LAUTECH Journal of Engineering and Technology 20 (1) 2026: 1-12
10.36108/laujet/6202.02.0110

Optimization of Green Corrosion Inhibitor Dosage in Acidic Medium: A Case Study of *Hunteria umbellata* Seed Extracts

[1]Adio O., [2]Olanite A. O., [2]Arinkoola A. O. and [2]Ogunleye O. O.

[1]Department of Chemical Engineering Technology, Kwara State Polytechnic, Ilorin, Kwara State, Nigeria
[2]Department of Chemical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Article Info

Article history:

Received: Oct 13, 2025
Revised: Nov 19, 2025
Accepted: Dec 27, 2025

Keywords:

Green inhibitor,
Hunteria umbellata,
Corrosion inhibitors,
Optimization study,
Box-Behnken design,
electrochemical analysis.

Corresponding Author:
adio.oseni@gmail.com

ABSTRACT

This study investigated the corrosion inhibition performance of Hunteria umbellata seed Extract (HUE) on mild steel in an acidic medium. A Box-Behnken design (BBD)-based optimization was used to analyze the factors affecting inhibition efficiency such as inhibitor concentration, temperature and time. Corrosion studies were carried out using gravimetric weight loss measurement and electrochemical polarization methods. The identification of the constituents of the HUE was done using phytochemical screening and GC-MS analysis. The surface morphology of the coupon was assessed using scanning electron microscopy (SEM). The research revealed that the inhibitor demonstrated good inhibition potential with optimum inhibition efficiency of 89.677% at a concentration of 0.98 g/L, after immersion time of 10 h at a temperature of 30.22°C.

INTRODUCTION

Corrosion is possibly the most important and costly cause of severe operational problems encountered in our daily life and industrial setups, such as manufacture of chemical plants, oil and gas production systems. In many industries, mild steels are still the most widely used engineering materials due to their low cost and mechanical properties. (Alaname *et al.,*2015). However, the usefulness of mild steel is constrained as it is highly susceptible to corrosion in many harsh environments (Nya *et al.*, 2018). Among the several methods available for the prevention and control of corrosion, the use of corrosion inhibitors has been considered the most versatile and effective method (Ogunleye *et al.,* 2019). Many organic compounds have been considered for corrosion inhibition. The functionality of these compounds has been attributed to their electronegative functional groups and the presence of π-electrons in triple or conjugated double bonds. They also contain heteroatoms such as nitrogen, sulphur or oxygen atoms in their structures, which make then form a protective film on the metal surface that revealed them as good inhibitors (Gopal *et al*., 2013). However, the use of synthetic inhibitors has been reduced in recent times due to their expense and harmful effects on the environment (Dehghani *et al*., 2020).

The effectiveness of some natural plant extracts in corrosion inhibitions have, however, been widely reported: (Ogunleye *et al.,* 2020, Ogunleye *et al*., 2019, Emembolu *et al.,*2022). *Hunteria umbellata* has been used severally for different herbal medicines for treatment of fever, abdominal discomfort, piles, infertility and diabetes (Udinyiwe and Agbedo, 2022; Josephs *et al.,* 2011; Aderele *et al.,* 2020). However, its use as a corrosion inhibitor

has been sparsely reported in the literature. Therefore, this study seeks to evaluate the corrosion inhibition performance of crude extract and isolated phtomolculesd of *Hunteria umbellate* seed on mild in 1M HCl solution. It is anticipated that understanding the dominant chemical constituent responsible for the inhibition action of plants would make it easier to produce the actual pure compound on a large scale from particular plants. This study will provide the necessary catalyst for the creation of sustainable inhibitors for commercial use (Nya *et al*., 2018).

Most corrosion studies reported the effect of individual parameters such as temperature, inhibitor concentration and immersion time on the corrosion inhibition process by keeping the level of other operating factors constant. These studies do not consider the combined effect of the above-mentioned parameters. However, in recent years, several types of statistical experimental design methods have been applied to investigating the adsorption of pollutants in wastewater treatment, with the advantage that in these statistical methods, all the factors affecting experimental results are simultaneously varied (Gu *et al.,*2015). The main benefit of this method is its ability to assess both the impact of individual factors and how significant each one is within the overall process. Therefore, in this study, the effects of temperature, inhibitor concentration and immersion time of HUE were evaluated by Box–Behnken design on the inhibition efficiency (IE) of the inhibitors for mild steel in hydrochloric acid solution. The optimum conditions were employed to probe the possible inhibition.

