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The Mathematical Model for Thiabendazole Electrochemical Determination in Pharmaceutical Formulations, Biological Liquids and Food Products

Volodymyr V. Tkach [1,*], Tetiana V. Morozova [2], Oksana O. Hlukhonets [3], Halyna V. Khorkova [3], Marta V. Kushnir [4], Sílvio C. de Oliveira [5], Igor G. Biryuk [6], Tetiana B. Sykyrytska [6], Yana G. Ivanushko [6], Petro I. Yagodynets [4,*], Adriano O. da Silva [7], Jarem R. Garcia [8], José Inácio Ferrão da Paiva Martins [9], Oleg P. Melnyk [10], Oleksii O. Melnyk [10], Maria V. Melnyk [10], Maria João Monteiro [1], Isabel O´Neill de Mascarenhas Gaivão [1], Liudmyla P. Hordiienko [11], Liudmyla O. Omelyanchik [12], Olga V. Luganska [12], Volodymyr M. Omelyanchik [13], Mykola P. Krasko [13], Vira M. Odyntsova [13], Karina V. Palamarek [14], Anatolii A. Vdovichen [14], Olha G. Vdovichena [14], Ramazon Safarzoda [15]

1. University of Trás-os-Montes and Alto Douro, Quinta de Prados, 5001-801, Folhadela, Vila Real, Portugal
2. State Scientific Institution "Institute of Ecological Restoration and Development of Ukraine", Environment Remediation Section, Mytropolite Vasyl Lypkivsky Str. 35, 01001 Kyiv, Ukraine
3. National Transport University, 02000, Omelianovych-Pavlenko Str. 1, Kyiv, Ukraine
4. Chernivtsi National University, 58001, Kotsyubynsky Str. 2, Chernivtsi, Ukraine
5. Institute of Chemistry. Federal University of Mato Grosso do Sul, 79074 – 460, Av. Sen. Felinto Müller, 1555, Vila Ipiranga, Campo Grande, MS, Brazil
6. Bukovinian State Medical University, 58001, Teatralna Sq, 9, Chernivtsi, Ukraine
7. Federal University of the West of Pará, Juruti Campus, 68170 – 000, Rua Veríssimo de Souza Andrade, s/n, Juruti, PA, Brazil
8. State University of Ponta Grossa, Uvaranas Campus, Av. Gal. Carlos Cavalcanti, 4748, 84030-900, Ponta Grossa, PR, Brazil
9. Engineering Faculty of the University of Porto, 4200-465, Rua Dr. Roberto Frias, s/n, Porto, Portugal
10. National University of Life and Environmental Science of Ukraine, 03041, Heroiv Oborony Str, 15, Kyiv, Ukraine
11. Poltava State Medical University, 36000, Shevchenka Str. 23, Poltava, Ukraine
12. Zaporizhzhia National University, 69600, Universytetska Str. 66, Zaporizhzha, Ukraine
13. Zaporizhzhia State University of Medicine and Pharmacy, 69600, Mayakovsky Ave. 24, Zaporizhzhia, Ukraine
14. Chernivtsi Institute of Trade and Economics of State University of Trade and Economics, 58000, Central Sq. 6, Chernivtsi, Ukraine
15. Avicenna Tajik State Medical University, 734007, Rudaki Ave., 139, Dushanbe, Tajikistan

* Correspondence: al2025173708@alunos.utad.pt (V.V.T.); ved1988mid@rambler.ru (P. I.Y.);

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Abstract: In this work, the electrochemical determination of thiabendazole in pharmaceutical formulations, biological liquids, and food has been described using a mathematical model, which was thereby analyzed using linear stability theory and bifurcation analysis. Three scenarios, including N-oxidation, S-oxidation, and electropolymerization, have been included in the model. The model analysis shows that, despite the presence of the electropolymerization scenario and the increase in the probability of oscillatory behavior, the electroanalytical process, performed anodically on copper sulfide nanoparticles, is efficient and may be used for both electrochemical determination and excess removal of thiabendazole. As for poly(thiobendazole), it is suitable for the determination and removal of heavy metal ions.

