ZIBELINE INTERNATIONAL PUBLISHING

Acta Chemica Malaysia (ACMY)

DOI: http://doi.org/10.26480/acmy.02.2024.66.80

ISSN: 2576-6724 (Print)
ISSN: 2576-6732 (Online)
CODEN: ACMCCG

CrossMark

RESEARCH ARTICLE

GREEN CORROSION INHIBITION: UTILIZING BANANA PSEUDO-STEM EXTRACT TO PROTECT MILD STEEL IN ACIDIC ENVIRONMENTS

Akpeji Bamidele Honesty[a], Nwabuoku Deborah Akachukwu[b], Adedokun John[c]

[a]Department of Chemistry, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria.
[b,c]Chemical Engineering Department, College of Engineering, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria.
Corresponding author email: nwabuokudeborah12@gmail.com

ARTICLE DETAILS

Article History:

Received 15 April 2024
Revised 23 May 2024
Accepted 26 June 2024
Available online 28 June 2024

ABSTRACT

This research investigates the corrosion inhibition potential of banana pseudo-stem extract on mild steel in acidic environments. Utilizing gravimetric analysis, the study evaluates inhibition efficiency over time and with varying inhibitor concentrations. Results indicate a maximum inhibition efficiency of 97% after 24 hours with 5% v/v inhibitor concentration and 0.5 M HCl. Phytochemical analysis reveals the presence of proteins, steroids, carbohydrates, flavonoids, tannins, saponins, and glycosides in the extract, supporting its role as a green corrosion inhibitor. Adsorption of inhibitor molecules aligns with Langmuir and Freundlich adsorption isotherm models, confirmed by Gibb's free energy values. Optimization through Response Surface Methodology predicts optimal conditions for maximum weight loss. Additionally, the study examines inhibition capacity in 0.5 M and 1.0 M HCl solutions, highlighting the extract's efficiency in reducing corrosion rates. This research contributes valuable insights into the inhibition characteristics of banana pseudo-stem extract under specific conditions, suggesting its potential as an effective corrosion inhibitor for mild steel.

KEYWORDS

Corrosion, Mild Steel, Banana pseudostem, Corrosion inhibitor, Hydrochloric Acid.

1. Introduction

Corrosion, an electrochemical process, poses a significant challenge across various industries worldwide. Metals and alloys, extensively used in engineering, are prone to deterioration when not properly maintained, succumbing to atmospheric gases, moisture, and other chemicals. This phenomenon, known as corrosion, results in substantial economic losses. In 2016, the global corrosion cost amounted to US$ 2.5 trillion annually, equivalent to 3.4% of the GDP. Neglecting corrosion prevention can lead to severe consequences such as metal loss, production downtime, leaks, and increased cleanup expenses (Gruca, 2019). Corrosion occurs when metals interact with moisture and oxygen, leading to a chemical reaction and electron flow on the corroded cell's surface. This accelerates the transformation of metal into low-grade ore, causing degradation and loss of useful properties. Mild steel, commonly used in various industries due to its cost-effectiveness, is particularly susceptible to corrosion (Alimohammadi et al., 2023).

To combat corrosion, industries utilize synthetic corrosion inhibitors, especially in acidic environments, to effectively control the deterioration of metals. Corrosion inhibitors, substances added in small amounts to corrosive mediums, work by forming protective films on metal surfaces, combining with corrosion product films, or forming precipitates that visibly coat and protect metal surfaces (Miralrio and Espinoza Vázquez, 2020). However, the widespread use of chemical inhibitors is constrained by environmental concerns, primarily due to their toxicity. Inorganic inhibitors like lead and chromium pose significant health risks when released into the environment (Gunavathy and Murugavel, 2012). As a result, there is a growing interest in natural organic plant extracts as environmentally friendly corrosion inhibitors, known as green corrosion prevention.

The utilization of natural organic compounds, such as Musa acuminate (banana pseudo stem extract), as corrosion inhibitors presents an attractive alternative. These compounds are relatively inexpensive, non-toxic, and readily available, often as agro-waste or agroindustrial waste. Previous studies have shown promising results regarding the effectiveness of plant extracts in inhibiting corrosion. For instance, research on Musa paradisiaca peel extract and banana peel extract demonstrated significant inhibition efficiency on mild steel in acidic mediums (Amodu et al., 2019; Bala Manikandan et al., 2019). This study aims to investigate the effectiveness of Musa acuminate (banana pseudo stem extract) as a green corrosion inhibitor for mild steel in hydrochloric acid. By exploring natural alternatives, this research contributes to the development of sustainable corrosion prevention strategies, addressing both economic and environmental concerns.

2. Materials and Methods

The mild steel for this study was sourced from a certified iron sheet merchandiser in Warri, Delta State. Also, the banana pseudostems were gotten from Ugbomoro Farm in Warri, Delta State. The Department of Mechanical Engineering, College of Engineering and Technology, Delta State, Nigeria, processed mild steel into standard coupons in their workshop. The surface organization of the coupons that were mechanically polished was done with the aid of sandpaper, washed by ethanol, degreased using acetone, and later dried at atmospheric temperature. Analytical grades of hydrochloric acid,acetone,and ethanol solutions were used, while deionized water was employed for sample

Quick Response Code	Access this article online	
	Website: www.actachemicamalaysia.com	**DOI:** 10.26480/acmy.02.2024.66.80

Cite the Article: Akpeji Bamidele Honesty, Nwabuoku Deborah Akachukwu, Adedokun John (2024). Green Corrosion Inhibition: Utilizing Banana Pseudo-Stem Extract to Protect Mild Steel in Acidic Environments. *Acta Chemica Malaysia, 8(2): 66-80.*

preparation. . The Jenway model meter (pH = 3510), vacuum drying oven (DZF 6021), digital weighing balance (JJ224BC), and beakers, were utilized for this oxidation process study.

2.1 Sample Preparation and Characterization

The Banana Pseudo stem were cleansed by thorough cleansing with clean water and then air dried before it was pulverized into powdered form with the aid of a kenwood laboratory blender. The sample (banana pseudo stem) was air dried for some days to remove the moisture content before it was grinded into powder with a Blender. Then it was sieved to get a smooth powdery form, in order to get a good extract during the extraction process.The sample was thereafter kept in a dessicator before use.

2.2 Phytochemical properties of banana pseudo stem extract

The phytochemical screening procedure was followed using the standard method of (Deepa and Sivakumar, 2020). The presence of these compounds has been reported to promote the inhibition of Mild steel in aggressive acid media. Test for Alkaloids, Flavonoids, Saponins, Steroids, Tannins, Glycosides, Terpenoids, phenols and Anthroquinones were carried out. (Odeja et al., 2015)

2.3 Analysis of Fourier Transform Infrared (FTIR) Spectroscopy

This method was used to determine the chemical composition, functional group and the type of bonding for organic inhibitor adsorbed on the metal surface. It was used to determine the degree of acetylation. The substrates were examined using Buck scientific infrared spectrophotometer model 530 with the range 500 – 4000cm-1 (wavelength). Potassium bromate (KBr) was used as a background material for the analysis.

2.4 Extraction of Banana Pseudo stem as inhibitor

The extraction was carried out using Reflux extraction.Here the solvent used for extraction was the Hydrochloric acid .250ml of HCl was added to 4g of the powdered extract in a conical flask which was fixed to the end of the 500ml Soxhlet apparatus. The whole set up is then heated on a heating mantle at a temperature of 80°C. The solvent was then allowed to remain in contact with the powdered banana pseudo material for 48 hr and the excess solvent was recovered using rotary evaporator. The extract was then separated from the solid residue (insoluble components of the pseudo stem) using filtration process with the aid of a filter paper.

2.5 Technique of Experimentation

Weight loss method was used in this study. The mild steel specimen was cut into coupons of the required sizes (4cm×2cm×0.1cm) and drilled with a hole of about 0.1 cm. The mild steel was abraded with a series of silicon carbide abrasive paper.It was then dipped in Ethanol and immersed also in acetone. The weight of the mild steel was taken. Mild steel specimens thereafter was then immersed in a specific volume of a concentration of HCl (0.5M and 1M) in a beaker with and without addition of different concentrations of banana pseudo stem extract. After some days interval of 24,48 and 72 hours at room temperature, the mild steel specimens were retrieved and dipped in distilled water, immersed in ethanol solution, scrubbed with a brush, to remove residual acids, and inhibitor and then be dried in acetone before reweighed. (Oshomogho et al., 2020).

2.6 Determination of Weight loss

The loss in weight loss of mild steel metal coupon is ascertained using equation 1

$$Weight\ loss\ (g) = Wo - Wf \quad (1)$$

Where, Wo is the initial mild steel coupon weight, Wf is the final mild steel coupon weight after oxidation study.

2.7 Determination of the Inhibition Efficiency

The inhibition efficiency is determined using equation (2) below:

$$IE\ (\%) = \frac{W1-W2}{W1} \times 100 \quad (2)$$

Where,

W1 = weight loss in the absence of inhibitor; W2 = weight loss in the presence of inhibitor. (Bala Manikandan et al., 2019).

2.8 Calculation of corrosion rate

The corrosion rate was determined using equation 3.

$$Corrosion\ rate\ (mmpy) = \frac{KW}{ATD} \quad (3)$$

Where, k is a constant with value as 87.6, W is the weight loss (mg), A is the cross sectional area (mm2), T is the time (hrs), D is the density (g/cm3). (Okewale, 2017).

2.9 Optimization studies of corrosion inhibition process on Mild steel

In order to optimize the inhibition of corrosion of mild steel in 0.5M and 1.0M, HCl using banana pseudo stem extract, inhibitor extract concentration, immersion time, and acid concentration on the inhibitor efficiency was investigated and optimized using Response Surface Methodology (RSM). A 17 run Box-Behnken Design (BBD) plan was generated and the results were analyzed and modelled using Design Experts 13 software.

Analysis of Variance (ANOVA) was used as a statistical analysis method to compare and evaluate the significance of the model and the model terms.

2.10 Adsorption study

Molecular adsorption will also be used to further explain the inhibition of corrosion. The surface charge and nature of the metal, organic compounds' chemical structures, types of aggressive media, and molecule charge distribution are identified as factors influencing the process of adsorption.

Langmuir adsorption isotherm

$$\frac{C}{\emptyset} = \frac{1}{K} + C \quad (4)$$

Where;

where C is the inhibitor concentration, is the degree of surface covered by the inhibitor, and K is the adsorption equilibrium constant obtained from a plot of C/ against C. K is also related to the standard free energy of adsorption (Δ). Using equation 3.6

$$\Delta G = -RT \ln(55.5 * K) \quad (5)$$

Freundlich adsorption isotherm.

The fitting of the ideal system will be performed by fitting the experimental data to the Freundlich adsorption isotherm (Okewale, 2017). This is expressed in equation (6).

$$\theta = KC\eta \quad (6)$$

Equation 3.8 can be rewritten as;

$$\ln\theta = K + \eta \ln C \quad (7)$$

Where; θ is the degree of surface coverage, k is the equilibrium constant of adsorption, and η is the molecular interaction parameter.

3. Results and Discussion

3.1 Ftir Result of The Banana Pseudo Stem Extract

Figure 1 gives the FTIR result of the banana pseudo stem extract. It can be seen that frequency (3785cm-1, 3703cm-1 and 3406cm-1) depict RO-H (Alcohol) wide rounded broad band,. The medium broad band with a weak intensity of frequency (2919cm-1, 2855cm-1) corresponds to C-H group , the broad band 1601cm-1 revealed the alkene group, ($C =$ C). The sharp band (1711cm-1) corresponds to C = O stretch ketone, The presence of the carbonyl double bond carbon group in the banana pseudo stem extract also suggests it to be a good corrosion inhibitor on mild steel in an acidic medium.

