://doi.org/10.1016/j.apsusc.2024.158735

Wang P (2020) Simple and rapid determination of tartrazine using poly(L-arginine)/electrochemically reduced graphene oxide modified glassy carbon electrode. Int J Electrochem Sci 15(9):8901–8912. https://doi.org/10.20964/2020.09.83

Wu L, Xu Y, Lv X, Chang X, Ma X, Xue T, Kong X (2021) Impacts of an azo food dye tartrazine uptake on intestinal barrier, oxidative stress, inflammatory response, and intestinal microbiome in crucian carp (*Carassius auratus*). Ecotoxicol Environ Saf 223:112551. https://doi.org/10.1016/j.ecoenv.2021.112551

Ye X, Du Y, Lu D, Wang C (2013) Fabrication of β-cyclodextrin-coated poly(diallyldimethylammonium chloride)-functionalized graphene composite film modified glassy carbon-rotating disk electrode and its application for simultaneous electrochemical determination of colorants sunset yellow and tartrazine. Anal Chim Acta 779:22–34. https://doi.org/10.1016/j.aca.2013.03.061

Zhao Y, Zheng W, Liao M et al (2023) Fluorescent detection of tartrazine based on the supramolecular self-assembly of cationic perylene diimide. Microchim Acta 190:290. https://doi.org/10.1007/s00604-023-05862-4

Ziyatdinova GK, Budnikov HC (2022) Voltammetric determination of tartrazine on an electrode modified with cerium dioxide nanoparticles and cetyltriphenylphosphonium bromide. J Anal Chem 77:664–670. https://doi.org/10.1134/S106193482206017X