Keywords: thiabendazole; electrochemical determination; electrochemical sensor; electrochemical oscillations; stable steady-state.

1. Introduction

Thiabendazole [1-5] is a widely used antihelmintic, antifungal, and larvicide, used to treat various parasitoses in humans and pets. Moreover, it is one of the few antihelmintic drugs registered as a conservant food additive (E239), usually added to protect fruits and vegetables from helminths and larvae. It is also used as an antidote for heavy metal poisoning [4,5] due to the presence of a complex-forming imidazole ring. Its pharmacological properties are due to the fact of combining the benzimidazolic ring with the thiazolic (Figure 1).

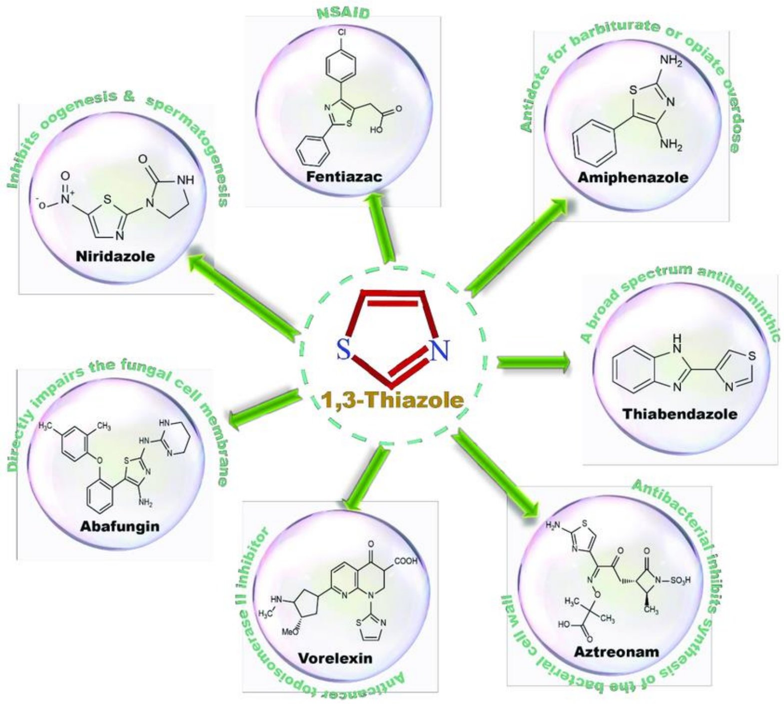

Figure 1. Thiabendazole (in the center to the right), among the other thiazole-based drugs.

Nevertheless, despite the relative safety of thiabendazol, the reason why it is both a drug and a food additive, its excess may lead to side effects, like anorexia, nausea, vomiting [6-10], and, in excess, even hallucinations and delirium. Moreover, it may possess a genotoxic effect [2, 9,10]. For this reason, the development of an efficient method for thiabendazole determination is currently relevant, and electrochemical systems may be used effectively for this purpose [11-15].

Because it possesses both donor and acceptor functional groups, thiabendazole can be detected either cathodically or anodically. In the case of anodic oxidation, strong oxidants, including peroxide ions (e.g., disulfate and caroates), trivalent copper, and tetravalent cobalt derivatives, may be used efficiently. In some cases, they might be obtained *in situ* on the electrochemical stage (1 – 2):

$$CuS + OH^- - e^- \rightarrow CuS(OH) \quad (1)$$

$$CoO(OH) + OH^- - e^- \rightarrow CoO_2 + H_2O \quad (2)$$

Therefore, both tetravalent cobalt and, even more so, trivalent copper, being strong oxidants, energetically attack the analyte, leading to a clear analytical signal.

Nevertheless, the presence of electrochemical instabilities, which make the analytical signal difficult to interpret, may be associated with different behavioural effects in electroanalytical processes [15-17]. Those instabilities are typical and may limit the electroanalytical and removal use of the electrochemical process. To foresee the possibility of electrochemical instabilities and the effects they may produce, it´s necessary to investigate the process from a mechanical point of view and analyze its behavior theoretically.

