https://chemclassjournal.com/
ChemClass Journal Vol. 9 Issue 1 (2025); 125-134
e-ISSN:0198-2734 p-ISSN:0198-5680
doi.org/10.33003/chemclas_2025_0901/010

Assessment of *Vitis labrusca* Extract as a Corrosion Inhibitor for Mild Steel in Acidic Media

Adamu Shaibu Onakpa[1*], Bilkis Abdullahi[1], Alfa Ebune[1], Ele-Ojo Ataguba[2], Mary Ekere[1], Aishat Aliyu[1], Khadijah Mamud[1]

[1]*Department of Chemistry, Federal University Lokoja, Kogi State.*
[2]*Department of Biochemistry, Federal University Lokoja, Kogi State.*

(*)Corresponding Author: writeadamu@outlook.com, Phone number: 08066663301

Abstract

This study explores the corrosion inhibition properties of *Vitis labrusca* (Concord grape) extract as a sustainable alternative. Weight loss measurements were used to assess the corrosion rates of mild steel in a 1M hydrochloric acid solution with varying concentrations of the plant extract. The results reveal a significant reduction in corrosion rates, with inhibition efficiency reaching 70.59% at the highest concentration of 0.8 ppm. The adsorption of bioactive compounds onto the metal surface and the formation of a protective film are identified as key mechanisms responsible for the corrosion inhibition. This study highlights the efficacy of *Vitis labrusca* extract as an eco-friendly corrosion inhibitor, offering a promising solution for possible industrial applications. Further research is recommended to optimize its practical use and evaluate its long-term effectiveness under varied environmental conditions.

Keywords: Corrosion inhibition, mild steel, *Vitis labrusca*, hydrochloric acid, phytochemicals, weight loss

Introduction

Corrosion is a natural electrochemical process that results in the degradation of metals due to their interaction with environmental elements [1]. It is most commonly observed in metals, particularly iron and its alloys, where it manifests as rust formation when exposed to moisture and oxygen [2]. This process not only leads to aesthetic deterioration but also compromises the structural integrity of materials, posing significant risks in various industries, including construction, transportation, and manufacturing [3], [4]. The significance of corrosion extends beyond mere material loss; it has profound economic implications. According to a study by the National Association of Corrosion Engineers (NACE), the cost of corrosion in the United States alone is estimated to exceed $276 billion annually, which accounts for approximately

3.1% of the nation's Gross Domestic Product (GDP) [5]. These costs arise from direct expenses related to maintenance, repair, and replacement of corroded structures, as well as indirect costs associated with downtime and accidents caused by corrosion-related failures.

In addition to economic factors, corrosion poses safety hazards. Structural failures due to corrosion can lead to catastrophic incidents, including bridge collapses, pipeline ruptures, and equipment failures. For instance, the failure of a corroded pipeline can result in hazardous material spills, endangering public health and the environment [6]. Thus, understanding and mitigating corrosion is critical for ensuring safety, reliability, and sustainability in various sectors.

The corrosion of mild steel in acidic media is primarily governed by electrochemical reactions. When mild steel is exposed to an acidic solution, the hydrogen ions (H^+) present in the acid react with the iron (Fe) in the steel, resulting in the formation of ferrous ions (Fe^{2+}). This reaction can be summarized by the following equation:

$$Fe + 2H^+ \rightarrow Fe^{2+} + H_2$$

To mitigate mild steel corrosion in acidic media, various strategies have been employed, including the use of protective coatings, cathodic protection, and corrosion inhibitors. These inhibitors can adsorb onto the metal surface, forming a protective film that reduces the rate of corrosion by blocking the active sites where corrosion reactions occur [7], [8], [9]. Natural products, such as plant extracts, have gained attention as eco-friendly alternatives to traditional synthetic inhibitors due to their effectiveness and lower environmental impact [10].

Vitis labrusca, commonly known as the Concord grape, is a potential candidate for use as a green corrosion inhibitor. This plant is rich in phytochemicals such as flavonoids and phenolic compounds [11], which have been shown to exhibit corrosion inhibition properties [12]. The antioxidant and antimicrobial properties of these compounds not only contribute to their effectiveness as corrosion inhibitors but also align with the growing demand for sustainable and biodegradable materials in industrial applications.