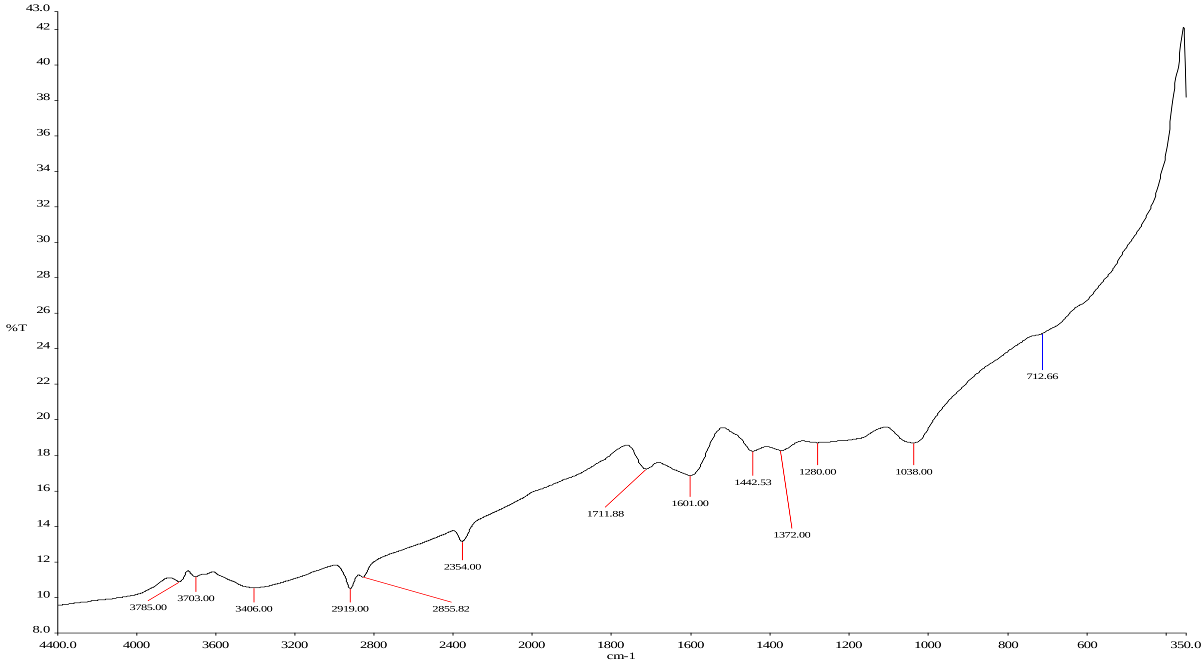

Figure 1: FTIR Spectra for banana pseudo stem extract.

3.2 Phytochemical Screening

A sound qualitative analysis test of phytochemical components was carried out on the banana pseudo stem extract. Qualitative determination can be seen from the change in colour. The presence of compounds such as proteins, steroids, carbohydrate, flavonoids, tannins, saponins, and glycosides showed that the banana pseudo stem extract has potential to inhibit corrosion in hydrochloric acid. The presence of these compounds has been reported to promote the corrosion inhibition of mild steel in acid media (Umoren et al., 2006).

Table 1: Phytochemical Analysis of Banana Pseudo Stem Extract

Test Performed	Results
Total Volume of sample	25mls
Appearance	Liquid
Colour Description	Light brown
Saponin	+
Reducing Sugars	-
Alkaloids	-
Protein (Amino acids)	+
Steroids	+
Tannins	+
Anthraquinones	-
Phenolic compounds	-
Carbohydrate	+
Terpenoids	-
Glycoside	+
Flavonoids	+

Keys: (+) indicates present, (-) indicates absent.

3.3 Optimization and Statistical Analysis

In order to optimize the inhibition of corrosion of mild steel in 0.5M and 1.0M, HCl using banana pseudo stem extract, inhibitor extract concentration, immersion time, and acid concentration on the inhibitor efficiency was investigated and optimized using Response Surface Methodology (RSM). A 17 run Box-Behnken Design (BBD) plan was generated and the results were analyzed and modelled using Design Experts 13 software.

Analysis of Variance (ANOVA) was used as a statistical analysis method to compare and evaluate the significance of the model and the model terms as seen in Table. 2 below.

The ANOVA result gives a F-value of 69.28 and a p-value of <0.0500 which shows that the model generated is significant hence the 2FI model represents the behaviour.

Table 2: Analysis of Variance of Regression Equation (ANOVA) I

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	0.5454	6	0.0909	69.28	< 0.0001 significant
A-Inhibitor concentration	0.0130	1	0.0130	9.89	0.0104
B-Immersion time	0.0883	1	0.0883	67.33	< 0.0001
C-Acid concentration	0.1456	1	0.1456	111.01	< 0.0001
AB	0.0018	1	0.0018	1.34	0.2744
AC	0.0038	1	0.0038	2.93	0.1178
BC	0.0225	1	0.0225	17.13	0.0020
Residual	0.0131	10	0.0013		
Cor Total	0.5585	16			

Table 3 shows that the Predicted R^2 of 0.9364 is in reasonable agreement with the Adjusted R^2 of 0.9624; i.e. the difference is less than 0.2. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 28.418 indicates an adequate signal. This model can be used to navigate the design space.

Table 3: Fit Statistics

Std. Dev.	0.0362	R^2	0.9765
Mean	0.2361	Adjusted R^2	0.9624
C.V. %	15.34	Predicted R^2	0.9364
		Adeq Precision	28.4176

In this case Inhibitor Concentration (A), Immersion time (B), and Acid Concentration (C), are significant model terms as shown in Table. 4. These interactions between factors were suggested as major factors that affect the corrosion of Mild Steel in 0.5M & 1M HCl using extract. The coefficient estimate represents the expected change in response per unit change in factor value when all remaining factors are held constant. The intercept in an orthogonal design is the overall average response of all the runs. The coefficients are adjustments around that average based on the factor settings. When the factors are orthogonal the VIFs are 1; VIFs greater than 1 indicate multi-colinearity, the higher the VIF the more severe the correlation of factors. As a rough rule, VIFs less than 10 are tolerable.

Table 4: Coefficients in Terms of Coded Factors						
Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.1528	1	0.0121	0.1259	0.1797	
A-Inhibitor concentration	-0.0465	1	0.0148	-0.0794	-0.0136	1.82
B-Immersion time	0.1213	1	0.0148	0.0884	0.1543	1.82
C-Acid concentration	0.1912	1	0.0181	0.1507	0.2316	1.06
AB	-0.0168	1	0.0145	-0.0492	0.0156	1.12
AC	-0.0391	1	0.0228	-0.0900	0.0118	1.97
BC	0.0946	1	0.0228	0.0437	0.1455	1.97

In an effort to optimize the model, the desirability function of the RSM was selected as a valid criterion. The optimum process variables obtained from the 2FI model developed were 4.45307%v/v inhibitor concentration, 0.09685M concentration of HCl, 59.762hours exposure time and with a predicted weight loss of 0.00387252g as shown in Table. 5.

Table 5: Model Optimization Values				
	Time (hrs)	Conc of HCl (M)	Conc of Inhibitor (%v/v)	Weight Loss (g)
Optimized Conditions	59.762	0.09685	4.45307	0.00387252

3.4 Model accuracy check

To get an adequate model, an accuracy check is indispensable. The model accuracy was checked by comparing the predicted and experimental corrosion rate. Figure 3 shows the linear relationship between them. Also, a normal plot of residuals between the normal probabaility (%) and the internally studentized residuals was also obtaiined. Figure 2 shows the relationship between them. The straight line means that no response transformation was requiired and there was no apparent problem with normality.

3.5 Optimization And Statistical Estimates Of Banana Pseudo Stem Extract

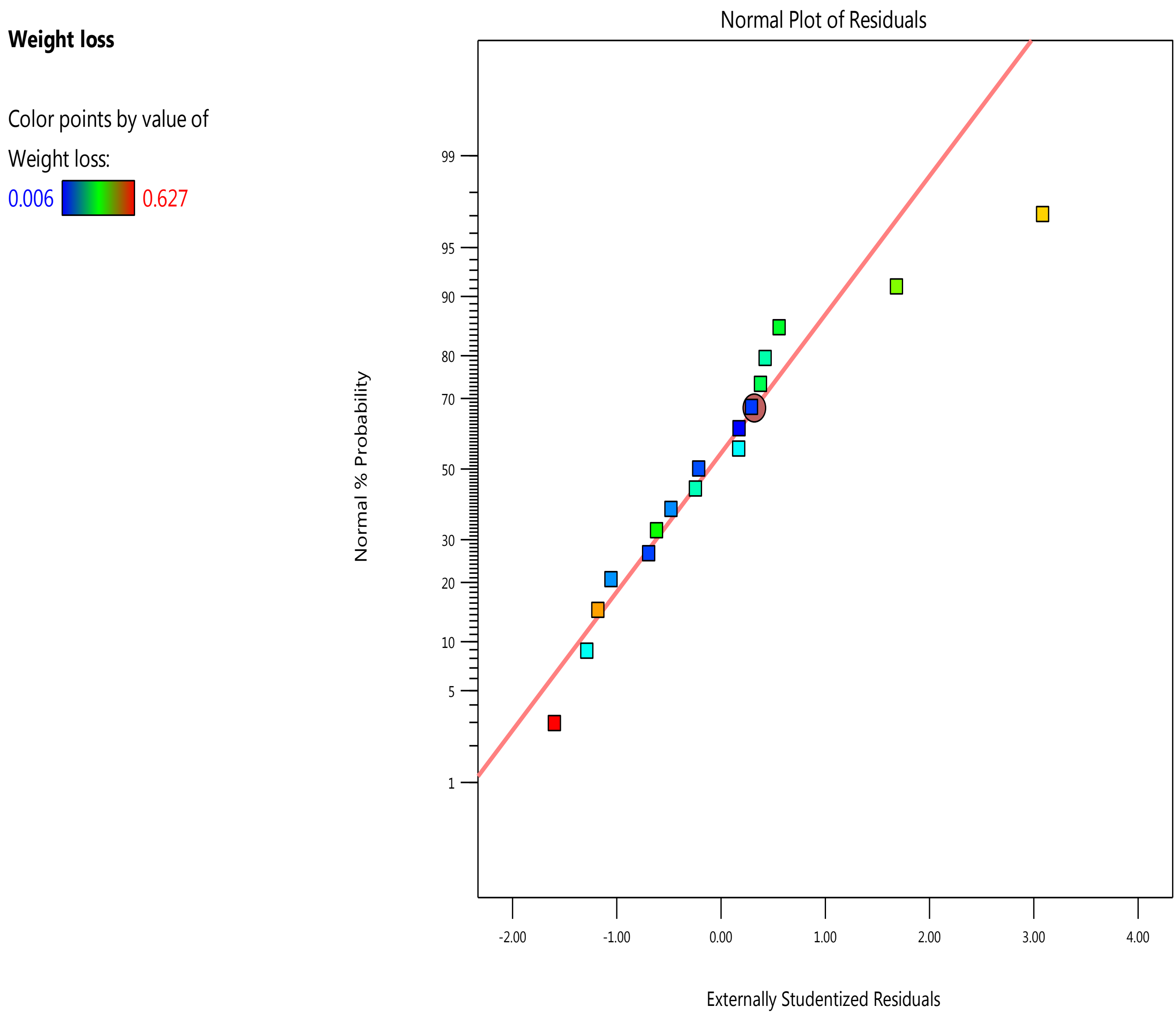

Figure 2: Normal plot of residue

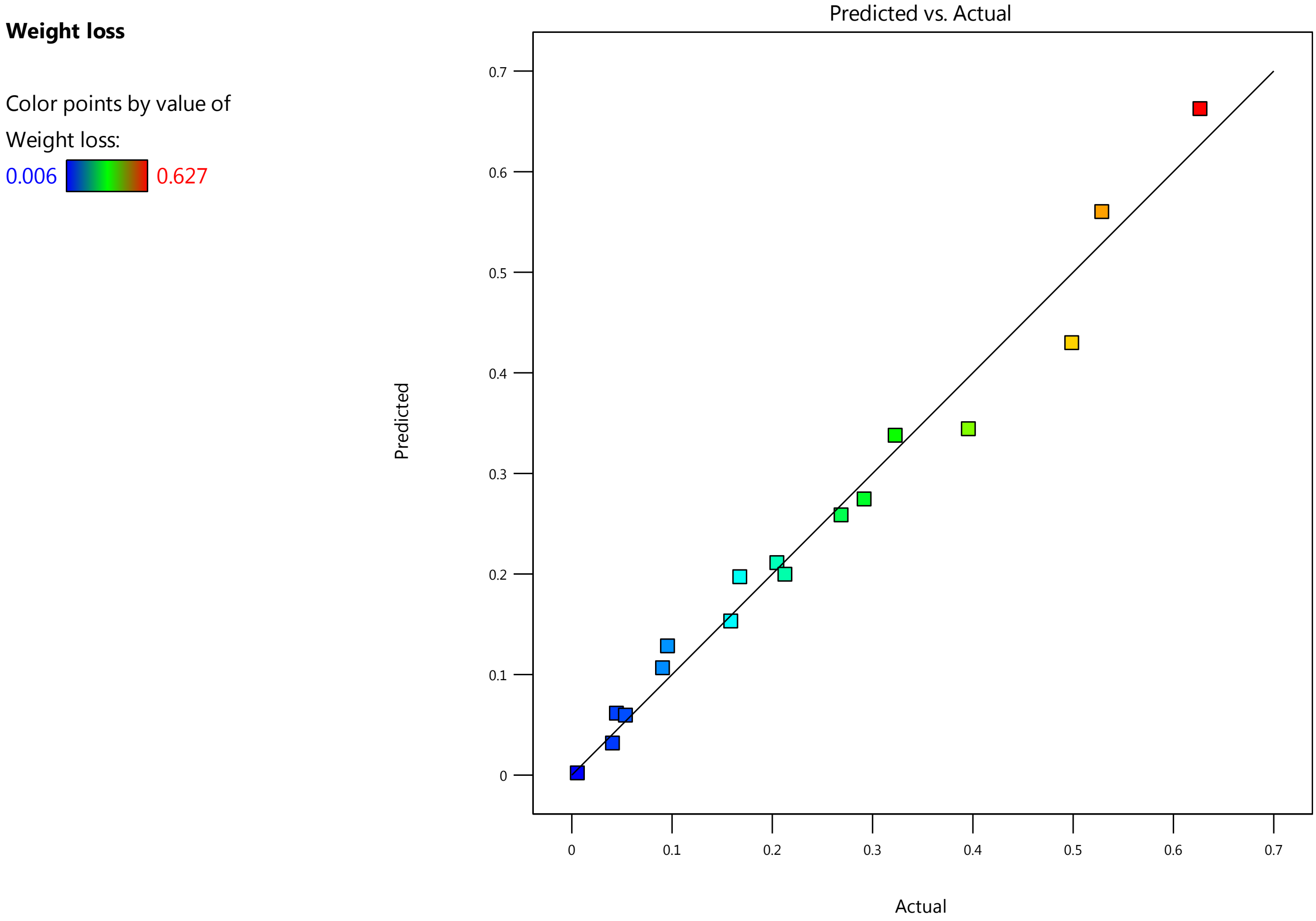

Figure 3: Predicted corrosion rate versus the actual corrosion rate

3.6 Surface response plots

To account for the surface response behaviour, 3-D response surface plots and contour plots were presented in the figure 4 to figure 10 respectively.