The goal of this work is to evaluate the mechanism of the anodic electrochemical determination of thiabendazole at the anode modified with CuS or CoO(OH) nanoparticles. The corresponding mathematical model is developed and analyzed using linear stability theory and bifurcation analysis. The theoretical investigation includes the comparison of the behavior of this system with that of similar ones [18-21].

2. Materials and Methods

Three oxidation scenarios may be anticipated for thiabendazole in this system: N-oxidation, S-oxidation, and electropolymerization (Figure 2).

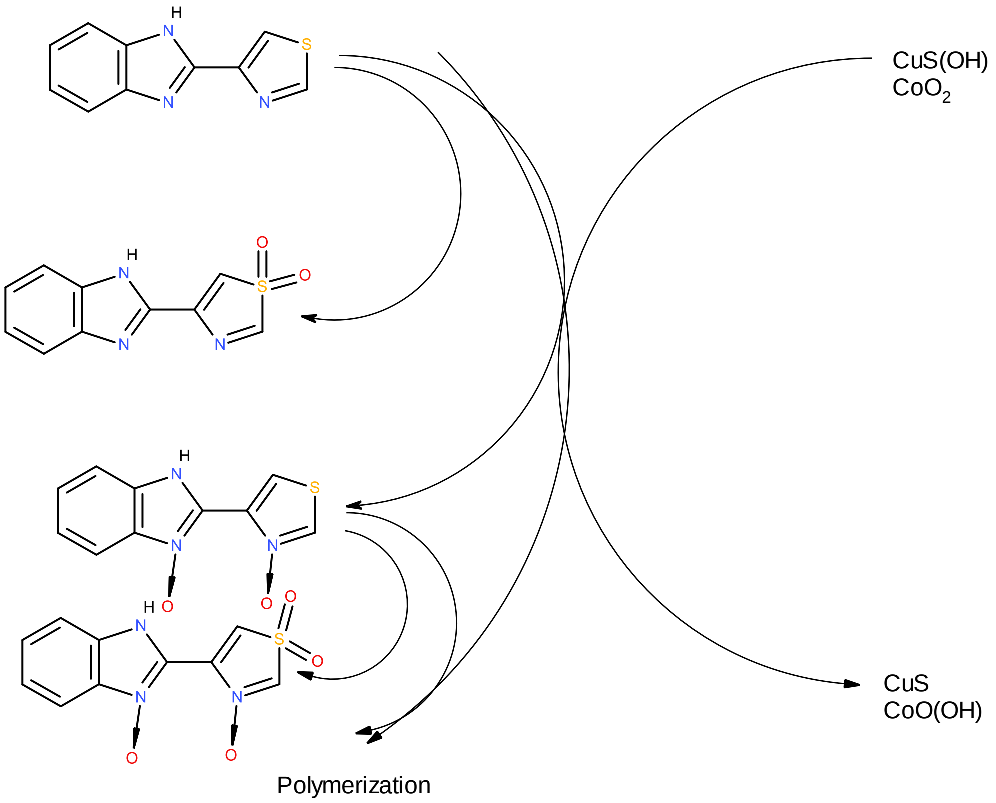

Figure 2. The scheme of the electroanalytical process for thiabendazole.

Considering the activating properties of the N-oxidized pyridinic nitrogen atom and the passivating properties of the sulfonic group, we expect that both S-oxidation products will participate to a limited extent in the electropolymerization process (hence their polymerization as monomers will be neglected), whereas the N-oxide will.

Therefore, considering the above-mentioned statements, like also certain assumptions [18-21], we describe the electrochemical behavior of the system by a trivariate balance differential equation set (3):

$$\begin{cases} \frac{dn}{dt} = \frac{2}{\delta}\left(\frac{\Delta}{\delta}(n_0 - n) - r_{\mathrm{N}} - r_{S1} - r_P\right) \\ \frac{dn*}{dt} = \frac{2}{\delta}(r_{\mathrm{N}} - r_{S2} - r_P) \\ \frac{dc}{dt} = \frac{1}{C}(r_{\mathrm{N}} + r_{S1} + r_P + r_{S2} - r_o) \end{cases} \quad (3)$$