Despite the promising potential of *Vitis labrusca* extracts, there is a notable gap in the literature regarding their specific efficacy in inhibiting corrosion of mild steel in acidic environments. Previous studies have primarily focused on other plant extracts or general corrosion inhibition mechanisms, leaving a need for targeted research on *Vitis labrusca* This study aims to address this gap by investigating the theoretical and experimental corrosion inhibition properties of *Vitis labrusca* extract on mild steel in acidic media.

Materials and Methods

- Mild Steel Coupons: Rectangular samples measuring 2 cm × 2 cm × 0.2 cm.
- Chemicals: Analytical-grade methanol (purity: 99.9%) and 37% Hydrochloric acid, reagent grade. Both chemicals obtained from Sigma Aldrich.
- Equipment: Soxhlet extractor, rotary evaporator, digital analytical balance, and desiccator.

Preparation of *Vitis labrusca* Extract

Fresh *Vitis labrusca* leaves were collected, cleaned, and air-dried at room temperature for 10 days. The dried leaves were ground into powder and extracted using 99.9% pure, Analytical-grade methanol (Sigma-Aldrich) in a Soxhlet apparatus at 65°C. This method is consistent with previous studies on plant extracts that have shown that Soxhlet extraction is effective for obtaining bioactive compounds [13], [14]. The concentrated extract was stored in an airtight container at 4°C until use.

Weight-Loss Measurements

The weight loss measurement was adapted from ASTM G31-21[15]. Mild steel coupons were polished with emery paper, degreased in acetone, rinsed with distilled water, and dried. Coupons were weighed and immersed in 100 mL of 1 M HCl containing various concentrations (0.1 to 0.8 ppm) of *Vitis labrusca* extract at 30°C for 24 hours. Post-immersion, the coupons were cleaned, dried, and reweighed. This procedure aligns with standard practices for evaluating corrosion inhibition where weight loss measurements are commonly used to assess the effectiveness of inhibitors [16], [17]. The weight loss, corrosion rate and inhibition efficiency were calculated as follows:

The weight loss of each specimen was calculated using the formula:

$$W = W_{initial} - W_{final} \quad \dots\dots\dots\dots\dots.\dots\dots \quad (1)$$

where:

- W_{initial} is the initial weight of the specimen,
- W_{final} is the final weight after immersion.

$$Corrosion\ Rate = \frac{Weight \times 87.6}{Area \times Time} \quad \dots\dots \quad (2)$$

$$Inhibition\ Efficiency = \frac{\text{Weight Loss}_{blank} - \text{Weight Loss}_{inhibitor}}{\text{Weight Loss}_{blank}} \dots\dots\dots\dots\dots\dots\dots \quad (3)$$

Langmuir Adsorption Isotherm

The experimental data was subjected to the Langmuir isotherm analysis by plotting a graph of inhibitor concentrations against theta (Θ), which is related to the inhibitor efficiencies as mathematically described below:

The Langmuir isotherm is expressed as:

$$\frac{C}{\Theta} = \frac{1}{K} + C \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (4)$$

The Gibbs free energy was calculated using:

$$\Delta G_{ads} = -RTln(K) \;\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

Where:

C: Inhibitor concentration, Θ: Surface coverage (Θ = (%IE)/100), K: Adsorption equilibrium constant (L/mg)

Freundlich Adsorption Isotherm

The experimental data was similarly subjected to the Freundlich isotherm analysis by plotting a graph of the logarithm of theta (Θ), against the logarithm of the inhibitor concentrations. theta (Θ) is related to the inhibitor efficiencies as mathematically described below:

The Freundlich isotherm is expressed as:

$$\log(\Theta) = \log(K_f) + n\log(C) \;\dots\dots\dots\dots\dots (6)$$

The Gibbs free energy was calculated using:

$$\Delta G_{ads} = -RTln(K_f) \;\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (7)$$

Where:

K_f: Freundlich adsorption constant

Results and Discussion

The experimental results of this study focused on evaluating the corrosion inhibition properties of *Vitis labrusca* (Concord grape) extract on mild steel in acidic environments. The assessment was conducted using weight loss measurements, and the results are presented in Table 1 below.