The surface plot gives an important evidence on the surface behaviour within the experimental design. The highest values of the response were credited to the considered factors in the design space as described by their peak in the 3-D response plot.

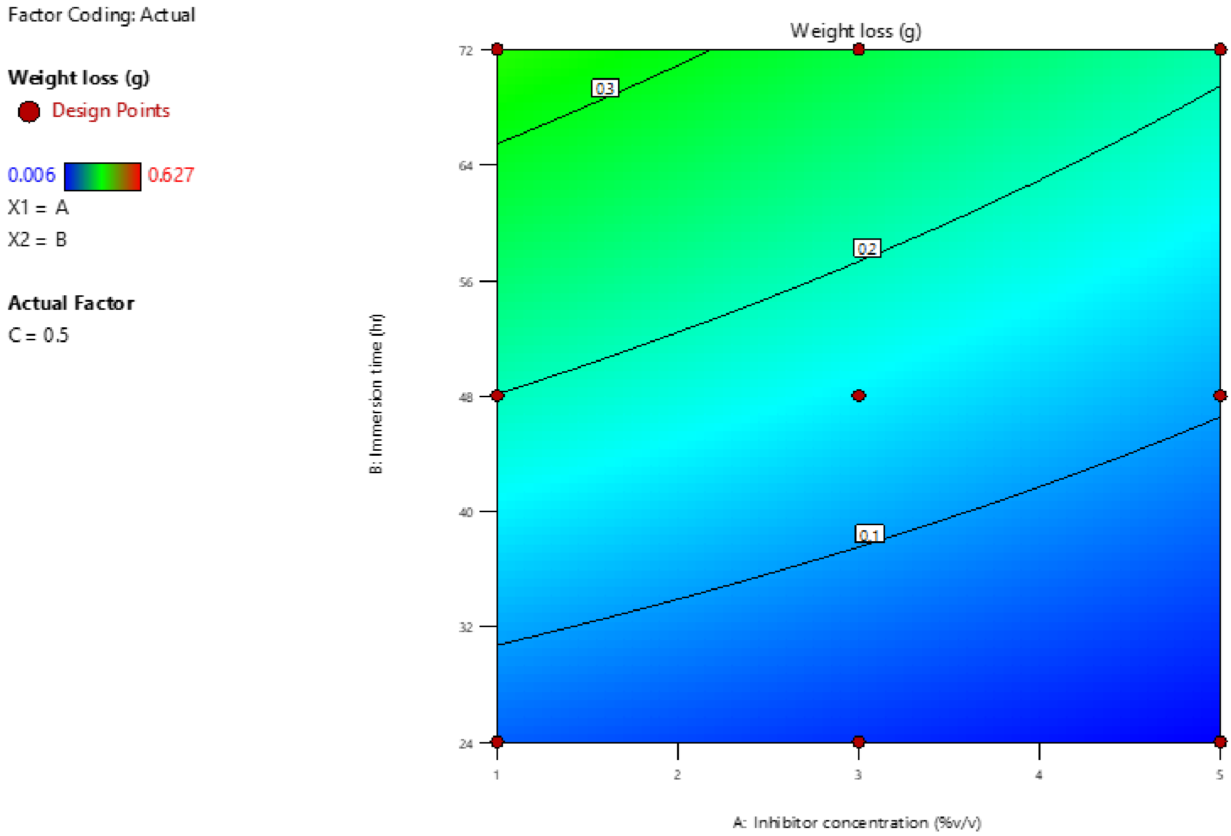

Figure 4: Design plot for the interaction between the exposure time and the inhibitor concentration.

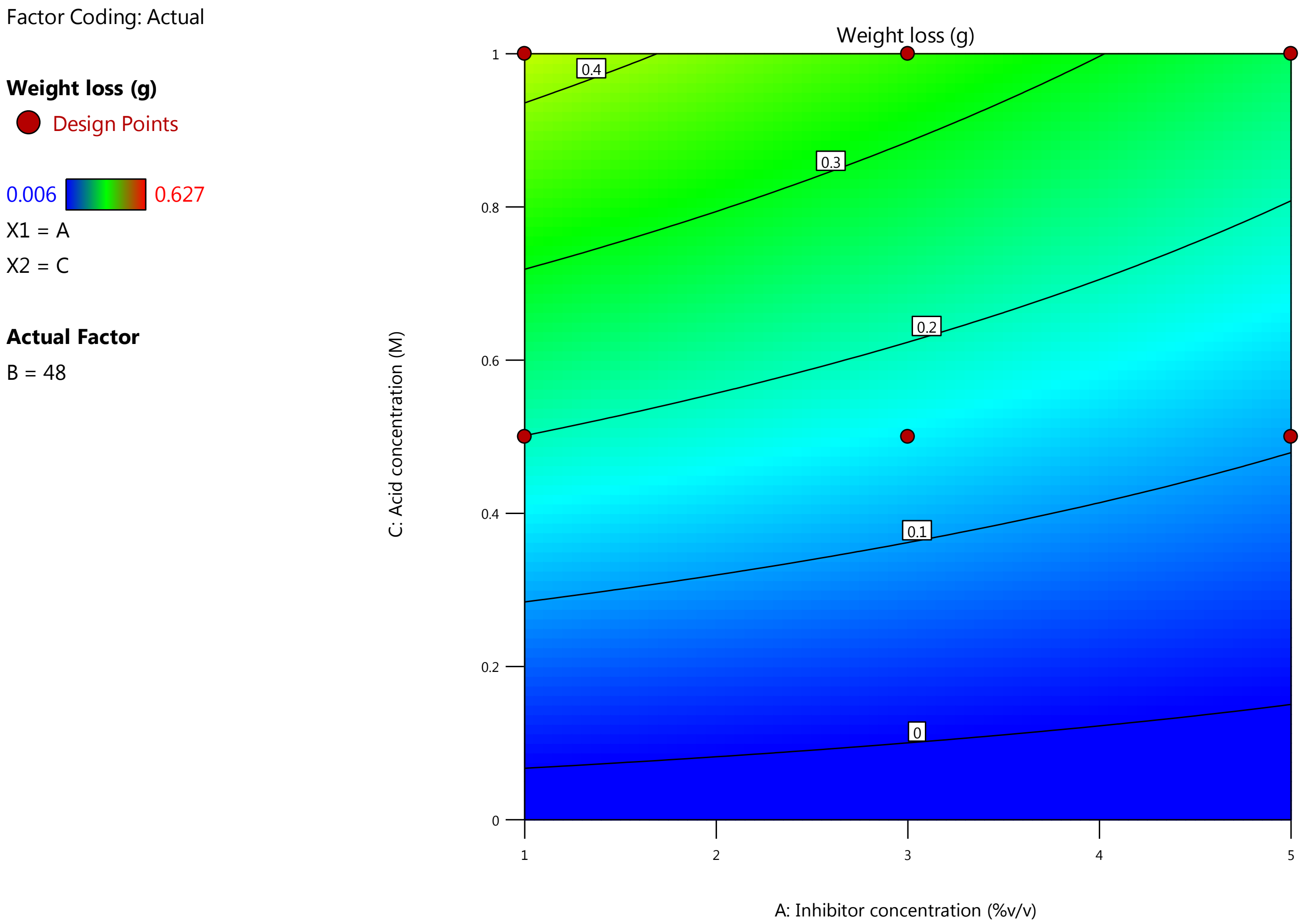

Figure 5: Design plot for the interaction between the Acid concentration and the inhibitor concentration

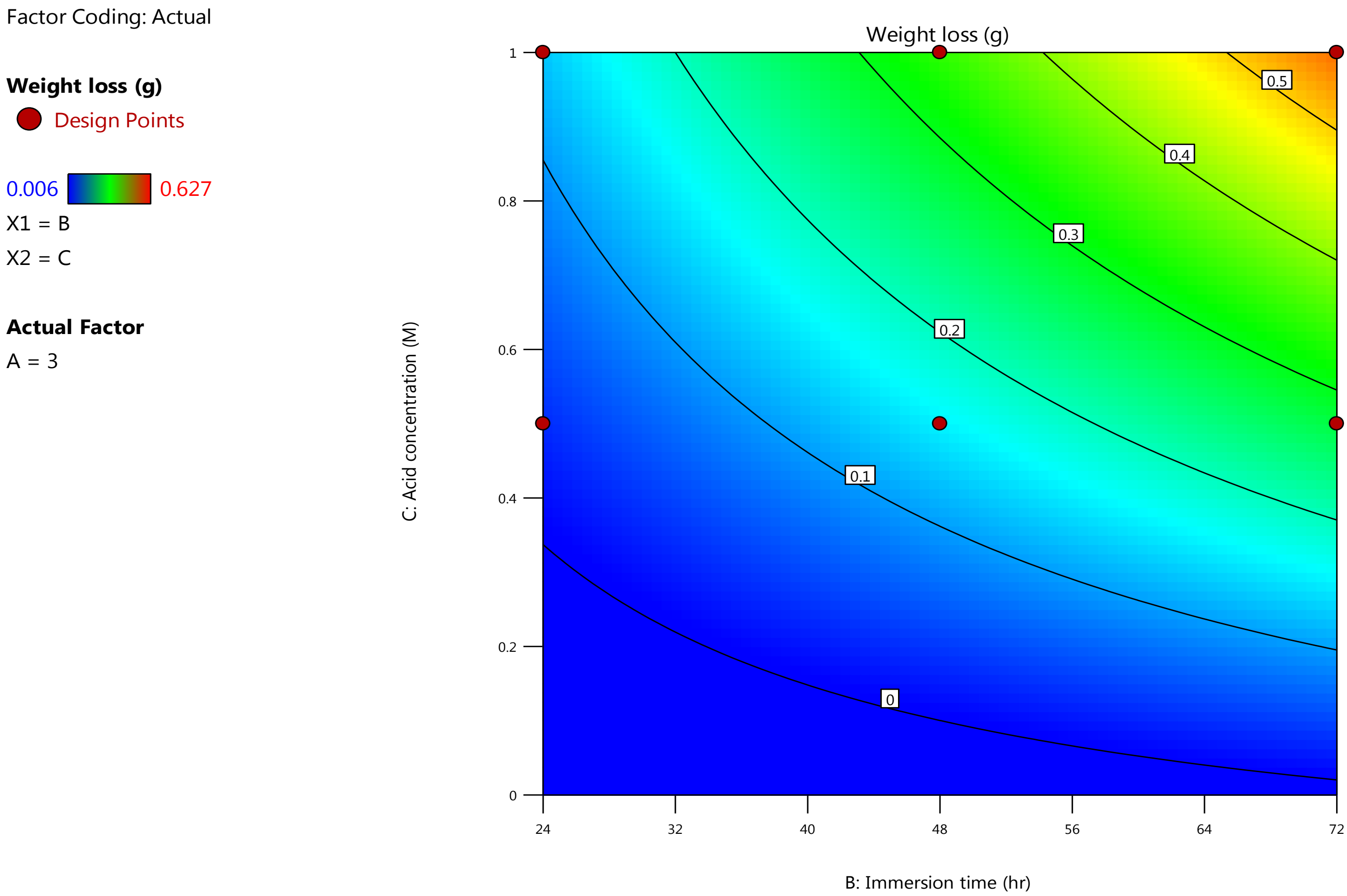

Figure 6: Design plot for the interaction between the Immersion time and the Acid concentration