Herein, n and n* are thiabendazole and its N-oxide pre-surface concentrations, δ is the diffusion pre-surface layer thickness, Δ is the diffusion coefficient, c is CuS (or CoO(OH)) surface coverage degree, C is its maximal concentration, and the parameters r are the correspondent reaction rates, calculated for neutral solutions (pH=7) as (4 – 8):

$$r_{\mathrm{N}} = k_{\mathrm{N}} n(1-c) \quad (4)$$

$$r_{\mathrm{S1}} = k_{\mathrm{S1}} n(1-c)^2 \quad (5)$$

$$r_{\mathrm{S2}} = k_{\mathrm{S2}} n*(1-c)^2 \quad (6)$$

$$r_P = k_P n^x n*^y (1-c)^z \exp(\alpha n n*) \quad (7)$$

$$r_o = k_o c \exp\left(\frac{F\varphi_0}{RT}\right) \quad (8)$$

Herein, the parameters k stand for the corresponding reaction rate constants, α is the parameter relating the growing polymer charge and conductivity with DEL ionic force, x, y, and z are polymerization reaction orders, F is the Faraday number, φ_0 is the zero-charge-related potential slope, R is the universal gas constant, and T is the absolute temperature.

The oscillatory behavior will have a higher probability because the electropolymerization process induces cyclic changes in DEL's electrophysical properties. Nevertheless, the analysis of the model presented below confirms the efficiency of this electroanalytical process for the electrochemical determination and removal of thiabendazole.

3. Results and Discussion

In order to describe the behavior of the electrochemical system with thiabendazole electrochemical determination, we analyze the equation set (3) alongside the algebraic relations (4 – 8) by linear stability theory. The steady-state Jacobian matrix elements for this case will be exposed as (9):

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \quad (9)$$

Herein:

$$a_{11} = \frac{2}{\delta}\left(-\frac{\Delta}{\delta} - k_{\mathrm{N}}(1-c) - k_{\mathrm{S1}}(1-c)^2 - xk_P n^{x-1} n*^y (1-c)^z \exp(\alpha n n*) + ak_P n^x n*^y (1-c)^z \exp(\alpha n n*)\right) \quad (10)$$

$$a_{12} = \frac{2}{\delta}(-yn^x n*^{y-1} (1-c)^z \exp(\alpha n n*) + ak_P n^x n*^y (1-c)^z \exp(\alpha n n*)) \quad (11)$$

$$a_{13} = \frac{2}{\delta}(k_{\mathrm{N}} n + 2k_{\mathrm{S1}} n(1-c) + \mathrm{z}k_P n^x n*^y (1-c)^{z-1} \exp(\alpha n n*)) \quad (12)$$

$$a_{21} = \frac{2}{\delta}(k_{\mathrm{N}}(1-c) - xk_P n^{x-1} n*^y (1-c)^z \exp(\alpha n n*) + ak_P n^x n*^y (1-c)^z \exp(\alpha n n*)) \quad (13)$$

$$a_{22} = \frac{2}{\delta}(-k_{\mathrm{S2}}(1-c)^2 - yn^x n*^{y-1} (1-c)^z \exp(\alpha n n*) + ak_P n^x n*^y (1-c)^z \exp(\alpha n n*)) \quad (14)$$

$$a_{23} = \frac{2}{\delta}(2k_{\mathrm{S2}} n*(1-c) + 2k_{\mathrm{S1}} n(1-c) + \mathrm{z}k_P n^x n*^y (1-c)^{z-1} \exp(\alpha n n*) - k_{\mathrm{N}} n) \quad (15)$$

$$a_{31} = \frac{1}{C}(k_N(1-c) - k_{S1}(1-c)^2 + xk_P n^{x-1} n *^y (1-c)^z \exp(\alpha nn *) - ak_P n^x n *^y (1-c)^z \exp(\alpha nn *)) \quad (16)$$

$$a_{32} = \frac{1}{C}(-k_{S2}(1-c)^2 + yn^x n *^{y-1} (1-c)^z \exp(\alpha nn *) - ak_P n^x n *^y (1-c)^z \exp(\alpha nn *)) \quad (17)$$

$$a_{33} = \frac{1}{C}\left(-k_N n - 2k_{S1} n(1-c) - 2k_{S2} n * (1-c) - zk_P n^x n *^y (1-c)^{z-1} \exp(\alpha nn *) - k_o \exp\left(\frac{F\varphi_0}{RT}\right) + jk_o c \exp\left(\frac{F\varphi_0}{RT}\right)\right) (18)$$

From the Jacobian main diagonal elements (10), (14), and (18), it is possible to conclude that the positive callback, necessary for the Hopf bifurcation, describing the oscillatory behavior, is possible, as the mentioned elements possess positive addenda.

