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Optimization of Blended Guava and Fluted Pumpkin Leaves Extract as Corrosion Inhibitor of Mild Steel in 0.5 m Hydrochloric Acid

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Abstract

There are many plant extracts that have been studied for possible use as corrosion inhibitors in the oil and gas industries. Hence, this work is focused on optimization of blended Guava and Fluted Pumpkin Leaves extract as corrosion inhibitor of mild steel in HCI using Weight loss method. Response Surface Methodology of Design Expert trial version 12 StatEase was used to design and analyze the result of the 35-run experiments. Three-factor-three level was adopted in the design. Time, Temperature and Inhibitor Quantity were the independent variables, while the acid concentration of 0.5M was constant throughout the experiments and Inhibition Efficiencies were measured using IE formula. Intervals of 1 hr, 0.2g, and 10℃ were chosen for the immersion time, inhibitor quantity and temperature, respectively. Phytochemical analysis carried out on the Guava and Fluted Pumpkin Leaves shows that each leaf extract contains phytochemicals which are responsible for inhibiting corrosion. Weight loss result shows that the Blended extract reduces the corrosion rate of mild steel in 0.5MHCI. Additionally,4 experiments for Blended Extract, Fluted Pumpkin, Guava Extract and Industrial Inhibitor were carried out at optimal conditions as predicted by the software at time 4.036 hr, temperature 49.5℃, inhibitor quantity 0.487g and ratio of 59.21GE:FP40.79 Inhibition Efficiencies of the Blended, Fluted Pumpkin, Guava Extracts and Industrial Inhibitor were 93.70%, 78.14%, 63.7% and 95.18%, respectively. The results show that the blended and Industrial Inhibitor compared well with the software predicted IE of 96.085%. Therefore, the blended extract could serve as good substitute to the industrial inhibitor.

Keywords: corrosion rate, fluted pumpkin leaf extract, guava leaf extract, inhibition efficiency, optimization, weight loss

1. INTRODUCTION

Corrosion is the deterioration of materials by chemical interaction with their environment [1]. It is an electrochemical process that gradually returns metals to its natural state in the environment [2]. The consequences of corrosion are many and varied and the effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than simple loss of a mass of a metal. Failure of various kinds and the need for expensive replacements may occur even though the amount of metal destroyed is quite small [3]. The total loss of pipeline due to corrosion in 2004 alone as reported by [4] was 396,000 metric tons, while the financial losses were estimated to be N19.66 billion (US$154.4m). In practice, it is almost impossible to prevent corrosion; however, it can be hindered or controlled to a reasonable level [5]. Due to problems from corrosion that are confronting industries, several methods of corrosion control and prevention have been put in place. These include cathodic protection, lubrication, anodic protection, alloying, coating, inhibition, amongst others. The choice and application of any of the methods is based on its efficiency, economic factors and the nature of the corrosive environment [3].

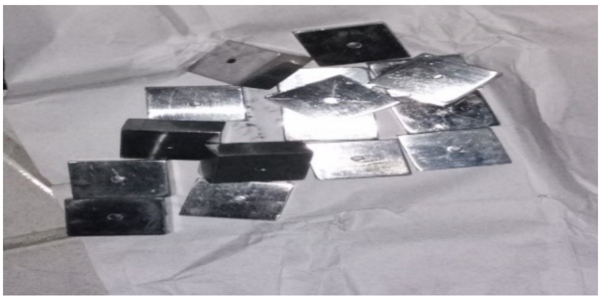

Figure 1: Samples of polished mild steel samples with drilled holes.