MATERIALS AND METHOD

The materials used include mild steel; reagents such as HCl, acetone, methanol, and distilled water, each of analytical grade. Plant seed extract of *Hunteria umbellata.* Soxhlet apparatus, evaporator, dryer, water bath and weighing balance were also employed for the experiments. Characterisations of materials and coupons were achieved by Gas Chromatography equipped with mass spectrophotometer (GC-MS; AGILENT 5789A), Scanning Electron Microscopy (SEM; ZEISS equipment) and Potentiostat/galvanostat 263 electrochemical system workstation. Design Expert software version 13-0 (STAT-EASE Inc., Minneapolis, USA) was used for optimization process

Extraction, Isolation and Characterization of Extracts

All the samples were washed with distilled water and air-dried. The dried samples were pulverised and screened to approximately 20 μm (Ogunleye *et al*., 2020). Each sample was kept in an air-tight cellophane bag for subsequent use. The extraction of the desired phytoconstituents from powder material was done using a Soxhlet extractor with methanol as the solvent. The obtained extract was concentrated using a rotary evaporator and stored at 4 °C in an air- tight sterile containers (Kasim, 2013). Alkaloids (HUAE), saponins (HUSE), flavonoids (HUFE), and tannins (HUTE) were extracted utilizing the method described by Ugi *et al,* (2020). The molecular constituents of the methanolic extract were determined using GC-MS analysis. Scanning Electron Microscopy (SEM) was employed to analyze the surface morphology of steel samples with or without inhibitors.

Preparation of Mild Steel and the solution for the corrosion test

Coupons measuring 3 cm × 2 cm × 0.3 cm were polished using emery paper, thereafter washed with acetone, dried, and weighed before utilization. Solutions of varying concentrations of the crude extracts and Phyto molecules were prepared and stored in desiccators

Corrosion Testing

***Weight Loss Method*:** Weight loss of Mild steel coupons submerged in 100 of ml 1 M HCl solutions in the absence and presence of different concentrations of the *Hunteria umbellata* crude extract (HUE) was determined. Each coupon was weighed in grammes before immersion (m_1) and retrieved from the test solution at various designated time then reweighed (m_2). The corrosion rate was calculated from Equations (1–4). (Ogunleye *et al.,* 2019)

$$W = m_1 - m_2 \quad (1)$$

$$CR = \frac{W}{A \times t} \quad (2)$$

$$IE = \left[\frac{CR_0 - CR_1}{CR_0}\right] \times 100\ \% \quad (3)$$

$$\theta = \frac{IE}{100} \quad (4)$$

Where CR_i *and* CR_o, *is the* corrosion rate with and without inhibitor, respectively, the coupon of surface area (A, cm^2) over time t.(h). W is the weight loss, θ is the degree of inhibitor surface coverage, and IE is the inhibition efficiency

Electrochemical measurements: Electrochemical measurement was carried out using Gamry Instruments reference 600 (potentiostat/ galvanostat/ ZRA). Mild steel plates with an exposure area of 3.142 cm^2 were used as the working electrode, platinum electrode (Pt) as the auxiliary electrode, while the saturated calomel electrode (SCE) was used as the reference electrode. All the electrochemical studies were carried out at room temperature (27 °C). The open circuit potential (OCP) was recorded as a function of time up to 30 minutes.

The Tafel polarisation curves were obtained by scanning the electrode potential from -300 mV to 300 mV from the E_{corr} with a scanning rate of 1 mVs^{-1}. The linear segments of the anodic and cathodic curves were extrapolated to E_{corr} to obtain the corrosion current densities (I_{corr}). The IE % was calculated using Equation 5 (Zulkifli *et al.,* 2021).

$$IE\ \% = \frac{I\_cor(O) - I\_cor(i)}{I_{cor(O)}} \times 100 \quad (5)$$

Where $I_{corr(o)}$ = corrosion current density of mild steel without the inhibitor

$I_{corr(i)}$ = corrosion current density of mild steel with the inhibitor at a certain concentration

Batch corrosion inhibition experiment/ optimization study

A set of experiments was carried out to study the effects of the process variable on IE and CR for the corrosion of mild steels while varying temperature, immersion time and inhibition concentration between (30–60ºC), (4–12 h) and (0.2–1.0 g/ L), respectively. Another set of experiments was performed using a Box-Behnken design to determine the optimal process parameters that maximize the corrosion inhibition of MS by inhibitors in 1M HCl solution using Response Surface Methodology (RSM). Here, the factors selected include concentration of inhibition, temperature and time of immersion (Ogunleye *et al*., 2020). Table 1 shows the summary statistics for the three selected factors. For each experimental run, the corrosion rate (CR) of the coupon of surface area (A, cm^2) over time (t) was calculated using weight loss (W). The degree of inhibitor surface coverage (θ) and efficiency of inhibition (IE) were also determined

Data Analysis

Analysis of data and development of response surface models for IE were achieved by Analysis of variance (ANOVA) and response surface methodology (RSM) for the selected inhibitors. The statistics that were considered are the F and p. P-values obtained at a 95% confidence level. The

goodness of models was ascertained using correlation coefficients (R^2 and adjusted R^2) which must be close to unity to show adequacy of the model to describe the process.