In this system, the oscillatory behavior is more probable than in the simplest case, but either way, it is less probable than in the acidic medium. It is caused by two factors, one against the other in the simplest case, but the DEL ionic force change factor is only manifested in the assisted electropolymerization reaction, which involves the appearance, transformation, and recombination of cation radicals, according to the standard Díaz or Kim mechanism. Also, the oscillatory behavior will be caused by the change of DEL and surface ionic force and conductivity in the electrochemical stage. Mathematically, it is manifested by the positivity of the elements $ak_P n^x n *^y (1-c)^z \exp(\alpha nn *) > 0$, $ak_P n^x n *^y (1-c)^z \exp(\alpha nn *) > 0$ if a>0, like also $jk_o c \exp\left(\frac{F\varphi_0}{RT}\right)$>0 if j>0. As for the oscillation frequency and amplitude, it will be dependent on the background electrolyte composition, as already shown both experimentally and theoretically [18-21].

Avoiding the cumbersome expressions during the steady-state stability investigation using the Routh-Hurwitz criterion, we rewrite the Jacobian determinant as (19):

$$\frac{4}{\delta^2 C}\begin{vmatrix} -\kappa - \Xi - \Lambda & -\Sigma & \Psi + P \\ \Xi - \Lambda & -T - \Sigma & P - \Psi \\ \Xi + \Lambda & T + \Sigma & -P - \Psi - \Omega \end{vmatrix} \quad (19)$$

Which may be transformed by using the determinant properties into (20):

$$\frac{4}{\delta^2 C}\begin{vmatrix} -\kappa & T & -\Omega \\ 2\Xi & 0 & -2\Psi - \Omega \\ \Xi + \Lambda & T + \Sigma & -P - \Psi - \Omega \end{vmatrix} \quad (20)$$

Opening the brackets, applying the Det J<0 requisite, salient from the criterion, like also Det J=0 monotonic stability criterion, and changing the signs to the opposite, we obtain the steady-state stability and monotonic instability (corresponding to the detection limit) requirement exposed as (21):

$$T(2\psi\Lambda + \Omega\Lambda + 2\kappa\Psi + 2\kappa\Omega + \Xi\Omega - 2\Xi P) + \Sigma(2\kappa\Psi + 2\kappa\Omega + \Xi\Omega)\begin{cases} > 0, steady - state\ stability \\ = 0, monotonic\ instability \end{cases} \quad (21)$$

defining a mostly kinetically controlled electropolymerization system [18-21], efficient from both an electroanalytical and electrosynthetic point of view.

In the absence of the side reactions or other factors capable of compromising the analyte and (or) modifier stability, excluding the reactions foreseen by the mechanism, the linearity between the electrochemical parameter and concentration is observed, providing an efficient analytical signal interpretation, which is really important for thiabendazole concentration monitoring.

The condition Det J=0 corresponds to the detection limit, manifested by the *monotonic instability*. It may be seen as an N-shaped part of the steady-state voltammogram, which depicts the margin between the stable steady-states and unstable states and corresponds to the steady-state multiplicity. In other words, multiple steady-states, each one unstable, coexist at this point.

If pH≠7, thiabendazole molecule becomes ionized, as it contains both pyrrolic and pyridinic nitrogen atoms. In this case, the reaction rate constants will include an ionization component, reflecting an increase in the probability of oscillatory behavior, which is more pronounced in an acidic medium than in an alkaline medium. A cathodic process is recommended for the acidic medium.