However, the use of corrosion inhibitors is about

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the most practical and economical method for corrosion protection and prevention of unexpected metal dissolution in aqueous aggressive media [6]. Organic inhibitors are mostly preferred to inorganic inhibitors especially heavy metal derivatives, because of the strict environmental regulations [4]. The presence of inhibitor retards the corrosion process and keeps the corrosion rate low, thus preventing economic loss due to metallic corrosion. A lot of research works have been carried out to combat the menace of corrosion of metals in the oil, metallurgical and other industries [4]. Extracts of some common plants and plant products (Carica papaya, Rosmarinus Officinalis, Damsissa, Murrayakoenigii, cashew, mango, Uncaria gambir and Fiscusycomorus) have been investigated, developed and tried as corrosion inhibitors for metals and alloys under different environment [7, 8]. The functionality of these compounds has been attributed to their electronegative functional groups and presence of π electrons in triple or conjugated double bonds. They also contain nitrogen, sulphur or oxygen atoms in their structures. Their mode of operation is by physical or chemical interactions between their molecules and the metal surfaces [8, 9].

In this study, weight loss technique was deployed to evaluate the Inhibition Efficiency of blended Fluted Pumpkin and Guava leaves Extract in 0.5M HCL using Response Surface Methodology of Design Expert Stat Ease trial version 12 to determine its optimum conditions. Subsequently, comparison was carried out between inhibitors from the leaves extract with Cronox CGW80437(industrial inhibitor) at optimum condition.

2. MATERIALS AND METHODS

2.1. Materials

The following locally sourced materials were used in this study: Fluted Pumpkin leaf, Guava leaf, mild steel (X65 grade) and Cronox CGW80437 (Industrial Inhibitor) also used were absolute ethanol and acetone, 0.5M HCl.

2.2. Equipment

The equipment used in this work were 250ml beaker, Soxhlet extractor, Heating Mantle, Rotary evaporator, Thermostatic water bath, EDXRF Analyzer, weighing balance and PRO X: Phehom world.

2.3. Methods

2.3.1. Chemical composition of mild steel

Mild steel X65 grade was prepared and sourced from SCC Company Bwari, Abuja, an Engineering Services company that fabricate and process steels for road construction. With the use of X-ray Fluorescence Spectroscopy at Umaru Musa Yar'Adua University Central laboratory, Katsina State, the mild steel was subjected to elemental composition test. The mild steel coupon was placed in EDXRF Analyzer, model no: ARL QUANT-1 X, S/no. 9952120, product Thermo-scientific Company, Switzerland. The XRF analysis was done using the standard method with mild steel coupon as a Thermo Fisher Scientific standard reference material. The mild steel coupon was first ground to a fine powder which was poured into a sample holder and covered with cotton wool to prevent it from spraying. The bottom of the sample holder is made of polypropylene which is a thermoplastic. The method was calibrated using geological calibration of oxide. The sample was run in the XRF spectrometer for 10 minutes after which the result was obtained.

2.3.2. Sample preparation

The mild steel sample of surface area 6.25cm^2 as shown in Fig. 1 was prepared by using the method adopted by [10]. The sheet was mechanically press - cut into 2.5 cm × 2.5 cm × 1.3cm and 0.3cm hole was drilled on the coupons for weight loss method and SEM analysis. Mill scales on these coupons were removed by milling and polishing to mirror finish using milling and polishing machines with a series of silicon carbide abrasive paper (200, 400, 600 respectively). The coupons were degreased in absolute ethanol, dipped in acetone before air-drying. They were then stored in moisture – free desiccator before use in corrosion and SEM studies.

2.3.3. Preparation of plant leaves and extraction

The Guava leaf as showed in Fig. 2b was sourced in Karomagiji village very close to the City gate Abuja, while the Fluted Pumpkin leaf was sourced at Kwali area of Abuja. The phytochemical screening of both leaves was carried out at Sheda Science and Technology Complex (SHESTCO), Kwali, Abuja. The Guava leaf was not sun dried to avoid drying up of the phytochemicals present but was rather air dried for 9 days. The air-dried leaves were macerated/grind to increase the surface area and packed into Soxhlet extractor before adding the solvent (ethanol). Heat was applied through the heating mantle at 78°C temperature for 72 hours. The extract was concentrated using rotary evaporator in order to remove the solvent (ethanol). The concentrated extract was put in fume cupboard/hood to remove residue ethanol. The same method was adopted for extraction of Fluted Pumpkin. The phytochemical screening was carried out according to methods reported by [7, 10–14]. Figures 2b and 2c show the ethanol extract of Guava and Fluted Pumpkin leaves.