Table 1: Process variables and their Levels

Variable	Units	Symbol	Levels		
			-1	0	+1
Concentration of inhibitors	g/L	X_1	0.4	0.7	1.0
Temperature	K	X_2	303	318	333
Immersion time	h	X_3	4	8	12

RESULTS AND DISCUSSION

Phytochemical screening

The phytochemical screening results in Table 2 show that phytochemicals such as steroids, flavonoids, saponins, lactone, diterpenes, and glycosides are moderately present in the methanolic crude extract of *Hunteria umbellata* seed. However, alkaloids, triterpenes and tannins were strongly present; a similar result was obtained by Adelere *et al* (2020) on the phytochemical screening of the methanolic extract of *Hunteria umbellate*. The presence of these active phytochemicals is an indication that the extract of *Hunteria umbellata* has a good corrosion inhibition potential since most of these organic compounds contain heteroatoms in molecules, as reported by Emembolu *et al* (2022); Ikemba and Okafor (2018).

Table 2: Phytochemical screening for the Methanolic extract of *Hunteria umbellata* seed

S/N	Phytochemical	Result	%
1	Steroids	+	1.34
2	Triterpeneses	++	2.97
3	Alkaloids	++	3.31
4	Tannins	+	1.06
5	Flavanoids	+	0.98
6	Lactone	+	1.82
7	Diterpenes	+	0.89
8	Glycoside	+	1.23
9	Saponins	++	2.98

KEY:++ strong present + present - absence

GC-MS analysis

The active compounds in the seed methanolic extract of the plant, the retention time, the molecular formula and % area is provided in Table 3**.** The methanol extract of HUE revealed several peaks that represent different compounds as shown in the

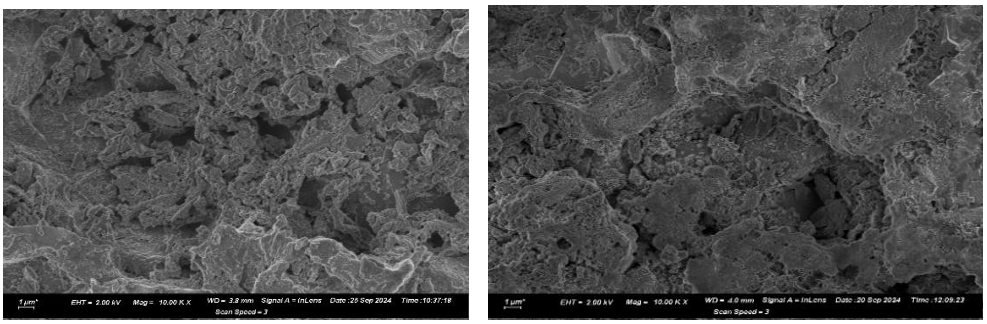
table. The result shows that the principal active constituent in the extract is Pyridine 3-ethyl with the highest peak value of (44.99%) and retention time (3.138 min). The identified compounds, such as carboxylic acid, pyrazine, hydroxyl and phenolic compounds, are well-known corrosion inhibitors, which suggests that the extract has good inhibitory potential (Ogunleye *et al.,* 2020).

Table 3: Gas Chromatography – Mass Spectrometry Analysis of HUE

Peak	Name of Comp in HUE	Molecular formula	Retention time	Area %
1	Pyridine, 3-ethyl-	C_7H_9N	3.138	44.99
2	Pyrazine, 2-methoxy-6-methyl-	$C_6H_8N_2O$	4.660	1.20
3	Benzoic acid, methyl ester	$C_8H_8O_2$	4.775	1.01
4	Benzene acetaldehyde, alpha. -met….	$C_9H_{10}O$	5.461	2.08
5	Cyclopropane, trimethyl methylene-	$C_{10}H_{16}$	9.108	2.65
6	cis-1,4-Cyclohexanediol, O, O'-bi….	$C_8H_{11}F_3O_3$	9.467	2.16
7	3-Methyl manno side	$C_7H_{14}O_6$	12.145	1.24
8	2,2-Diethoxytetrahydrofuran	$C_6H_{12}O$	12.259	3.13
10	Dibutyl phthalate	$C_{16}H_{22}O_4$	13.718	1.28
11	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	13.810	5.15
12	9-Octadecenoic acid (Z)-, methyl ester	$C_{19}H_{36}O_2$	14.857	2.71
13	9-Octadecenoic acid, (E)-	$C_{18}H_{34}O_2$	15.252	21.21
14	Octadecanoic acid	$C_{18}H_{36}O_2$	15.383	1.83
15	Methanamine, 1-(4-acridinyl)-	$C_{14}H_{13}N_3$	16.757	1.62
16	Hexadecane, 1-chloro-	$C_{16}H_{33}Cl$	18.988	1.61
17	Bis(2-ethylhexyl) phthalate	$C_{24}H_{38}O_4$	19.498	1.43
18	Sebacic acid, di (3-oxobut-2-yl) ester	$C_{22}H_{38}O_6$	21.243	1.70

Surface morphology of the mild steel coupon

The digital images of the corroded metal in acid medium considered in the absence and presence of the plant extracts, are presented in Figures 1. The SEM micrograph for uninhibited metal coupons immersed in 1M HCl had a severely damaged surface, with a large number of pits and microcracks caused by the acid media.