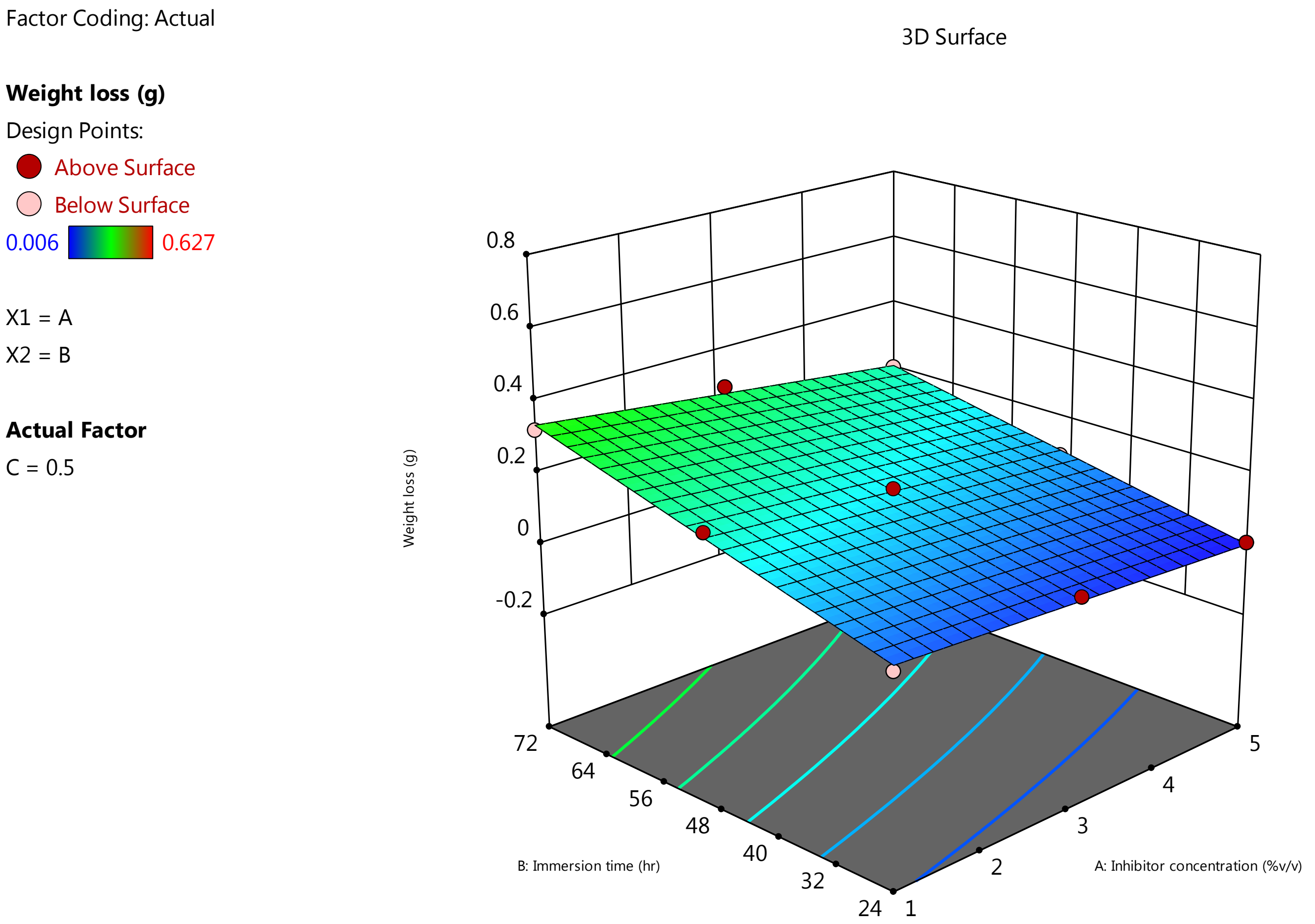

Figure 7: 3-D response surface plot for the interaction between inhibitor concentration, immersion time and interface with weight loss

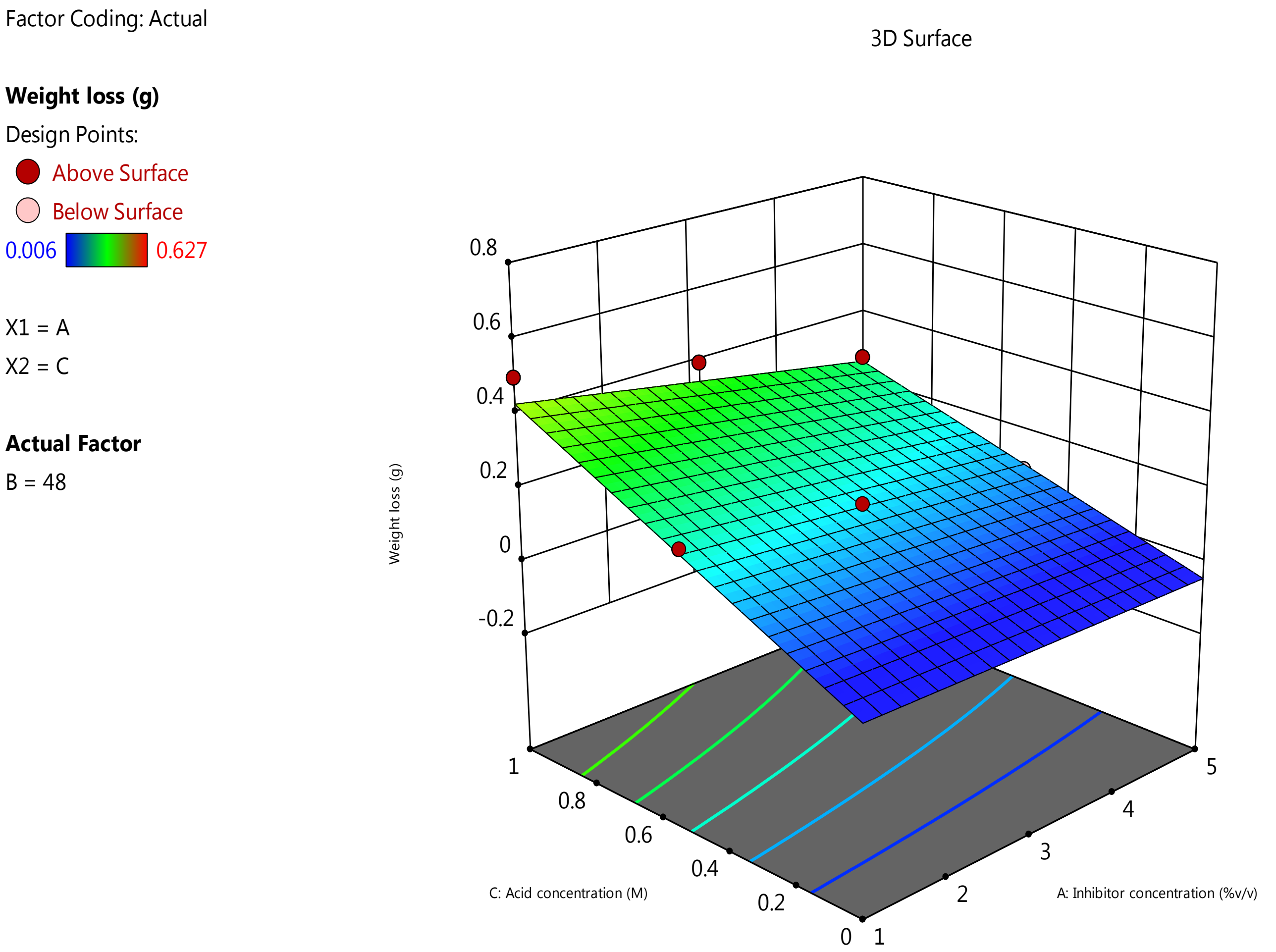

Figure 8: 3-D response surface plot for the interaction between inhibitor concentration, Acid concentration and interface with weight loss

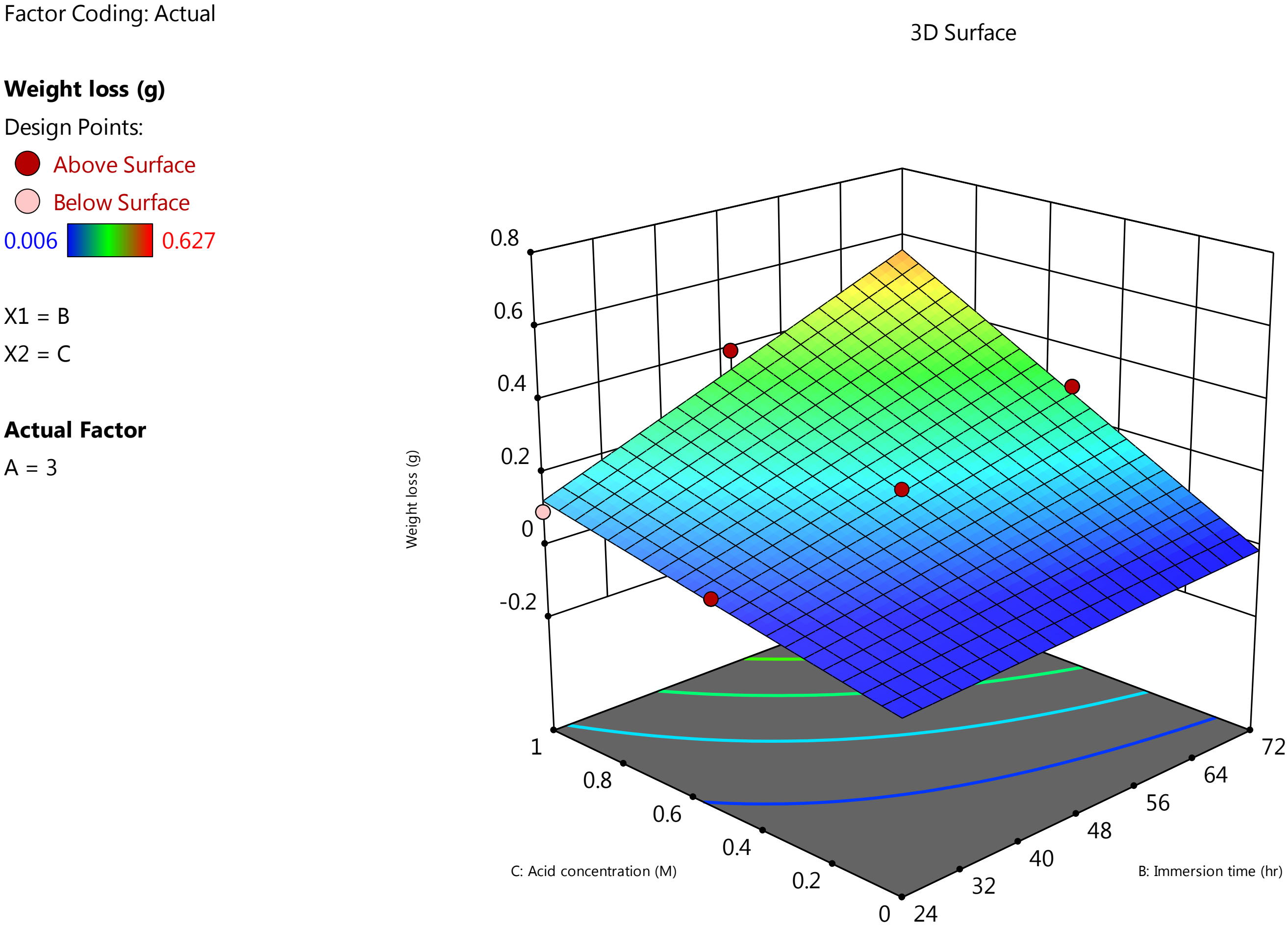

Figure 9: 3-D response surface plot for the interaction between Acid Concentration, immersion time and interface with weight loss