Table 1: Weight loss measurements of the c**orrosion inhibition properties of *Vitis labrusca* extract on mild steel in acidic environment**

Concentration (ppm)	Average Weight Loss (g)	Corrosion Rate (mm/year)	Inhibition Efficiency (%)
0	0.294	0.034	-
0.1	0.219	0.025	26.47
0.2	0.167	0.019	44.12
0.4	0.126	0.014	58.82
0.6	0.104	0.012	64.71
0.8	0.091	0.01	70.59

From Table 1, the application of *Vitis labrusca* extracts reduces the corrosion rate significantly. Previous studies have shown that natural extracts can effectively inhibit corrosion by adsorbing onto metal surfaces and forming a protective film [18], [19]. The presence of phytochemicals such as tannins and flavonoids *in Vitis labrusca a* contributes to this protective effect [20].

Table 1 also presents the weight loss, and inhibition efficiency for mild steel in 1 M HCl with varying concentrations of *Vitis labrusca* extract. The findings reveal a concentration-dependent enhancement in inhibition efficiency, reaching 70.59% at 0.8 ppm of *Vitis labrusca* extract. This pattern is consistent with previous research showing that the efficiency of natural extracts as corrosion inhibitors improves with increasing concentration [21]. Comparisons with neem and moringa extracts underscore the extract's comparable effectiveness as a sustainable inhibitor, with similar studies reporting high inhibition efficiencies for these extracts in acidic environments [22]. The reduction in weight loss and corrosion rate observed indicates that *Vitis labrusca* extract forms a protective film on the steel surface, thereby mitigating the corrosive impact of the acidic medium [23].

Literature suggests that tannins form chelates with iron ions while flavonoids scavenge radicals; saponins reduce surface tension collectively creating a protective barrier that inhibits corrosion [24], [25], [26]. This synergistic action enhances the overall protective effect of *Vitis labrusca* extracts against corrosion in acidic environments.

Langmuir Isotherm

From the Linear plot of C/ Θ vs C (figure1), an r^2 value of 0.99763 was obtained. K was determined to be 44.21 L/mg. The Gibbs free energy was calculated using $\Delta G_{ads} = -RT\ln(K)$ and this yielded a value of −5.86 kJ/mol kJ /mol. The negative value of $\Delta G_{ads} < 0$ indicates that the adsorption process is spontaneous [27].