(a) **(b)**

Figure 1. SEM micrograph of mild steel in 1M HCl (a) without inhibitor (b) with 1g/L of *Hunteria umbellata* seed extract

However, the surface morphology of the mild steel in the presence HUE revealed a reduction in corrosion activity as seen from the decrease in coupon localized corrosion areas in the acid solution, this due to the formation of a protective film of extract on the mild steel surface. (Ogunleye *et al.,* 2020).

Sensitivity of CR and IE to concentration and temperature

Figure 2 shows the variation of inhibition efficiency (IE) for HUE in 1M HCl solution. The effect of temperature and concentration of isolated secondary metabolite of HUE on CR and IE in I M HCl evaluated by the weight loss method is presented in Table 4. It was observed that the corrosion rate increased as the temperature of the system increased, but decreased as the concentration of the extracts increased. The uninhibited mild steel has a higher corrosion rate compared to the inhibited system as the temperature increased, indicating that various concentrations of the plant extracts inhibited the corrosion of mild steel for the environments studied. The dissolution of mild steel occurred more rapidly as the temperature increased, which is demonstrated by a higher corrosion rate as the temperature increased. This can be explained by the tendency of the reacting molecules at the elevated temperature to collide faster, leading to more consumption and formation of corrosion products (Ogunleye *et al.,* 2020). The IE demonstrated by the metabolites can be attributed to the presence of hetero atoms in the plant, the nature of pi bonds, double bonds, structural orientation and aromaticity exhibited by the hetero compounds present (Ugi *et al*, 2020). Inhibition efficiency was, however, seen to take progression, HUAE > HUSE > HUTE > HUFE for the secondary metabolite from *Hunteria umbellate.*

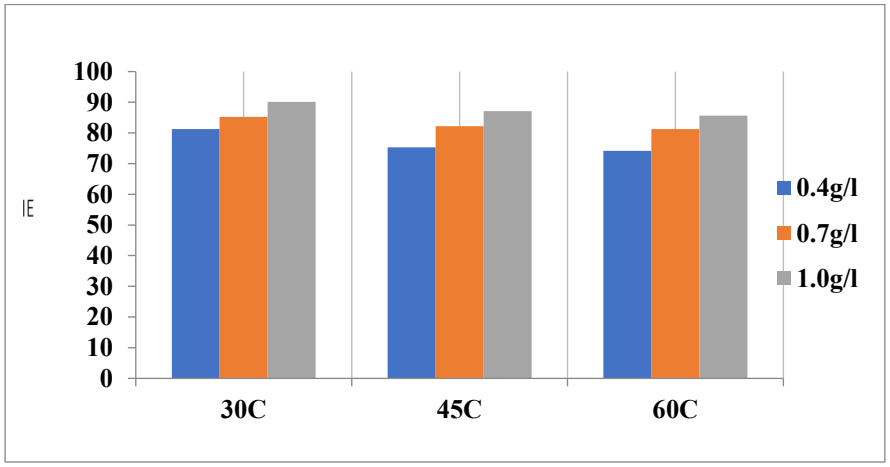


Figure 2: Inhibition Efficiency in 1M HCl after 12h for the temperatures at 30 °C, 45 °C, and 60 °C in the absence and different concentrations of HUE

Figure 3 (a) shows the variation in OCP with time in the absence and presence of different concentrations of HUE at room temperature. In the absence of an inhibitor, there was a fluctuation of potential with time, oscillating between 0.4 and 0.3 EV. On the introduction of inhibitors, a sharp decrease in OCP and establishment of a quasi-steady state with very little disturbance (oscillations) was observed. The value of the OCP decreases as the concentration increases. A low potential indicates a significant film protection of mild steel surfaces and reduction of cathodic corrosion reactions (Saad, 2011). A little oscillation of OCP is an indication of low-keyed interactions among the inhibitor molecules and the substrates. Therefore, completely stable adsorbed layers could

not be established on the substrates. From the electrochemical parameters shown in Table 5, corrosion potential (E_{corr}) and current density (I_{corr}) varied with concentration of the inhibitor and Figure 3(b) clearly showed that the presence of HUE extracts decreases both cathodic and anodic slopes indicating that the extracts influence the dissolution of the mild and the hydrogen evolution processes, and can be suggested to function as mixed-type inhibitors. The maximum inhibition efficiency at 1 g/L was 90.19% (Table 5), and it is consistent with the result obtained from the weight loss. The inhibition action of HUE extracts is thus attributed to adsorption and the formation of a barrier film on the metal surface

Table 4: Variation in CR and IE of mild steel for different concentrations of Phytomolecules of HUE Electrochemical measurement

		HUAE		HUSE		HUTE		HUFE	
	Conc (g/L)	CR (g/m$_2$ h)	IE %	CR (g/m^2 h)	IE %	CR (g/m^2 h)	IE %	CR (g/m^2 h)	IE %
	Blank	1.583	-	1.583	-	1.583	-	1.583	-
	0.2	0.488	69.211	0.722	54.386	0.818	48.333	0.840	46.930
1M									
HCl	0.4	0.439	72.281	0.610	61.491	0.567	64.211	0.592	62.631
	0.6	0.294	81.404	0.403	74.561	0.493	68.860	0.546	65.526
	0.8	0.201	87.281	0.250	84.211	0.411	74.035	0.439	72.281
	1	0.161	89.825	0.210	86.754	0.317	80.000	0.354	77.632

.