As for poly(thiabendazole), its principal application might be as a conducting polymer coating for the extraction and recycling of heavy-metal ion waste due to complex formation. The resulting material may also have multiple applications, including electroanalysis, energy storage and conversion, and supercapacitor preparation.

4. Conclusions

From the analysis of the system, using electrochemical determination and removal of dibenzoxazepine via assisted N-oxidation and electropolymerization over CuS or CoO(OH) nanoparticles, paired with trivalent copper and tetravalent cobalt, respectively, it is possible to conclude that the electroanalytical process is efficient. Moreover, the neutral and lightly alkaline medium is more efficient than the acidic and strongly alkaline solutions. Although oscillatory behavior is possible, even more probable than in the simplest case, it will be less probable than in alkaline or acidic solutions. As for the electroanalytical-electrosynthetic process, it is mostly kinetically controlled, and the electroanalytical signal is easy to interpret.

Author Contributions

Conceptualization, T.V.M.; V.V.T.; I.O.M.G.; O.O.H.; H.V.K..; P.I.Y.; Y.G. I. and A.A.V..; methodology, V.V.T.; T.V.M.; O.O.H.; H.V.K.; M.V.K.; S.C.O.; I.G.B.; T.B.S.; Y.G.I.; P.I.Y.; A.O.S.; J.R.G.; J.I.F.P.M.; O.P.M.; O.O.M.; M.V.M.; M.J.M; I.O.M.G.; L.P.H. L.O.O.; O.V.L.; V.M.O.; M.P.K.; V.M.O.; K.V.P.; A.A.V; O.G.V. and R.S; validation, V.V.T.; T.V.M.; O.O.H.; H.V.K.; M.V.K.; S.C.O.; I.G.B.; T.B.S.; Y.G.I.; P.I.Y.; A.O.S.; J.R.G.; J.I.F.P.M.; O.P.M.; O.O.M.; M.V.M.; M.J.M; I.O.M.G.; L.P.H. L.O.O.; O.V.L.; V.M.O.; M.P.K.; V.M.O.; K.V.P.; A.A.V; O.G.V. and R.S formal analysis, V.V.T.; T.V.M.; O.O.H.; H.V.K.; M.V.K.; S.C.O.; I.G.B.; T.B.S.; Y.G.I.; P.I.Y.; A.O.S.; J.R.G.; J.I.F.P.M.; O.P.M.; O.O.M.; M.V.M.; M.J.M; I.O.M.G.; L.P.H. L.O.O.; O.V.L.; V.M.O.; M.P.K.; V.M.O.; K.V.P.; A.A.V; O.G.V. and R.S investigation, V.V.T.; T.V.M.; O.O.H.; H.V.K.; M.V.K.; S.C.O.; I.G.B.; T.B.S.; Y.G.I.; P.I.Y.; A.O.S.; J.R.G.; J.I.F.P.M.; O.P.M.; O.O.M.; M.V.M.; M.J.M; I.O.M.G.; L.P.H. L.O.O.; O.V.L.; V.M.O.; M.P.K.; V.M.O.; K.V.P.; A.A.V; O.G.V. and R.S; resources, V.V.T.; T.V.M.; O.O.H.; H.V.K.; M.V.K.; S.C.O.; I.G.B.; T.B.S.; Y.G.I.; P.I.Y.; A.O.S.; J.R.G.; J.I.F.P.M.; O.P.M.; O.O.M.; M.V.M.; M.J.M; I.O.M.G.; L.P.H. L.O.O.; O.V.L.; V.M.O.; M.P.K.; V.M.O.; K.V.P.; A.A.V; O.G.V. and R.S, data curation, V.V.T.; T.V.M.; O.O.H.; H.V.K.; M.V.K.; S.C.O.; I.G.B.; T.B.S.; Y.G.I.; P.I.Y.; A.O.S.; J.R.G.; J.I.F.P.M.; O.P.M.; O.O.M.; M.V.M.; M.J.M; I.O.M.G.; L.P.H. L.O.O.; O.V.L.; V.M.O.; M.P.K.; V.M.O.; K.V.P.; A.A.V; O.G.V. and R.S writing—original draft preparation, . V.V.T.; T.V.M.; O.O.H.; H.V.K.; M.V.K.; S.C.O.; I.G.B.; T.B.S.; Y.G.I.; P.I.Y.; A.O.S.; J.R.G.; J.I.F.P.M.; O.P.M.; O.O.M.; M.V.M.; M.J.M; I.O.M.G.; L.P.H. L.O.O.; O.V.L.; V.M.O.; M.P.K.; V.M.O.; K.V.P.; A.A.V; O.G.V. and R.S writing—review and editing, .