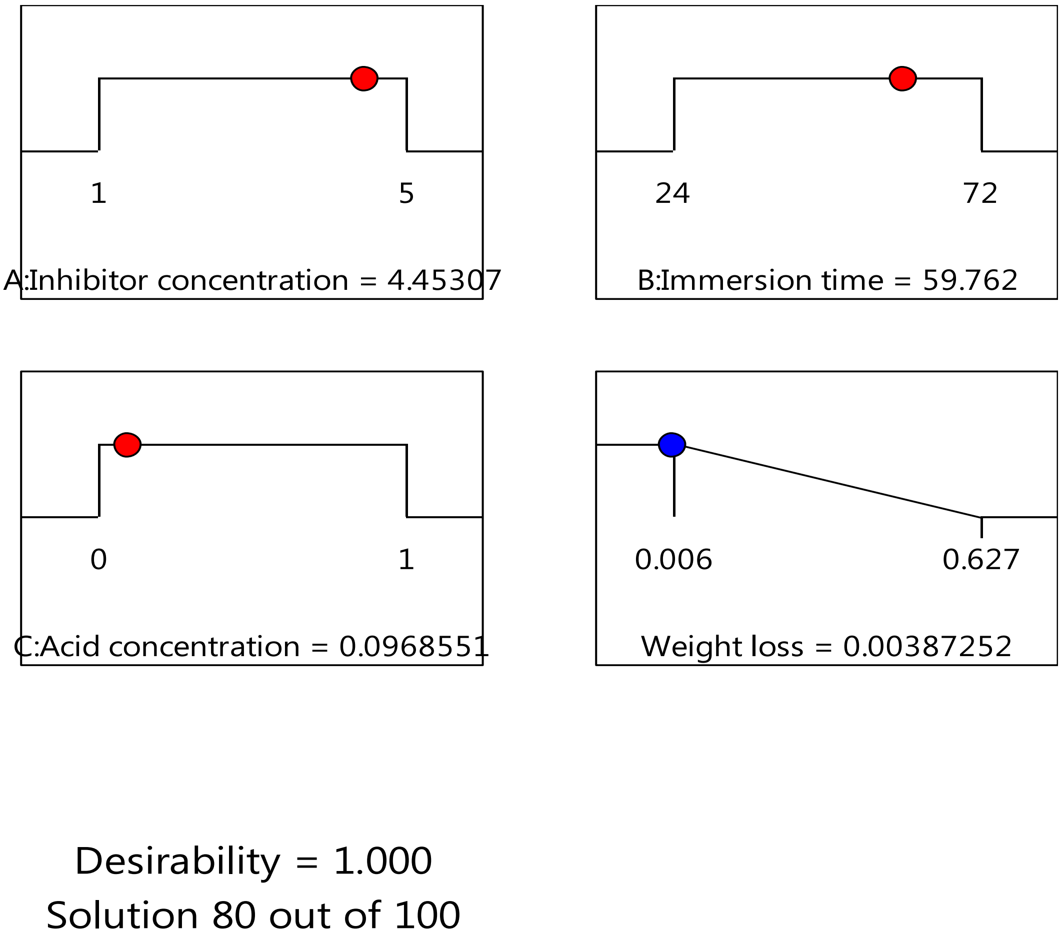

Figure 10: Showing the Ramp plot for the optimization

3.7 Weight Loss Analysis

The result obtained from weight loss method for mild steel immersed in 0.5M and 1.0M HCl in the absence and presence of different concentration of inhibitor (banana pseudo stem extract) is shown in figure 11 and figure 12. It can also be seen that the result obtained denotes a higher numerical value of weight loss for control, (without BPSE). It further revealed that the sample with the highest inhibitor concentration had the lowest weight loss while sample without inhibitor had the highest weight loss. It can also be seen that comparing figure 4.2 and 4.3 that as the concentration of the HCL medium increases, the weight loss increases also (Sanni, 2018).

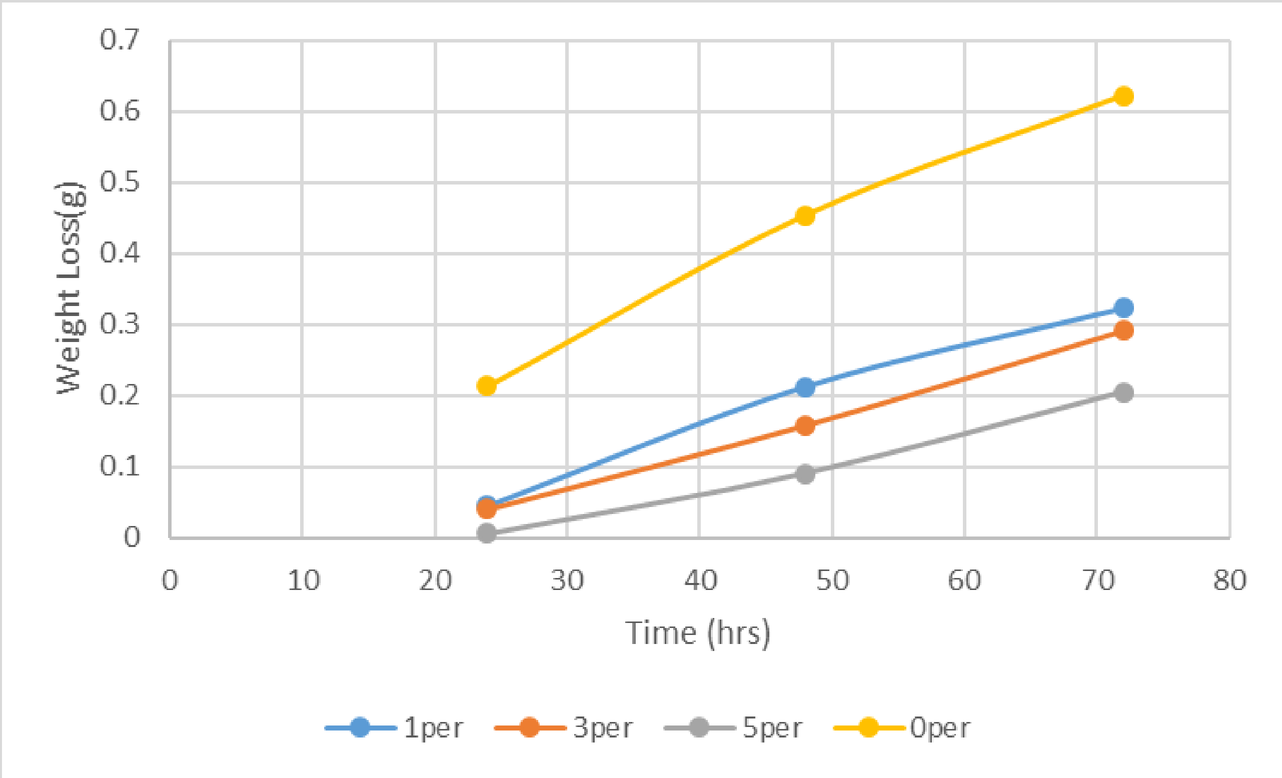

Figure 11: The graph of weight loss against immersion time at room temperature for 0.5 M HCL

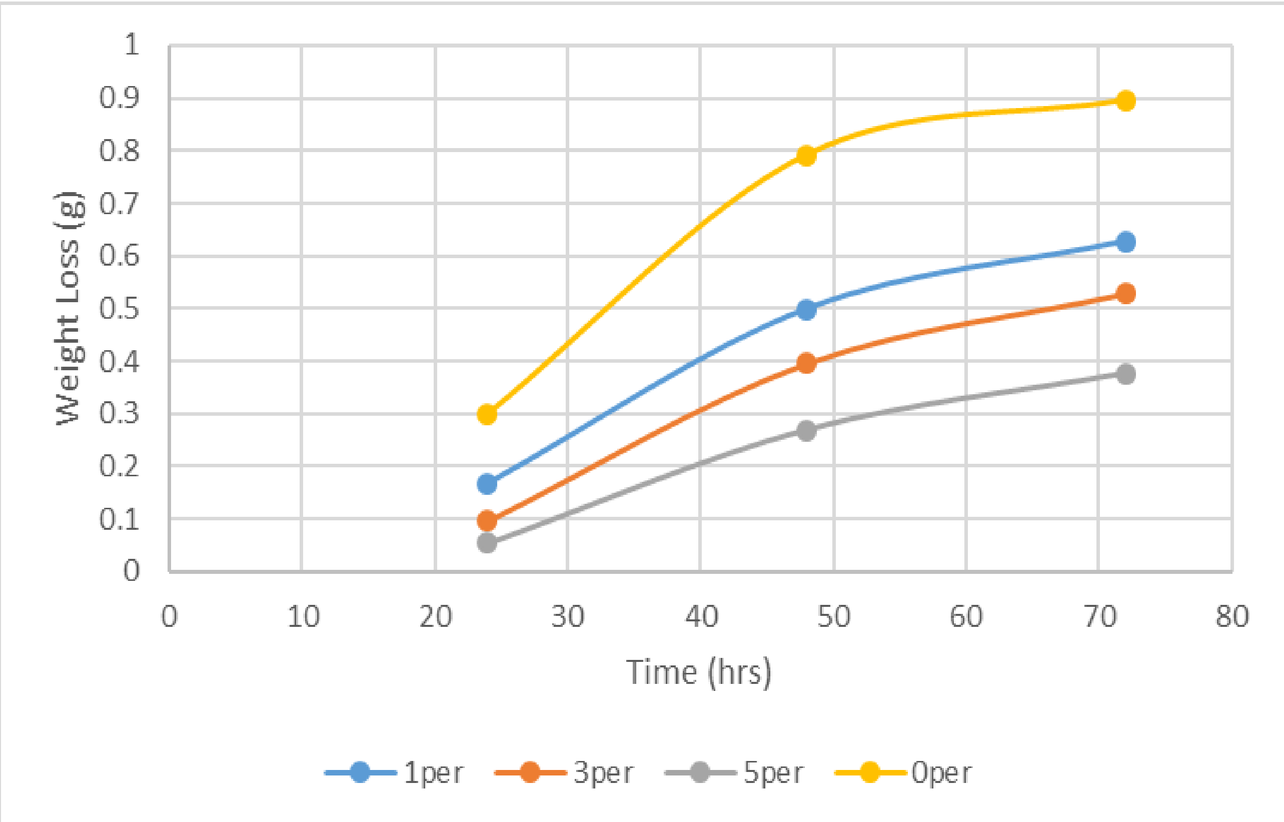

Figure 12: The graph of weight loss against immersion time at room temperature for 1.0M HCL

3.8 Effect of Inhibitor Concentration on Weight Loss

It can be seen from figure 13 and figure 14 that as the inhibitor concentration increases, weight loss decreases. This indicate that an increase in extract concentration increase the number of inhibitor molecules adsorbed on the metal surface and reduces the area of surface that is available for the direct attack (Yetri et al., 2015).

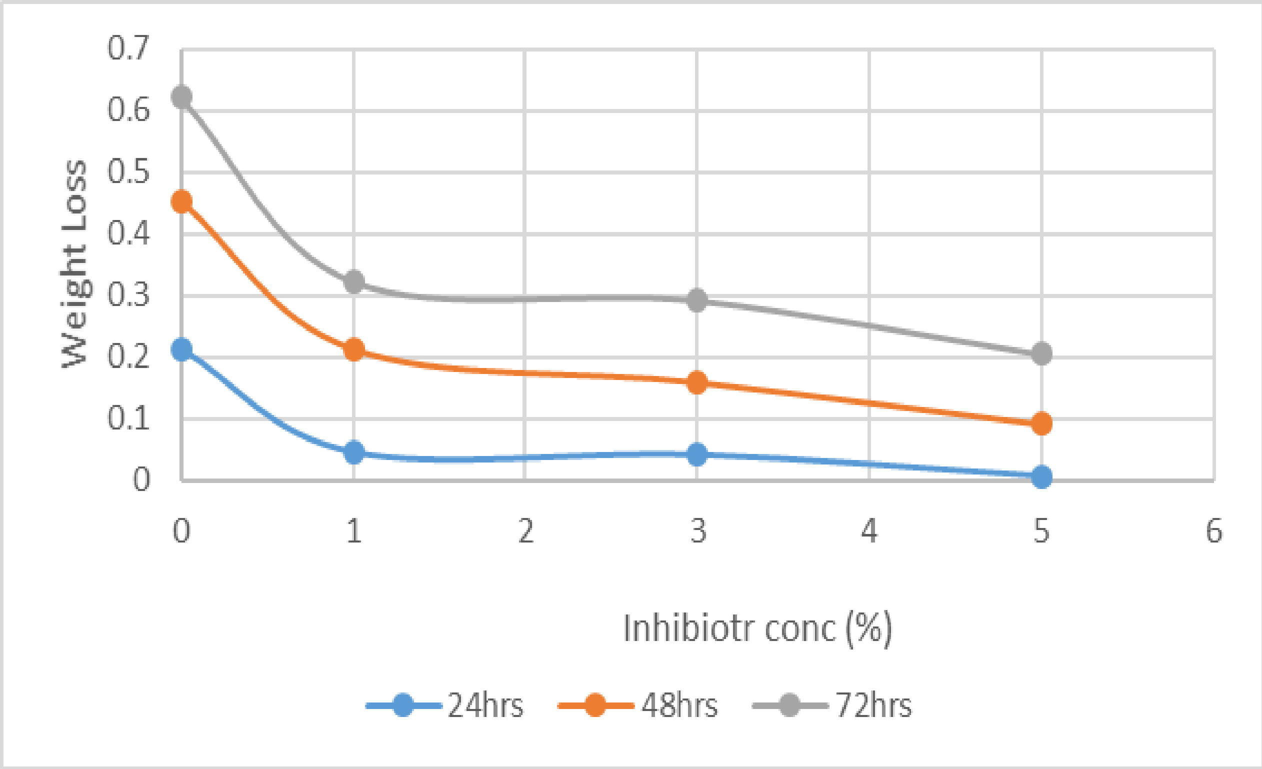

Figure 13: The graph of weight loss against inhibitor concentration at room temperature for 0.5M HCL.