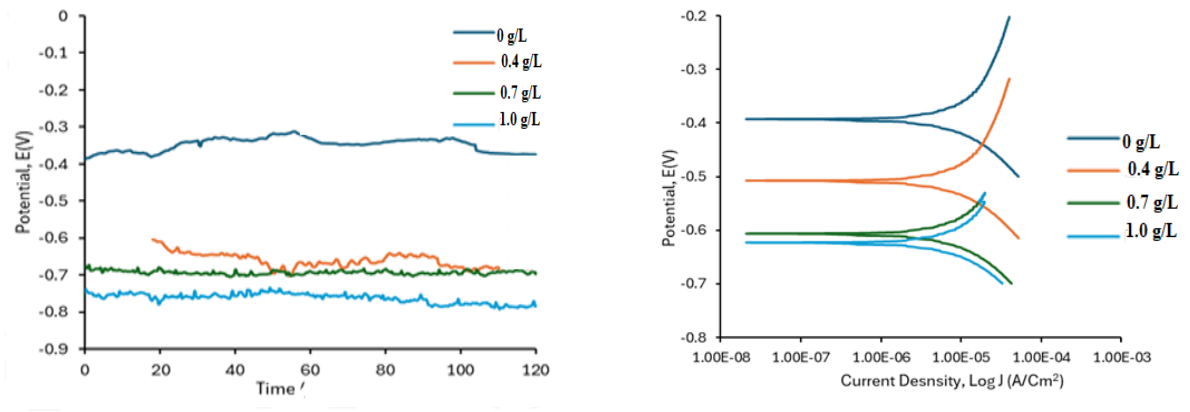


Figure 3: (a) OCP against time curve and (b) potentiodynamic polarization curve, for uninhibited and inhibited mild steel in different concentrations of HUE in 1M HCl

Optimization study

Model Developed: The scheme and the outcome of the experimental design carried out in this study are presented in Table 6. A total of 15 experiments were used for the RSM modelling. The data show the variation of IE with inhibitor concentrations, temperature, and time for the corrosion inhibition of mild steel. The model obtained was analyzed by analysis of variance (Table 7). The suitability of the quadratic model developed for IE was confirmed with the F-value of 86.38. The p-value of less than 0.0001 for IE, as recorded in Table 6, attests to the

reliability of the analysis with 95 percent confidence
level.

Table 5 Electrochemical parameters for corrosion of mild steel in HCl in the absence and presence of different concentrations of HUE

Concentration (g/L)	Ecorr (V)	Jcorr (A/cm^2)	CR (mm/yr)	IE %	Pr (Ω)
Blank	-0.5368	4.14E-05	0.69394		552.68
0.4g/L	-0.4795	7.70E-06	0.26175	81.4	660.82
0.7g/L	-0.6411	6.11E-06	0.20539	85.24	713.68
1.0 g/L	-0.5753	4.06E-06	0.1863	90.19	743.84

An empirical model in term of coded factor excluding the insignificant terms was expressed for IE as follow for HUE in equation 6

HUE (I E %) = $81.89 + 5.88 * A + 1.94375 * B - 2.58625 * C - 0.5575 * AB + 0.5225 * AC + 0.105 * BC - 1.55 * B^2 + 1.005 * C^2$ **(R^2= 0.99, Adj. R^2=0.98) …… (6)**

Positive signs in front of terms represent a synergistic effect, whereas a negative sign indicates an antagonistic effect. The quality of the model developed is measured in terms of the correlation factor R^2= 0.99, which is close to unity with a small standard deviation of 0.9564, indicating the high precision predictability of the model. The adjusted $R^{2,}$ which is suited for comparing model with different numbers of independent variables, was 0.98 and predicted R^2= 0.96 are in reasonable agreement with each other, with their values close to unity. This showed that the model predicted value for the inhibition efficiency would be more accurate and closer to the actual value.

Table 6 Design matrix for experiment run using Box-Behnken design

SD	Run	Factor 1 A: Conc	Factor 2 B: time	Factor 3 C: temp	Response 1 CR	Response 2 IE
		g/L	H	°C	g/m^2h	%
10	1	0.7	12	30	2.49	85.18
8	2	1	8	60	12.29	84.5
5	3	0.4	8	30	4.58	80.04
3	4	0.4	12	45	7.56	75.34
7	5	0.4	8	60	21.58	72.79
11	6	0.7	4	60	31.08	77.3
12	7	0.7	12	60	10.82	81.25
13	8	0.7	8	45	7.94	81.89
6	9	1	8	30	2.38	89.66
14	10	0.7	8	45	7.94	81.89
9	11	0.7	4	30	7.04	81.65
15	12	0.7	8	45	7.94	81.89
2	13	1	4	45	11.38	84.16
1	14	0.4	4	45	21.42	70.19
4	15	1	12	45	3.96	87.08