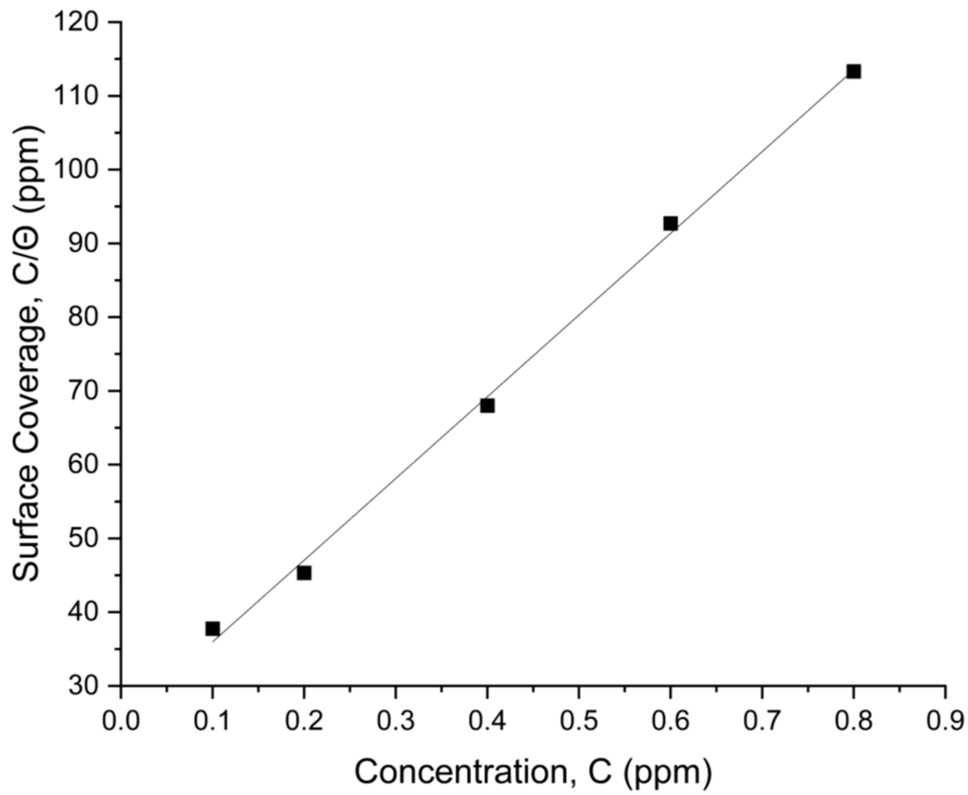

Figure 1: Linear plot of C/ Θ vs C

Freundlich Isotherm

From the linear plot of log(Θ) vs log C (figure 2), an r^2 value of 0.95534 was obtained and the K_f was calculated to be equal to 0.835 $mg^{1-1/n} \cdot L^{1/n}$, The Gibbs free energy was calculated using: $\Delta G_{ads} = -RT\ln(K_f)$. This yields $\Delta G_{ads} = -4.32$kJ/mol. This value also indicates a spontaneous adsorption process further supporting the effectiveness of *Vitis labrusca* extracts as corrosion inhibitors in acidic media[28].