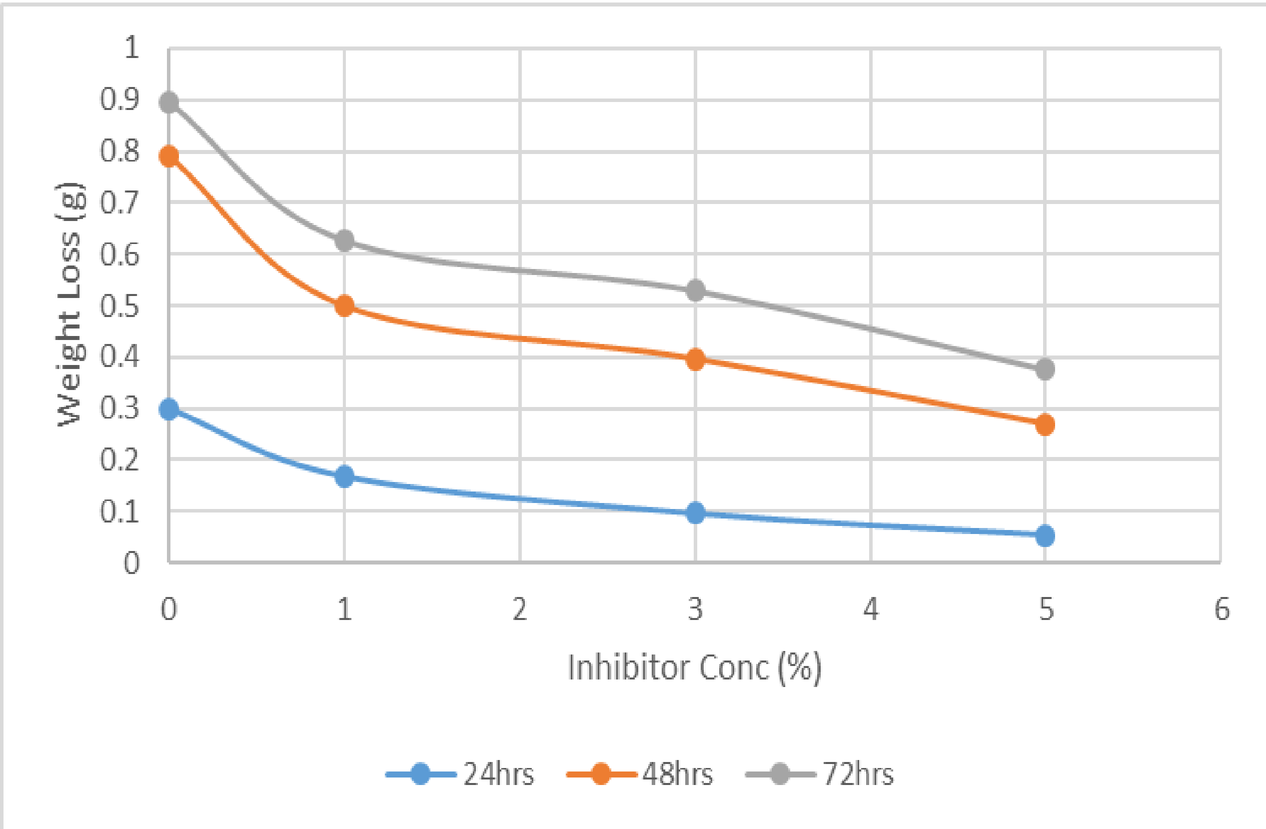

Figure 14: The graph of weight loss against inhibitor concentration at room temperature for 1.0M HCL.

3.9 Effect of Inhibitor Concentration on Inhibition Efficiency and Surface Coverage.

The inhibition efficiency of the inhibitor against concentration is shown in figure 15 and figure 16 for 0.5 M and 1.0 M HCl respectively. It was observed that the inhibition efficiency increased with increase in the concentration of banana pseudo stem extract which resulted in the decrease in corrosion rate. The increase in efficiency can be as a result of increase in the constituent molecule of the number of inhibitor adsorbed on the surface of the mild steel forming passive layer that protect the mild steel (Bala et al., 2019)

Also, the degree of surface coverage of the inhibitor against concentration graph is shown in figure 17 and figure 18 for 0.5 M and 1.0 M HCl respectively. It is further revealed that the degree of surface coverage of the inhibitor increase with increase in concentration. This indicate that an increase in extract concentration increase the number of inhibitor molecules adsorbed on the metal surface and reduces the area of surface that is available for the direct attack (Yetri et al., 2015). It can also be seen that comparing figure 15 and figure 16, also comparing figure 17 and figure 18 that as the concentration of the HCl medium increases, the inhibition efficiency and of course surface coverage decreases respectively as well.

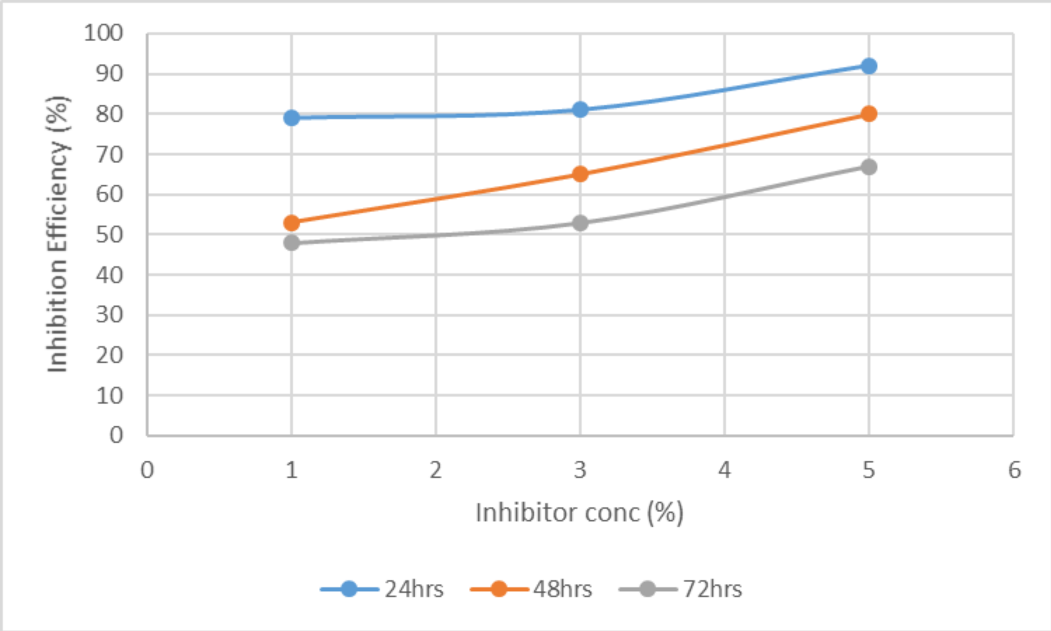

Figure 15: The graph of inhibition efficiency against inhibitor concentration in 0.5M HCl.

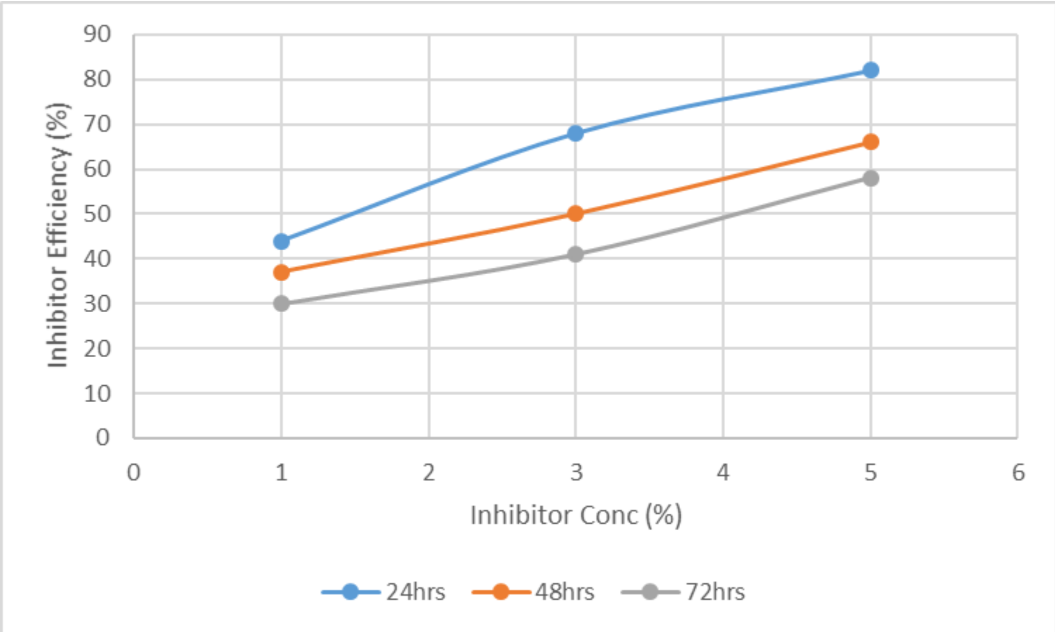

Figure 16: The graph of inhibition efficiency against inhibitor concentration in 1.0M HCl.

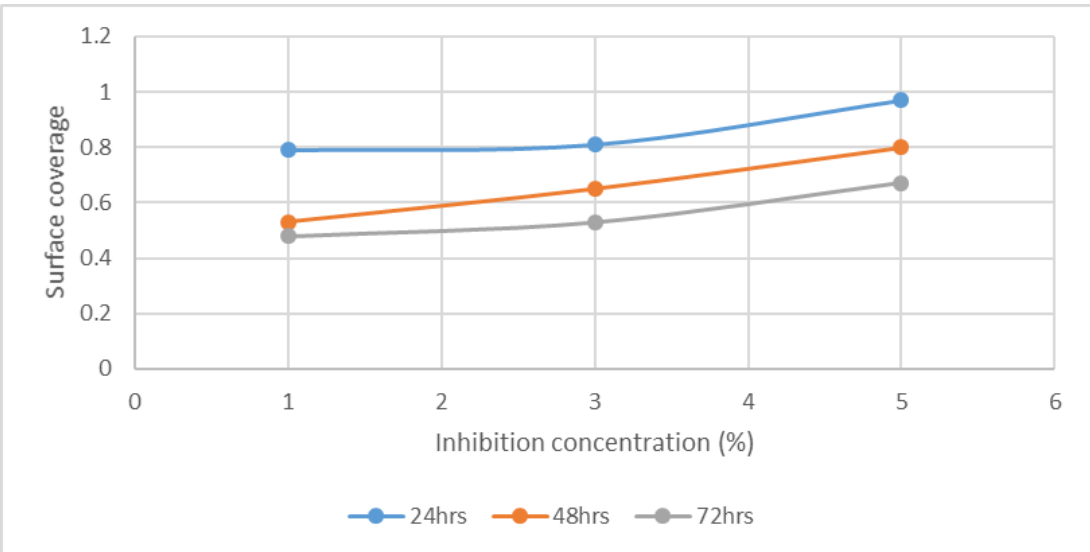

Figure 17: The graph of surface coverage against inhibitor concentration in 0.5M HCl.