Table 7 ANOVA for Quadratic model for HUE

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	911.40	9	101.27	86.38	< 0.0001	Significant
A-Conc	78.94	1	78.94	67.33	0.0004	
B-time	265.54	1	265.54	226.49	< 0.0001	
C-temp	439.26	1	439.26	374.68	< 0.0001	
AB	10.37	1	10.37	8.84	0.0310	
AC	12.57	1	12.57	10.72	0.0221	
BC	61.70	1	61.70	52.63	0.0008	
A^2	0.2216	1	0.2216	0.1890	0.6818	
B^2	30.95	1	30.95	26.40	0.0037	
C^2	15.10	1	15.10	12.88	0.0157	
Residual	5.86	5	1.17			
Lack of Fit	5.86	3	1.95	1.03	1.0234	Not significant
Pure Error	0.0000	2	0.0000			
Cor Total	917.26	14				

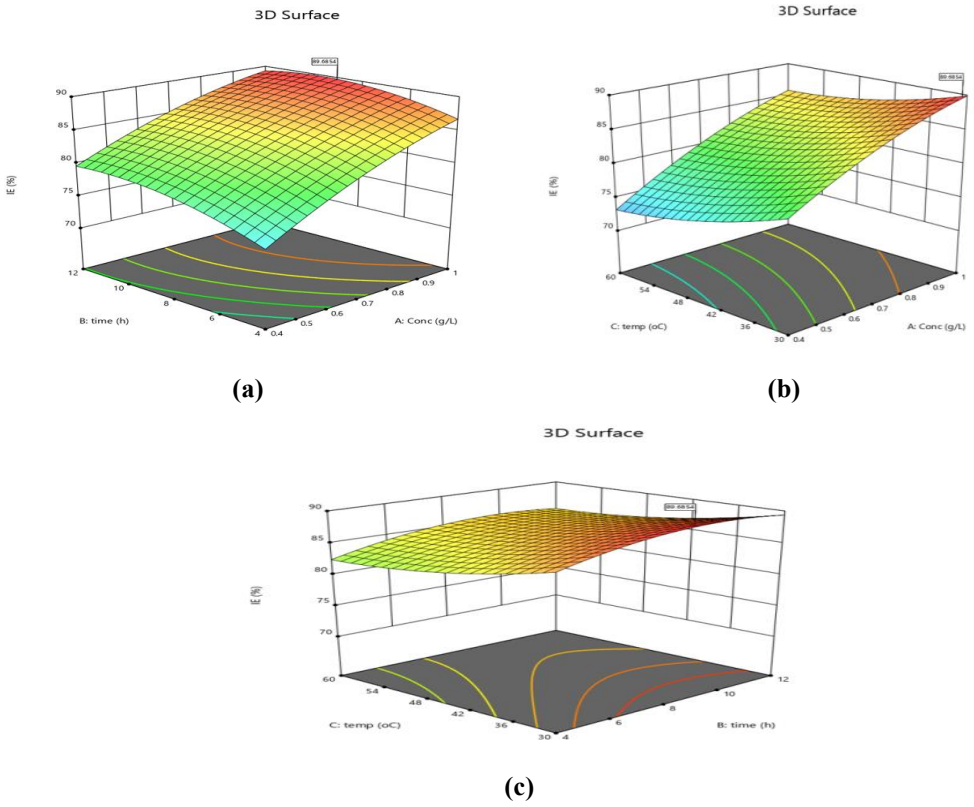
Interactive effect of process variables on the IE

Figure 4 is the 3D plots showing factor interaction as it affects the IE and of HUE in 1M HCl. Figure 4 (a) shows the effect of inhibitor concentration and immersion time on IE at fixed temperature of 30.11^{o}C. At low immersion time of 4.h with increase inhibitor concentration, inhibition efficiency increased from 75.25 to 86.72 %. As the immersion time increases to 12 h, the IE increases accordingly reaching the maximum at 89.36 %. Therefore, the IE increases with increase in inhibitors concentration and immersion time. The effect of temperature and inhibitor concentration on the response was shown in Figure 4 (b). At fixed immersion time of 9.91 h, as temperature increases from 30 to 50^{o}C the IE decreases from 80.29 to 75.56 % but increases as the inhibitor concentration increases. Figure 4 (c) showed the effect of temperature and immersion time on the IE for fixed inhibitor concentration at 0.9751 g/L and at a temperature of 30 ^{o}C. It can be observed that as the immersion time increased the IE increased from 86.50 to 89.04 %. As the temperature increased to 55.5^{o}C, the IE slightly decreased from 86.36 to 85.39%. Therefore, IE is highly influenced by both temperature and time. Corrosion inhibition of mild steel in 1M HCl at different concentrations of HUCE revealed an increase in the IE with inhibitors concentration. However, a decrease in IE was observed at high temperature. These observations are in agreement with the previous studies by Abdulwahab *et al*., (2012); Ugi *et al*. (2020) and Emembolu *et al. (*2022).