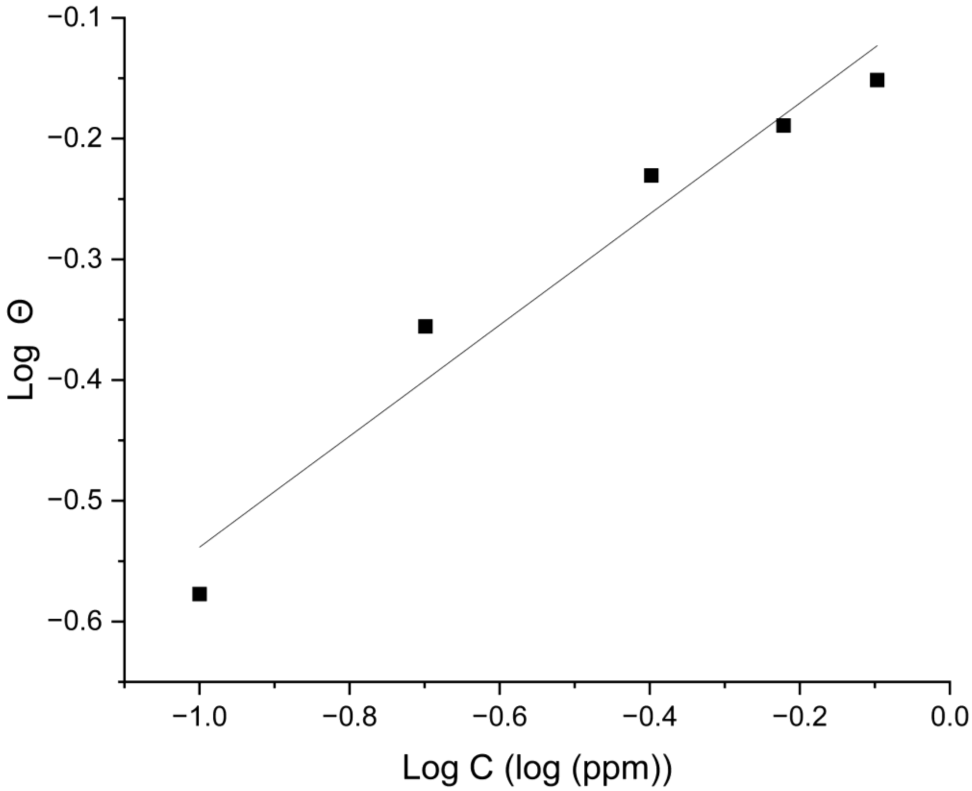

Figure 2: Linear plot of log(Θ) vs log C

Implications of the Langmuir and Freundlich Isotherm Results

The results indicate that both isotherms suggest spontaneous adsorption ($\Delta G_{ads} < 0$). However, both the Langmuir and Freundlich models yielded ΔG_{ads} values much higher than -20kJ/mol indicating physisorption [29]. Physisorption has been reported in many studies of plant extracts as corrosion inhibitors[22], [30], [31]. That the linear plots of both the Langmuir and Freundlich yield similar figures (3.91 L/mol and 3.92 respectively) implies both single and multilayer adsorption were taking place at nearly the same rate[32]. The linear plot plot of the Langmuir isotherm however yields a higher r^2 value and that makes it a better fit compared to the Freundlich isotherm.

Conclusion

This study demonstrated the effectiveness of *Vitis labrusca* extract as a sustainable and eco-friendly corrosion inhibitor for mild steel in acidic environments. Using weight loss measurements, the extract significantly reduced corrosion rates, achieving a maximum inhibition efficiency of 70.59% at a concentration of 0.8 ppm. The adsorption behaviour, as evaluated by Langmuir and Freundlich isotherms, suggests that the inhibition mechanism primarily involves physisorption. The negative Gibbs free energy values further confirmed the spontaneous nature of the adsorption process. These findings underscore the potential of *Vitis labrusca* extract as a viable green alternative to synthetic corrosion inhibitors in industrial applications. Further research should focus on optimising extraction methods, evaluating long-term performance, and exploring its efficacy under different environmental conditions and temperatures.

Acknowledgment

The authors acknowledge the staff and students of the department of chemistry federal university Lokoja for their various contributions to making this work a reality.

References

[1] H. H. Uhlig and R. W. Revie, *Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering*. Hoboken, NJ: Wiley, 2011.

[2] B. Jeffrey Ken B, "Corrosion of Metals: Factors, Types and Prevention Strategies," *Journal of Chemical Health Risks www.jchr.org JCHR*, vol. 14, no. 1, pp. 79–87, 2024, [Online]. Available: www.jchr.org

[3] A. S. Agdas and Y. Zand, "International Journal of Researches on Civil Engineering with Artificial Intelligence Analyzing the Impact of Sustained Loading and Corrosion on the Structural Integrity of Reinforced Concrete Beams: a Hybrid Neural Network Approach Citation," *Int. J. Res. Civ. Eng. AI*, vol. 1, no. 1, pp. 59–72, 2024, doi: 10.22105/SA.2021.281500.1061.

[4] M. Witek, "Structural integrity of steel pipeline with clusters of corrosion defects," *Materials*, vol. 14, no. 4, pp. 1–15, Feb. 2021, doi: 10.3390/ma14040852.

[5] G. H. Koch, M. P. H. Brongers, N. G. Thompson, Y. P. Virmani, and J. H. Payer, "'Corrosion Costs and Preventive Strategies in the United States (FHWA-RD-01-156),'" 2002.

[6] K. E. Perumal, "Corrosion risk analysis, risk based inspection and a case study concerning a condensate pipeline," *Procedia Eng*, vol. 86, pp. 597–605, 2014, doi: 10.1016/j.proeng.2014.11.085.

[7] F. Marhamati, M. Mahdavian, and S. Bazgir, "Corrosion mitigation of mild steel in hydrochloric acid solution using grape seed extract," *Sci Rep*, vol. 11, no. 1, Dec. 2021, doi: 10.1038/s41598-021-97944-7.

[8] N. E. Nya, A. I. Ikeuba, P. C. Okafor, B. U. Ugi, V. M. Bassey, and A. I. Obike, "Mild Steel Corrosion Mitigation in Sulphuric Acid via Benign Isolated Phytochemicals from <I>Viscum album</I>," *Journal of Materials Science and Chemical Engineering*, vol. 06, no. 04, pp. 132–146, 2018, doi: 10.4236/msce.2018.64014.