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Data supporting the findings of this study are available upon reasonable request from the corresponding author.

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Conflicts of Interest

The authors declare no conflict of interest.

References

1. He, J.; Zhu, X.; Xu, K.; Li, Y.; Zhou, J. Network toxicological and molecular docking to investigate the mechanisms of toxicity of agricultural chemical Thiabendazole. *Chemosphere* **2024**, *363*, 142711, https://doi.org/10.1016/j.chemosphere.2024.142711.
2. Park, J.; An, G.; Park, H.; Hong, T.; Lim, W.; Song, G. Developmental defects induced by thiabendazole are mediated via apoptosis, oxidative stress and alteration in PI3K/Akt and MAPK pathways in zebrafish. *Environment International* **2023**, *176*, 107973, https://doi.org/10.1016/j.envint.2023.107973.
3. Zhao, S.-S.; He, Z.-H.; Liu, X.; Shen, Y.; Tan, X.-C.; Wang, Q.; Yan, J.; Zhu, W.-W. Dialdehyde starch-enclosed silver nanoparticles substrate with controlled-release "hotspots" for ultrasensitive SERS detection of thiabendazole. *Food Chemistry* **2024**, *436*, 137706, https://doi.org/10.1016/j.foodchem.2023.137706.
4. Hamdis, N.; Haroun, N.; Izemrane, D.; Yahiaoui, K. Green tea beverage protects against thiabendazole-induced kidney and liver injury through antioxidant actions in rats in vivo. *Int. J. Env. Stud.* **2024**, https://doi.org/10.1080/00207233.2024.2393531.
5. Fauteux, M.; Côté, N.; Bergeron, S.; Maréchal, A.; Gaudreau, L. Differential effects of pesticides on dioxin receptor signaling and p53 activation. *Scientific Reports* **2023**, *13*, 21211, https://doi.org/10.1038/s41598-023-48555-x.