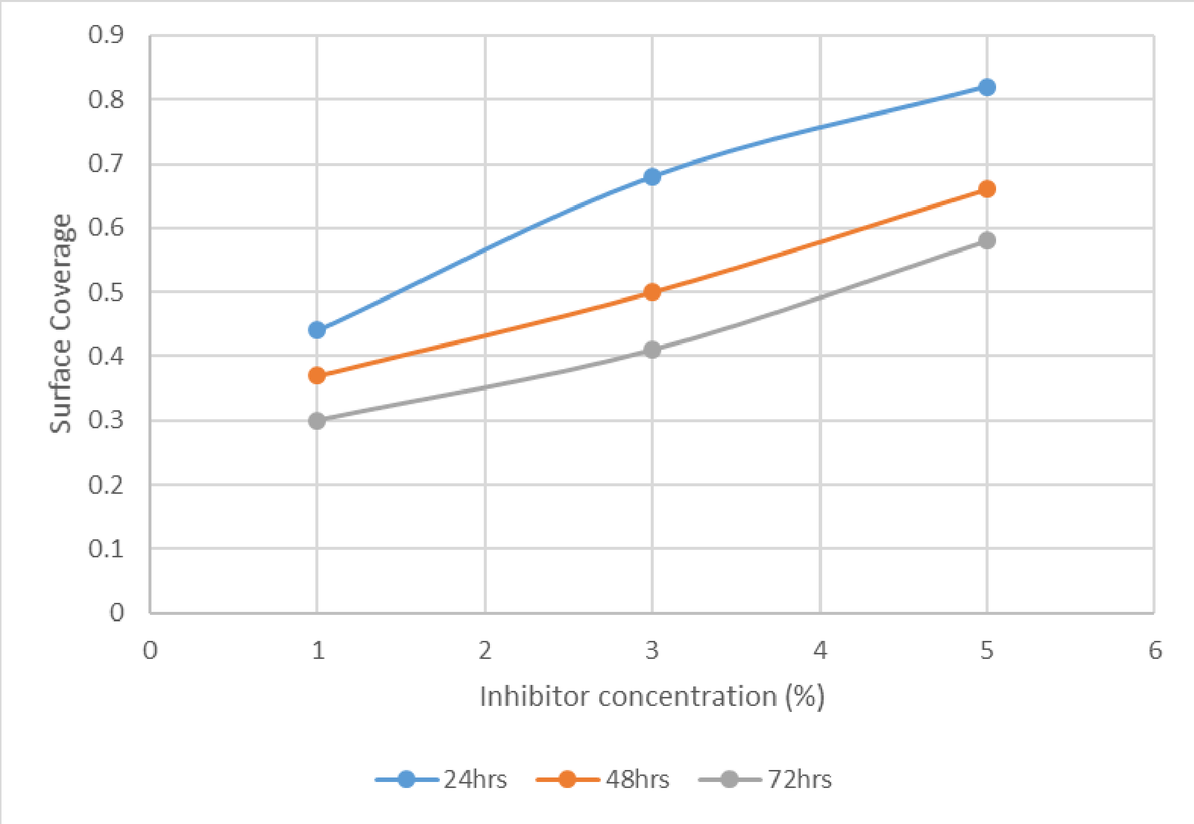

Figure 18: The graph of surface coverage against inhibitor concentration in 1.0M HCl.

3.10 Corrosion rate with respect to inhibitor concentration

Figure 19 and figure 20 revealed that the corrosion rate with the banana pseudo stem extract decrease as the inhibitor concentration increases. This showed that there is a good indication that the rate of penetration of the corrosion is reduced. The decrease in corrosion rate of mild steel with inhibitor extract can be attributed to the adsorption of the banana pseudo stem extract molecules on the surface of Mild steel. The Banana Pseudo Stem extract inhibitor molecule acts as physical barrier that restrict the diffusion of ions to and from the Mild steel surface which in turn prevent the Mild steel atoms (ions) from participating in further anodic or cathodic reactions (redox reaction), hence resulting in decrease in the corrosion rate this corroborates the work of (Buoklah et al., 2006). It can also be seen that comparing figure 19 and figure 20 that as the concentration of the HCl medium increases, the corrosion rate increases also.

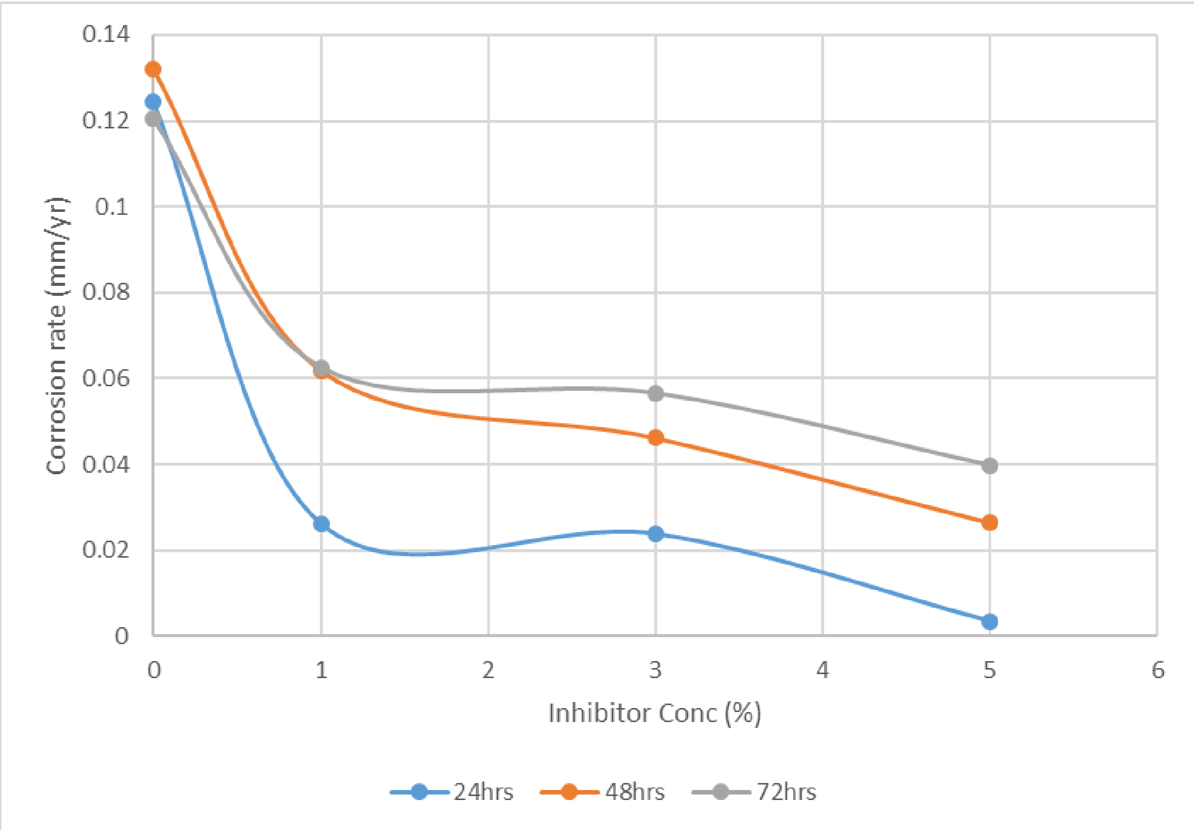

Figure 19: The graph of corrosion rate against Inhibitor concentration in 0.5 M HCl

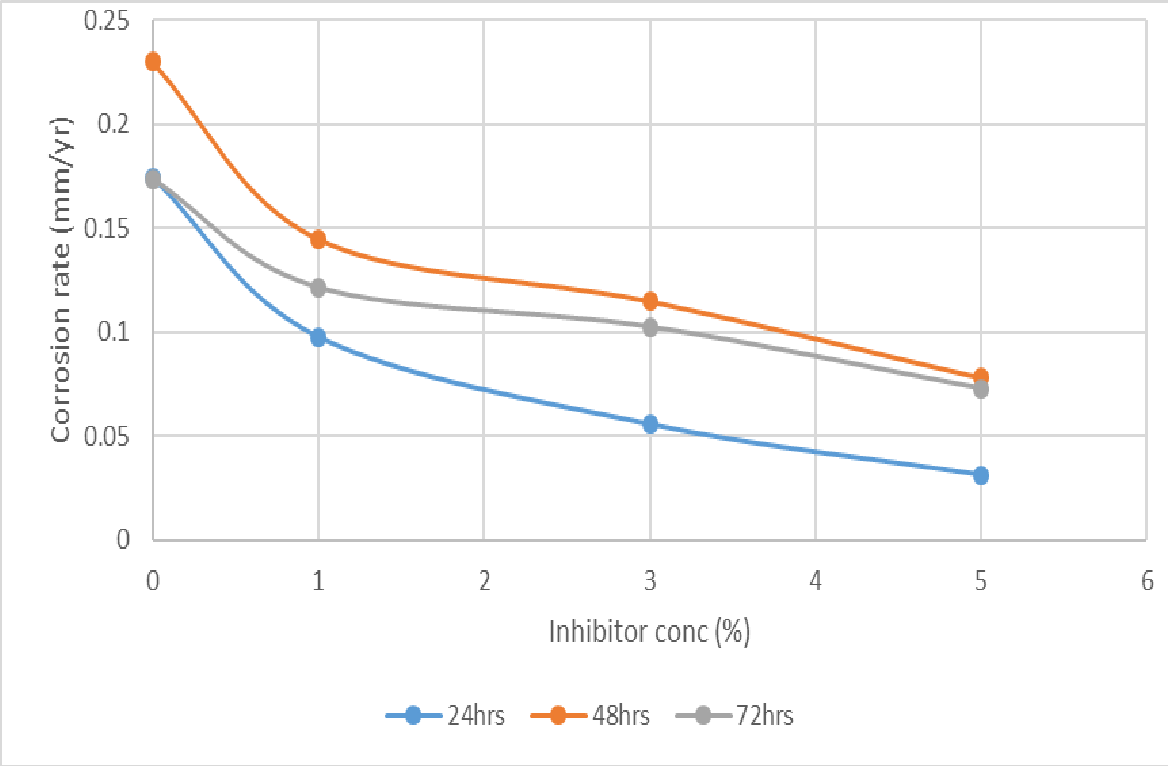

Figure 20: The graph of corrosion rate against Inhibitor concentration in 0.5 M HCl

3.11 Adsorption Isotherms

Values of the degree of surface coverage (θ) were evaluated at different concentrations of the inhibitor in 0.5M and 1.0M HCl solution from weight loss measurements. The values were fitted into Langmuir and Freudlich adsorption isotherm model to check which model best fit the data by comparing their R2 values (Sahin et al., 2002). The adsorption provides the information about the interaction around the adsorbed molecules themselves as well as the understanding on how pure components can be accommodated by a solid adsorbent. From the different isotherm and tables of values as seen in Tables 6 and 7, it is observed that the data fitted to Langmuir adsorption isotherm strongly by giving a straight line and also very obvious from the strong correlation co-efficient (R2 > 0.9) from 0.5M and 1.0M HCL as shown in figure 21.

Langmuir adsorption isotherm shows that the banana pseudo stem extract contain organic compound having polar atoms or groups which are adsorbed on the metal surface may interact by mutual repulsion or attraction (Subhashini, 2004; Sivaraju and Kannan, 2010). The experimental data also fitted into Freundlich adsorption isotherm as shown in figure 22, this is very obvious from the correlation coefficient (R2) value of 0.9351 greater on 0.9 for 0.5 M HCL. This suggests that extract molecules form a monolayer on the mild steel surface (Okewale, et al., 2017). The ΔGo (Gibb's free energy) value obtained from the isotherms were less than -20 kJmol-1, this indicates that the study process is spontaneous, and that the inhibitor is physically adsorbed on mild steel surface since the value of ΔGo obtained does not lies in the range of (-21 to -42kJ/mol) that signify chemical adsorption process for organic inhibitors (Yaro and Khadom, 2008). The negative value of ΔGoads ensures that the adsorption process is stably adsorbed on the metal surface.