[9] C. I. Ekeocha, B. I. Onyeachu, I.-I. N. Etim, and E. E. Oguzie, "Review of forms of corrosion and mitigation techniques: A visual guide," *African Scientific Reports*, p. 117, Oct. 2023, doi: 10.46481/asr.2023.2.3.117.

[10] A. O. Alao, A. P. Popoola, M. O. Dada, and O. Sanni, "Utilization of green inhibitors as a sustainable corrosion control method for steel in petrochemical industries: A review," Jan. 09, 2023, *Frontiers Media S.A.* doi: 10.3389/fenrg.2022.1063315.

[11] M. J. R. da Silva *et al.*, "Phytochemical profile of Brazilian grapes (Vitis labrusca and hybrids) grown on different rootstocks," *PLoS One*, vol. 17, no. 10 October, Oct. 2022, doi: 10.1371/journal.pone.0275489.

[12] O. E. Belhaddad *et al.*, "Phytochemical characterization, biological screening and corrosion inhibition of mild steel from extracts of Juniperus oxycedrus L.," *Not Sci Biol*, vol. 15, no. 4, pp. 11635–11635, Dec. 2023, doi: 10.55779/NSB15411635.

[13] J. Redfern, M. Kinninmonth, D. Burdass, and J. Verran, "Using Soxhlet Ethanol Extraction to Produce and Test Plant Material (Essential Oils) for Their Antimicrobial Properties," *J Microbiol Biol Educ*, vol. 15, no. 1, pp. 45–46, May 2014, doi: 10.1128/jmbe.v15i1.656.

[14] S. Sasidharan, Y. Chen, D. Saravanan, K. M. Sundram, and L. Y. Latha, "Extraction, Isolation and Characterization of Bioactive Compounds from Plants' Extracts," *Afr J Tradit Complement Altern Med*, vol. 8, no. 1, pp. 1–10, 2011.

[15] NACE International and ASTM International, "NACE TM0169-2021/ASTM G31-21, Standard Guide for Laboratory Immersion Corrosion Testing of Metals," Jan. 01, 2021, *ASTM International, West Conshohocken, PA.* doi: 10.1520/G0031-21.

[16] V. C. Anadebe, O. D. Onukwuli, M. Omotioma, and N. A. Okafor, "Optimization and electrochemical study on the control of mild steel corrosion in hydrochloric acid solution with bitter kola leaf extract as inhibitor," *South African Journal of Chemistry*, vol. 71, pp. 51–61, 2018, doi: 10.17159/0379-4350/2018/v71a7.

[17] M. A. Abba-Aji, A. B. Muhammad, and D. D. Onwe, "Corrosion Inhibition of Mild Steel Determined Using Blended Bitter Leaf (Vernonnia amygdalina) Extract and Honey in Dilute H2SO4 And HCl Acid Solutions," *Arid Zone Journal of Engineering, Technology & Environment*, vol. 16, no. 4, pp. 763–772, 2020, [Online]. Available: www.azojete.com.ng

[18] A. K. Satapathy, G. Gunasekaran, S. C. Sahoo, K. Amit, and P. V. Rodrigues, "Corrosion inhibition by Justicia gendarussa plant extract in hydrochloric acid solution," *Corros Sci*, vol. 51, no. 12, pp. 2848–2856, Dec. 2009, doi: 10.1016/j.corsci.2009.08.016.

[19] P. C. Okafor, M. E. Ikpi, I. E. Uwah, E. E. Ebenso, U. J. Ekpe, and S. A. Umoren, "Inhibitory action of Phyllanthus amarus extracts on the corrosion of mild steel in acidic media," *Corros Sci*, vol. 50, no. 8, pp. 2310–2317, Aug. 2008, doi: 10.1016/j.corsci.2008.05.009.

[20] A. M. Abdel-Gaber, B. A. Abd-El-Nabey, and M. Saadawy, "The role of acid anion on the inhibition of the acidic corrosion of steel by lupine extract," *Corros Sci*, vol. 51, no. 5, pp. 1038–1042, May 2009, doi: 10.1016/j.corsci.2009.03.003.