6. Radulovic, J.; Lucic, M.; Nesic, A.; Onija, A. Multivariate Assessment and Risk Ranking of Pesticide Residues in Citrus Fruit. *Foods* **2023**, *12*, 2454, https://doi.org/10.3390/foods12132454.
7. Valencia-Quintana, R.; Milić, M.; Bonassi, S.; Ochoa-Ocaña, M.A.; Campos-Peña, V.; Tenorio-Arvide, M.G.; Pérez-Flores, G.A.; Sánchez-Alarcón, J. Effect of pesticide exposure over DNA damage in farmers from Los Reyes, Michoacan in Mexico. *Toxics* **2023**, *11*, 122, https://doi.org/10.3390/toxics11020122.
8. Álvarez–Fernández, L.; Blanco–Paniagua, E.; Millán–García, A.; Velasco-Díez, M.; Álvarez, A.I.; Merino, G. The ABCG2 protein in vitro transports the xenobiotic thiabendazole and increases the appearance of its residues in milk. *Environmental Toxicology and Pharmacology* **2024**, *107*, 104421, https://doi.org/10.1016/j.etap.2024.104421.
9. Solano, G.S.M.; Andrioli, N.B. Genotoxic effects induced by iprodione and tebuconazole in meristematic cells of *Allium cepa*: responses dependent on concentration and exposure time. *Env. Sci. Poll. Res.* **2024**, *31*, 17289 – 17298, https://doi.org/10.1007/s11356-024-32351-9.
10. Sonzogni, L.; Ferlazzo, M.L.; Granzotto, A.; Fervers, B.; Charlet, L.; Foray, N. DNA double-strand breaks induced in human cells by 6 current pesticides: intercomparisons and influence of the ATM protein. *Biomolecules* **2022**, *12*, 250, https://doi.org/10.3390/biom12020250.
11. Budetic, M.; Kopf, D.; Dandic, A.; Samardzic, M. Review of Characteristics and Analytical Methods for Determination of Thiabendazole. *Molecules* **2023**, *28*, 3926, https://doi.org/10.3390/molecules28093926.
12. Hajikhani, M.; Kousheh, S.; Zhang, Yi.; Li, M. Design of a novel SERS substrate by electrospinning for the detection of thiabendazole in soy-based foods. *Food Chem.* **2024**, *436*, 137703, https://doi.org/10.1016/j.foodchem.2023.137703.
13. Feng, J.-Y.; Ma, Q.-K.; Yang, Y.-H.; Wu, Y.-B.; Dong, G.-Y. Two new zinc (II) coordination polymers containing bis (thiabendazole) ligands for fluorescence detection of Fe3+ ions and norfloxacin/ornidazole. *Polyhedron* **2023**, *244*, 116580, https://doi.org/10.1016/j.poly.2023.116580.
14. Fan, X.-F.; Li, D.-Y.; Deng, X.-C.; Fu, L.; Cui, G.-H. Two d^{10} metal coordination polymers involving thiabendazole ligands for efficient detection of norfloxacin/oxytetracycline and Ni^{2+}/Fe^{3+}. *Polyhedron* **2023**, *241*, 116456, https://doi.org/10.1016/j.poly.2023.116456.
15. Budetić, M.; Samardžić, M.; Bubnjar, K.; Dandić, A.; Živković, P.; Széchenyi, A.; Kiss, L. A new sensor for direct potentiometric determination of thiabendazole in fruit peels using the Gran method. *Food chemistry* **2022**, *392*, 133290, https://doi.org/10.1016/j.foodchem.2022.133290.
16. Sun, J.; Zhao, H.; Wang, Zh. Nonenzymatic Glucose Sensor Based on Porous Co_3O_4 Nanoneedles. *J. Env. Publ Health* **2022**, *2022*, 6442241, https://doi.org/10.1155/2022/6442241.
17. Lisnund, S.; Blay, V.; Muamkhunthod, P.; Thunyanon, K.; Pansalee, J.; Monkrathok, J.; Maneechote, P.; Chansaenpak, K.; Pinyou, P. Electrodeposition of cobalt oxides on carbon nanotubes for sensitive bromhexine sensing. *Molecules* **2022**, *27*, 4078, https://doi.org/10.3390/molecules27134078.
18. Das, I.; Goel, N.; Agrawal, N.R.; Gupta, S.K. Growth patterns of dendrimers and electric potential oscillations during electropolymerization of pyrrole using mono-and mixed surfactants. *J. Phys. Chem. B* **2010**, *114*, 12888-12896, https://doi.org/10.1021/jp105183q.
19. Bazzaoui, M.; Bazzaoui, E.A.; Martins, L.; Martins, J.I. Electropolymerization of pyrrole on zinc–lead–silver alloys electrodes in acidic and neutral organic media. *Synthetic Metals* **2002**, *130*, 73-83, https://doi.org/10.1016/S0379-6779(02)00101-7.
20. Tkach, V.; Kucher, M.; Kushnir, M.; Ivanushko, Y.; Akınay, Y.; Karakoyun, N.; Yagodynets, P.; Kormosh, Z. The Theoretical Description for Psilocin Electrochemical Determination over Cobalt Oxyhydroxide. *Orbital: The Electronic Journal of Chemistry* **2023**, *15*, 27-30, https://doi.org/10.17807/orbital.v15i1.18012.
21. Tkach, V.V.; Kushnir, M.V.; Omelianchyk, L.O.; Kopiika, V.O.G.V.V.; Yagodynets, P.I.; Palytsia, Y.V.; Pochenchuk, G.M. The theoretical evaluation of the hydrogen peroxide electrochemical sensing, based on COSN (OH) 6. *Applied Journal of Environmental Engineering Science* **2023**, *9*, 16-22, https://doi.org/10.48422/IMIST.PRSM/ajees-v9i1.33281.

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