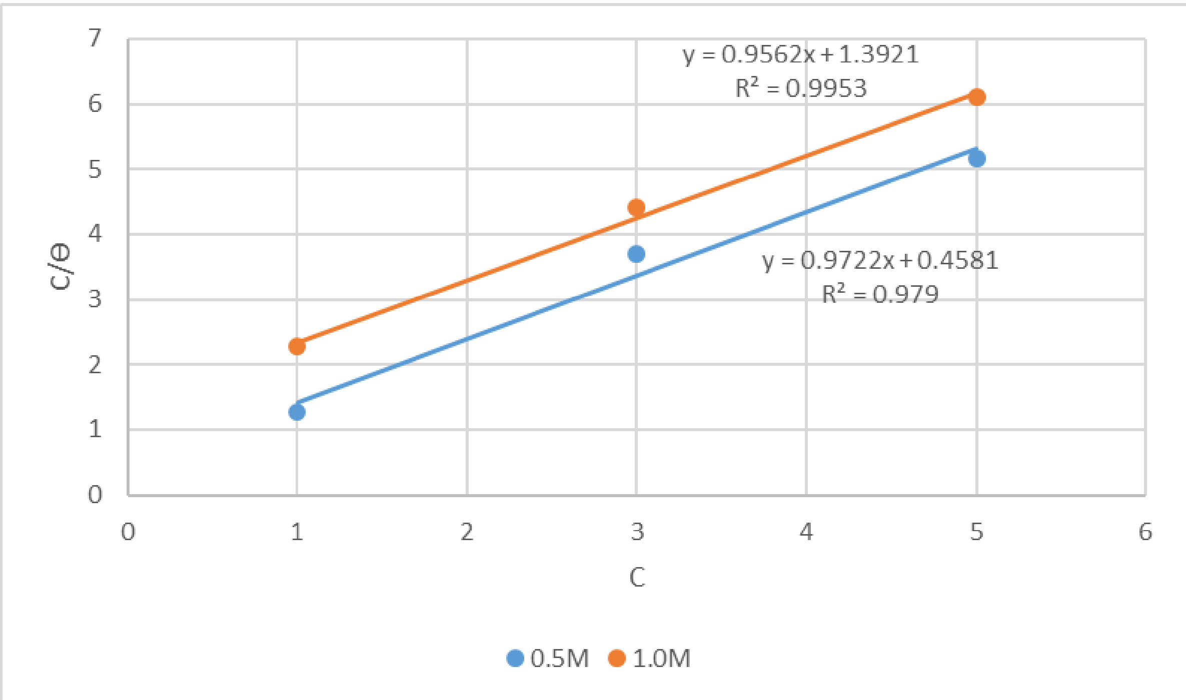

Figure 21: Langmuir adsorption isotherm plot

Table 6: Langmuir adsorption isotherm model result for R2, Slope and Kads, values at room temperature (298K)

Concentration	Kads	R2	Slope	ΔG(kJ/mol
0.5 M	1.029	0.979	0.9722	-10.022
1.0 M	1.046	0.9953	0.9562	-10.062

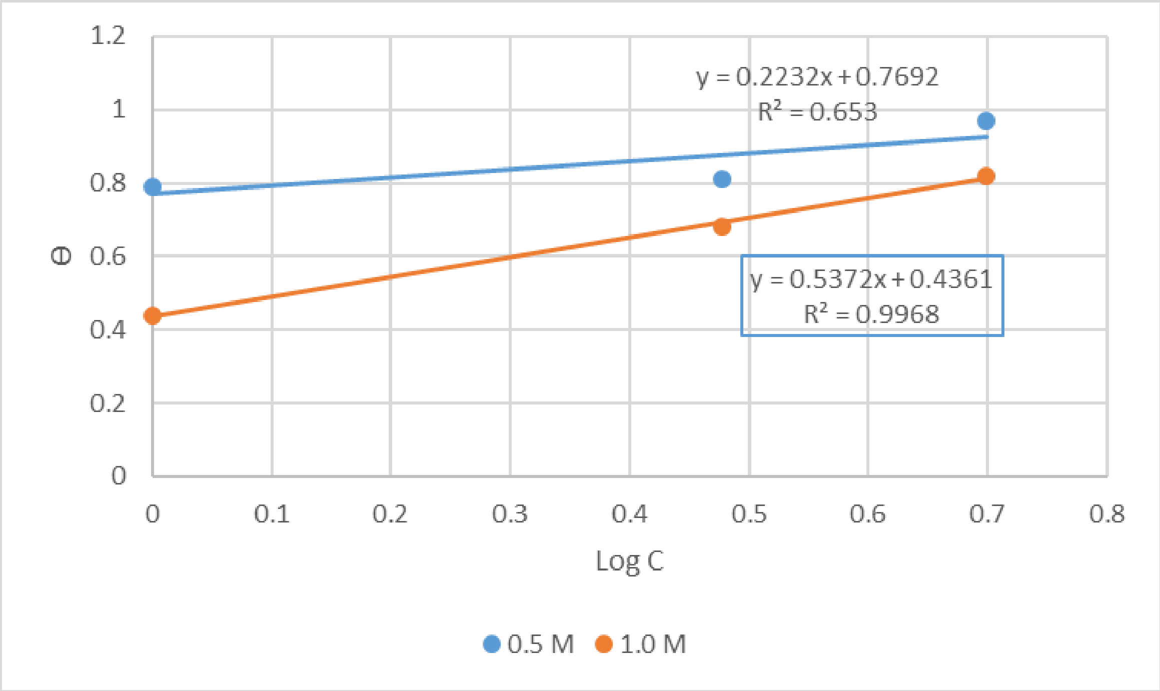

Figure 22: Freundlich adsorption isotherm plot

Table 7: Freundlich adsorption isotherm model result for R2, Slope and Kads, values at room temperature (298K)

Concentration	Kads	R2	Slope	ΔG(kJ/mol
0.5 M	4.4803	0.653	0.2232	-13.666
1.0 M	1.8615	0.9968	0.5372	-11.490

4. CONCLUSION

This research has demonstrated the remarkable potential of banana pseudo-stem extract as a green corrosion inhibitor for mild steel in acidic environments. Through comprehensive analysis employing gravimetric weight loss method, phytochemical investigation, and FTIR spectroscopy, we have elucidated the inhibitive properties of the extract. Our findings reveal a significant corrosion inhibition efficiency of up to 97%, achieved through the adsorption of inhibitor molecules on the mild steel surface. Notably, the inhibition efficiency escalates with increasing inhibitor concentration, highlighting the extract's promising role in corrosion prevention. Moreover, by employing Response Surface Methodology (RSM), we optimized process variables to maximize mild steel weight loss inhibition. The resultant model predicted optimal conditions, further validating the efficacy of the banana pseudo-stem extract as a corrosion inhibitor. Furthermore, this study contributes valuable insights into the inhibition characteristics under specific conditions, shedding light on the corrosion inhibition mechanisms. The presence of various phytochemical compounds underscores the extract's multifaceted inhibitory action, while FTIR analysis confirms its efficiency in acidic environments. In essence, this research underscores the potential of natural extracts in combating corrosion, offering a sustainable and effective solution for industrial applications. Future investigations can delve deeper into the extract's mechanism of action and explore its application in real-world scenarios, paving the way for eco-friendly corrosion mitigation strategies.

RECOMMENDATIONS

- Further Investigation: Conduct additional studies to explore the long-term effectiveness of banana pseudo-stem extract as a corrosion inhibitor for mild steel under various environmental conditions, including different acidic concentrations and temperatures.
- Optimization of Process Variables: Continue optimizing the process variables such as time of exposure, acid concentration, and inhibitor concentration to enhance the corrosion inhibition efficiency of banana pseudo-stem extract, possibly through advanced statistical techniques or computational modeling.
- Real-world Application: Evaluate the practical applicability of banana pseudo-stem extract as a green corrosion inhibitor in industrial settings, considering factors like cost-effectiveness, scalability, and compatibility with existing corrosion control methods.
- Mechanistic Understanding: Further investigate the adsorption mechanism of inhibitor molecules onto the mild steel surface to gain deeper insights into the corrosion inhibition process and to potentially enhance the performance of the inhibitor.
- Environmental Impact Assessment: Assess the environmental impact of using banana pseudo-stem extract as a corrosion inhibitor, including its biodegradability, ecotoxicity, and sustainability compared to conventional inhibitors, to ensure its overall environmental benefits.

REFERENCES

Alimohammadi, M., Ghaderi, M., Ramazani S.A.A., and Mahdavian, M., 2023. Falcaria vulgaris leaves extract as an eco-friendly corrosion inhibitor for mild steel in hydrochloric acid media. Scientific Reports, 13 (1), Pp. 3737. https://doi.org/10.1038/s41598-023-30571-6

Amodu, S.O., Odunlami, O.M., Akintola, T.J., Ntwampe, K.S., and Akoro, M.S., 2019. Exploring Musa paradisiaca Peel Extract as a Green Corrosion Inhibitor for Mild Steel Using Factorial Design Method. In Corrosion Inhibitors. IntechOpen. https://doi.org/10.5772/intechopen.82617

Bala Manikandan, C., Balamurugan, S., Balamurugan, P., and Beneston, S.L., 2019. Corrosion inhibition of mild steel by using banana peel extract. International Journal of Innovative Technology and Exploring Engineering, 8 (6), Pp. 1372–13.

Betti, N., Al-Amiery, A.A., Al-Azzawi, W.K., 2022. Experimental and Quantum Chemical Investigations on the Anticorrosion Efficiency of a

Nicotinehydrazide Derivative for Mild Steel in HCl. Molecules., 23;27 (19), Pp. 6254. doi: 10.3390/molecules27196254. PMID: 36234791; PMCID: PMC9571654

Bouklah, M., Hammouti, B., Benhadda, T. and Benkadour, M., 2006. Thiophene Derivatives as Effective Inhibitors for the Corrosion of Steel in 0.5 M H2SO4, Journal of Applied Electrochemistry, 35, Pp. 1095-1101.

Deepa and Sivakumar, 2020. Phytochemical Analysis and Antibacterial Efficacy of Ethanolic Extract of Musa paradisiaca. Research Biotica, 2 (3), Pp. 126-130.

Gruca, A., 2019. Green corrosion inhibitors. A review. Inżynieria Materiałowa, 1 (1), Pp. 21–26. https://doi.org/10.15199/28.2019.1.4

Gunavathy, N., and Murugavel, S.C., 2012. Corrosion inhibition studies of mild steel in acid medium using Musa acuminata fruit peel extract. E-Journal of Chemistry, 9 (1), Pp. 487–495. https://doi.org/10.1155/2012/952402

Miralrio, A., and Espinoza Vázquez, A., 2020. Plant Extracts as Green Corrosion Inhibitors for Different Metal Surfaces and Corrosive Media: A Review. Processes, 8 (8), Pp. 942. https://doi.org/10.3390/pr8080942

Odeja, O., Ogwuche, C.E., Elemike, E.E., and Obi, G., 2016. Phytochemical screening, antioxidant and antimicrobial activities of Acalypha ciliata plant. Clinical Phytoscience, 2, Pp. 12. DOI 10.1186/s40816-016-0027-2

Okewale, A.O.A., 2017. The Use of Rubber leaf Extract as a Corrosion Inhibitor for Mild Steel in Acidic Solution. International Journal of Materials and Chemistry, 7 (1), Pp. 5–13. https://doi.org/10.5923/j.ijmc.20170701.02

Oshomogho, F.O., Akhihiero, T.E., Edokpayi, O., and Ossai, J.E., 2020. Green corrosion inhibition of mild steel using Prunus Dulcis seeds extract in an acidic medium. Global Journal of Pure and Applied Sciences, 26 (2), Pp. 171–178. https://doi.org/10.4314/gjpas.v26i2.9

Sahin, K., Kucuk, O., Sahin, N., Sari, M., 2002. Effects of vitamin C and vitamin E on lipid peroxidation status, some serum hormone, metabolite, and mineral concentrations of Japanese quails reared under heat stress (34°C). Int J Vitam Nutr Res., 72, Pp. 91–100.

Sanni, O., Popoola, A.P.I., and Fayomi, O.S.I., 2018. The inhibitive study of egg shell powder on uns n08904 austenitic stainless steel corrosion in chloride solution. Defence Technology, 14 (5), Pp. 463–468. https://doi.org/10.1016/j.dt.2018.07.015

Singh, P., Kumar, M., Quraishi, M.A., Haque, J., and Singh, G., 2018. Bispyranopyrazoles as Green Corrosion Inhibitors for Mild Steel in Hydrochloric Acid: Experimental and Theoretical Approach. ACS Omega, 3 (9), Pp. 11151–11162. https://doi.org/10.1021/acsomega.8b01300

Sivaraju, V., Kannan, K., 2010. Inhibitive properties of plant extract (Acalypha indica L.) on mild steel corrosion in 1N phosphoric acid. International Journal of Chem. Tech Research, 2 (2), Pp. 1143-1153.

Subhashini, D.V., 2016. Effect of NPK fertilizers and co-inoculation with phosphate-solubilizing arbuscular mycorrhizal fungus and potassium-mobilizing bacteria on growth, yield, nutrient acquisition and Quality of Tobacco (Nicotiana tabacum L. Communications in Soil Science and Plant Analysis, 47 (3), Pp. 328-337.

Umoren, S.A., Eduok, U.M., Solomon, M.M., and Udoh, A., 2016. Corrosion inhibition by leaves and stem extracts of sida acuta for mild steel in 1M H2SO4 solutions investigated by chemical and spectroscopic techniques. Arabian, (9), Pp. 209–224.

Unnimaya, S.P., Kumari, P., and Kagatikar, S., 2023. Glutathione as green corrosion inhibitor for 6061Al-SiC(p) composite in HCl medium: electrochemical and theoretical investigation. Journal of Solid State Electrochemistry, 27 (1), Pp. 255–270. https://doi.org/10.1007/s10008-022-05315-7S

Yaro, A.S., and Khadom, A.A., 2008. Evaluation of the performance of some chemical inhibitors on corrosion inhibition of copper in acid media, Journal of Engineering, 2 (14), Pp. 2350 – 2362

Yetri, Y., Emriadi, E., Jamarun, N., and Gunawarman, G., 2015. Corrosion Inhibitor of Mild Steel by Polar Extract of Theobroma cacao Peels in Hydrochloric Acid Solution. Asian Journal of Chemistry, 27 (3), Pp. 875 – 881.