[21] P. M. Ejikeme, S. G. Umana, and O. D. Onukwuli, "Corrosion inhibition of aluminium by Treculia Africana leaves extract in acid medium," *Portugaliae Electrochimica Acta*, vol. 30, no. 5, pp. 317–328, Mar. 2013, doi: 10.4152/pea.201205317.

[22] Y. Lanre Shuaib-Babata, M. Oloduowo Ameen, B. Olanrewaju Yusuf, and I. Owolabi Ambali, "Performance and Corrosion Inhibitive Mechanism of Prosopis Africana Pod Extracts on Mild Steel in Acidic Medium," *Uniport Journal of Engineering & Scientific Research*, vol. 6, no. 2, pp. 34–43, 2022, [Online]. Available: www.ujesr.org

[23] P. Katuwal, R. Regmi, S. Joshi, and J. Bhattarai, "Assessment on the Effective Green-Based Nepal Origin Plants Extract as Corrosion Inhibitor for Mild Steel in Bioethanol and its Blend," *European Journal of Advanced*

Chemistry Research, vol. 1, no. 5, Sep. 2020, doi: 10.24018/ejchem.2020.1.5.16.

[24] E. E. Oguzie, “Evaluation of the inhibitive effect of some plant extracts on the acid corrosion of mild steel,” *Corros Sci*, vol. 50, no. 11, pp. 2993–2998, Nov. 2008, doi: 10.1016/j.corsci.2008.08.004.

[25] N. C. Michael, “The Corrosion Inhibition of Mild Steel in Sulphuric Acid Solution by Flavonoid (Catechin) Separated from Nypa Fruticans Wurmb Leaves Extract,” *Science Journal of Chemistry*, vol. 2, no. 4, p. 27, 2014, doi: 10.11648/j.sjc.20140204.11.

[26] F. Chen, Q. Tang, H. Ma, K. Bian, N. P. Seeram, and D. Li, “Hydrolyzable Tannins Are Iron Chelators That Inhibit DNA Repair Enzyme ALKBH2,” *Chem Res Toxicol.*, vol. 32, no. 6, pp. 1082–1086, Jun. 2009, doi: 10.1021/acs.chemres-tox.8b00398.

[27] L. Taofeek Popoola, A. Shehu Grema, G. Kayode Latinwo, B. Gutti, and A. Saheed Balogun, “Corrosion problems during oil and gas production and its mitigation,” *International Journal of Industrial Chemistry (IJIC)*, vol. 4, no. 35, 2013, [Online]. Available: http://www.industchem.com/content/4/1/35

[28] S. O. Adejo, M. M. Ekwenchi, J. A. Gbertyo, T. Menengea, and J. O. Ogbodo, “Determination of Adsorption Isotherm model best fit for methanol leaf extract of Securinega virosa as corrosion inhibitor for corrosion of mild steel in HCl,” *JOURNAL OF ADVANCES IN CHEMISTRY*, vol. 10, no. 5, pp. 2737–2742, Jun. 2014, doi: 10.24297/jac.v10i5.891.

[29] A. Royani *et al.*, “Unveiling green corrosion inhibitor of Aloe vera extracts for API 5L steel in seawater environment,” *Sci Rep*, vol. 14, no. 1, Dec. 2024, doi: 10.1038/s41598-024-64715-z.

[30] A. Miralrio and A. E. Vázquez, “Plant extracts as green corrosion inhibitors for different metal surfaces and corrosive media: A review,” Aug. 01, 2020, *MDPI AG*. doi: 10.3390/PR8080942.

[31] J. Emmanuel, F. Ngasoh, A. Bello, V. Anye, and A. Onwualu, “Phytochemical Study of Some Plant Extracts to Assess their Synergistic Corrosion Inhibition Performance-A Comparative Analysis,” Jun. 14, 2024. doi: 10.21203/rs.3.rs-4498767/v1.

[32] M. Abdullah Dar, “A review: Plant extracts and oils as corrosion inhibitors in aggressive media,” Jun. 21, 2011. doi: 10.1108/00368791111140431.