Numerical optimization

The optimization problem was set up to minimize or maximize the objective functions, subject to a selected set of constrained. Equation 6 serves as the objective functions, with the set of constraints set as

ranges of variables used during the experiment. The solution is achieved by maximizing the inhibition efficiency while simultaneously minimizing the corrosion rate.



(a) **(b)**

(c)

Figure 4 IE against (a) concentration and time, (b). concentration and temperature and (c). time and temperature, for HUE in 1M HCL

This equation was used for searching combinations of factors that satisfy the constraint placed on each of the response. The model equation which serves as the objective function is used to maximized the IE under the set constrained. The optimum IE of 89.677 % was obtained at inhibitor concentration of 0.979 g/L, temperature of 30.22^{o}C and immersion time of 10.158 h. Design Expert also displays the result of the optimization as depicted on the ramps diagram shown in Figure 5. The numerical values obtained was validated with another set of experiments carried out at the optimum process variables. The predicted and measured value of the response IE obtained is shown in Table 7.

Table 8 Result Validation for Corrosion Inhibition of Mild Steel in HCl

Inhibitor Plant extracts	**Inhibitor Concentration (g/L)**	**Time (h)**	**Temperature (K)**	**Predicted Inhibition efficiency IE %**	**Experimental inhibition efficiency IE %**	**Error percentage %**
HUE	0.979	10.158	303.22	89.677	90..084 ± 0.022	0.4538

It can be observed that the measured IE is close to the calculated value, with an error percentage of 0.4538. This shows the consistency and reliability of the model for prediction purposes as well as the suitability of the RSM approach for optimizing the corrosion inhibition process (Emembolu *et al.,* 2022 and Ogunleye *et al.,* 2020).

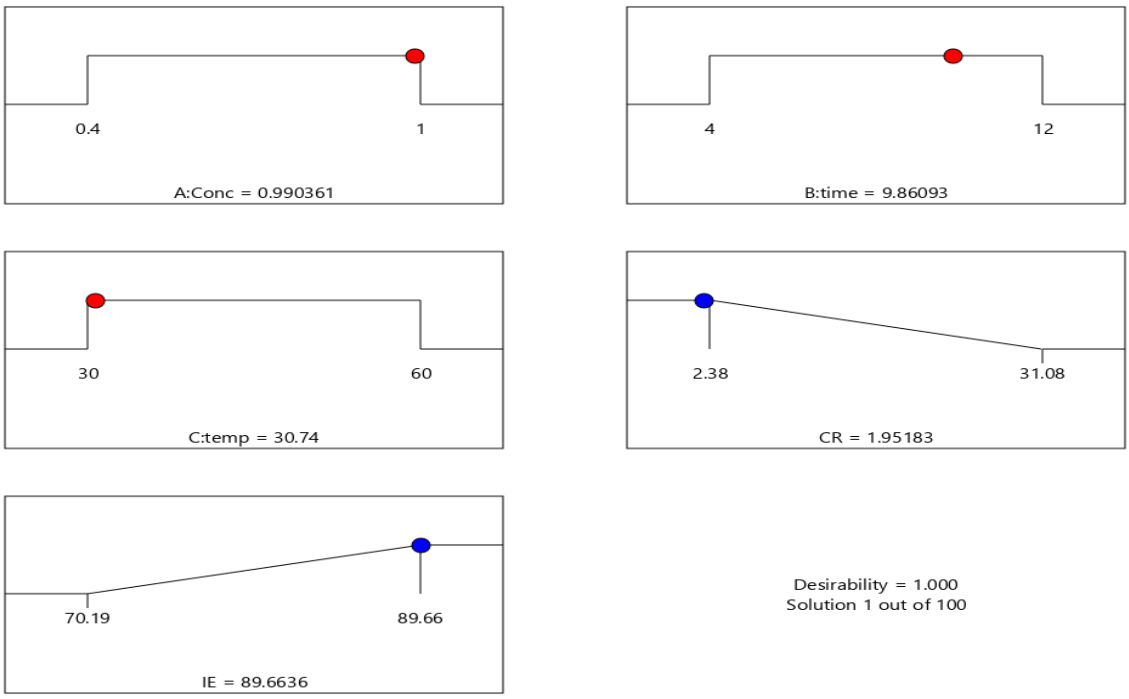


Figure 5: Ramp diagram showing optimal conditions

CONCLUSION

1. The extracts of *Hunteria umbellata* seed and its isolated phytomolecules showed good corrosion inhibition characteristics as a result of the presence of phytochemicals and active chemical compounds such as alkaloid, tannins, saponin, flavonoid, lactone, glycosides, terpenes, pyridine, and 9-Octadecenoic acid, (E)-

2. The inhibition efficiency IE increases with an increase in time of immersion and concentration of the inhibitors, and decreases as the temperature increases. All the inhibitors performed better in 1M HCl solution and acted as mixed inhibitors. The results produced by the two methods of corrosion analysis were in very good agreement with one another. Inhibition efficiency performance for the isolated phytomolecules followed the trend HUAE > HUSE > HUTE > HUFE in all three media.

3. The quadratic model developed as process proxies were adequate, with good prediction efficiency. The optimum IE of 89.677% at 30.22 °C, immersion period of 10.158 h and inhibitor concentration of 0.979 g/L was obtained for the HUE in 1M HCl

REFERENCES

Abdulwahab, M., Kasim, A., Bello, K. A., and Gaminana, J. O. (2012). Corrosion inhibition of multi-component aluminium alloy in hydrochloric acid solution by aqueous extract of bitter leaf (*Verninia amygdalina*) powder. *Advanced Materials Research*, *367*, 319–325.

Aderele R.O., Rasaq A.K., and Momoh J.O. (2020). Phytochemical Screening Mathematical Analysis and Antimicrobial Activity of Methanolic Seed Extract of *Hunteria umbellate*. *European Journal of Medicinal plants31* (16): 1-17.

Alaneme. K. K., Olusegun. S. J., and Adelowo O.T. (2015). Corrosion Inhibition and Adsorption

Mechanism Studies of *Hunteria umbellate* Seed Husk Extracts on Mild Steel Immersed in Acid Solution. *Alenxandria Engineering Journal*, *1*,1-10.

Chapagain. A, Acharya. D, Das. A. K.., Chnetri K., Oli B. H and Yadav A.P. (2022). Alkaloid of *Rhynchosstylisretusa* as Green Inhibitors for Mild Steel Corrosion in 1M H_2SO_4 Solution. *Electrochemistry.3*, 211-224.Emembolu, L. N.

Achugbu O. E.., and Onukwuli O. D. (*2022,*) Bio inhibition of Corrosion of Mild Steel in 1 M NaOH by Ethanolic Extract of *Dialium guineense* Leaves Using Different Corrosion Techniques. *Manila Journal of Science* 15(2) pp. 1–18.

Dehghani, A., Bahlakeh, G., Ramezanzadeh, B., and Ramezanzadeh, M. (2020). Potential role of a novel green eco-friendly inhibitor in corrosion inhibition of mild steel in HCl solution: Detailed macro/micro-scale experimental and computational explorations. *Construction and Building Materials*, 245, 118464.

Gopal, J., Dwivedi, P., Sundaram, S., and Prakash, R. (2013). Inhibitive effect of *Chlorophytum borivilianum* root extract on mild steel corrosion in HCl and H_2SO_4 solutions. *Industrial and Engineering Chemistry Research, 52, 10673–10681.*

Ikemba A. I., and Okafor P. C., (2018)"Green corrosion protection for mild steel in acidic media: saponins and crude extracts of *Gongronema latifolium" Pigment and Resin Technology*. https://doi.org/10.1108/PRT-03-2018-0020

Kasim A. (2013). Plant Extract Nano particles Hybrid as Corrosion Inhibition for AA (2024) Aluminium Alloy. Ph.D. Dissertation. Ahmadu Bello University, Zaria.pp 1-304.

Nya N.E, Ikeuba A.I, Okafor P.C, Ugi B.U, Bassey V.M, and Obike A.I, (2018). Mild SteelCorrosion Mitigation in Sulphuric Acid via Benign Isolated Phytochemical from *viscumalbium. Journal of Material science and Chemical Engineering* 6, 132- 146.

Ogunleye. O .O.,Arinkoola . A.O., Eleta. O.A., Agbede O. O., Osho.Y. A., Morakinyo . A.F and Hamed. J. O. (2020). Green Corrosion Inhibition and Adsorption Characteristics of Luffa Cylindrica leaf extract on Mild Steel in Hydrochloric Acid Environment. *Heliyon* 6, 1-12.

Ogunleye.O.O., Arinkoola .A.O., Alagbe .S.O., Agbede .O.O., Omodele .A.F., Morakinyo .A.F., and Osho . Y.A. (2019). Synthesis of Green Inhibitor for Mild Steel in Acidic Environment. *Indian Chemical Engineer*. 0(0), 1-15.

Udiniyiwe C.O., and Agbedo E. S. (2022). Proximate Composition, Phytochemical and Antimicrobial Activity of Aqueous and Ethanolic Extract of Hunteria umbellate on some clinical Isolate. *Journal Appl. Sci. Environ. Manage*. 26 (1): 31-36.

Ugi, B.U., Bassey,V.M., Obeten, M.E., Adalikwu, S.A. and Nandi,D.O. (2020) Secondary Plant Metabolitesof Natural Product Origin—Strongylodo nmacrobotrys as Pitting Corrosion Inhibitors of Steel around Heavy Salt Deposits in Gabu, Nigeria. *Journal of Materials* ***Science*** *and Chemical Engineering*,8,38 60.https://doi.org/10.4236/msce.2020.8500.

Zulkifli.M.F. R, Bahrin. S.S, Abdullahi.S., Ghazali.M. S. M, and Wanik.W. M. N. (2021) *Citrus Aurantifolia* leaf Extract as a Potential Anti-Corrosion Additives in Alkyd Paint for Mild Steel. *Journal of Sustainable Science and Manangement*. 3, 10-20. http://doi.org/10.46754/jssm.2021.04.002