2.4. Experimental Design

A Central Composite Design (CCD) of 35 experimental runs which included 3-operating variables was established for the experiments used for studying effect of temperature, immersion time and inhibitor quantity of the Guava Extract (GE) and Fluted Pumpkin Extract (FPE). There were 9 controls employed and the Inhibition Efficiency was the expected response of the study. The factor levels with the corresponding values are shown in

Table 1 while the Design Matrix is shown in Table 2. The matrix for the three variables was varied at 3 levels (Minimum -1, Centre 0 and Maximum +1).

Table 1: Independent Variables Experimental Range.

Independent variable	Symbols	Range and Levels		
		-1	0	+1
Immersion time (hours)	X1	3	4	5
Temperature (°C)	X2	30	40	50
Inhibitor quantity (g)	X3	0.2	0.4	0.6

The experiments were performed in random order to avoid systematic error, as adopted in literature [15]. The CCD was used to analyse the response. The ANOVA and graphical analyses of the Inhibition Efficiencies were carried out. The mathematical models in terms of coded and actual factors were obtained which agrees with [11].

2.5. Weight Loss Measurement

Weight loss measurement was conducted under total immersion using a 250ml beaker containing prepared solution at a temperature range of 30°C to 50°C which was placed in a thermostat-regulated water bath, a method adopted by [16] in his study.

The mild steel samples were immersed in 250ml of 0.5M HCL with inhibitor quantity range of 0.2g, to 0.6g with variable immersion time of 3h, 4h, 5h for each run using the design matrix format for variables interaction. At the end of each run, the mild steel coupon was withdrawn from the solution, washed, rinsed with distilled water to remove the corrosion product and then reweighed to get the difference in weight. From the initial and final masses of the mild steel samples, the weight (mass) loss was calculated using Eq. (1) for both the controls (untreated) and treated as adopted by [17]. At the end of the corrosion study, experimental data were recorded which was used to calculate the weight loss, Corrosion Rate and Inhibition Efficiency (IE) according to the Eqs. (1), (2) and (3) as adopted by [8, 18].

$$\Delta W = W_I - W_F \tag{1}$$

$$CR = \frac{\Delta W}{AT} \tag{2}$$

$$IE = \left(1 - \frac{\Delta W}{W_I}\right) \times 100 \tag{3}$$

Where ΔW: weight loss (g), W_I: Weight of the mild steel before immersion, W_F: Weight of the mild steel after immersion. CR: Corrosion rate ($gcm^{-1}hr^{-1}1$), IE: Inhibition Efficiency, A: Area of the mild steel coupons, T: Immersion time.

Table 2: Central composite design factors and level.

STD	Run	Time (Hr.)	Temp. (°C)	Ratio GE:FP	Quantity (gm)
25	1	4	40	50:50	0.4
22	2	4	40	70:30	0.4
14	3	5	30	60:40	0.6
19	4	4	30	50:50	0.4
11	5	3	50	40:60	0.6
6	6	5	30	60:40	0.2
20	7	4	50	50:50	0.4
9	8	3	30	40:60	0.6
4	9	5	50	40:60	0.2
21	10	4	40	30:70	0.4
1	11	3	30	40:60	0.2
15	12	3	50	60:40	0.6
13	13	3	30	60:40	0.6
2	14	5	30	40:60	0.2
5	15	3	30	60:40	0.2
8	16	5	50	60:40	0.2
10	17	5	30	40:60	0.6
16	18	5	50	60:40	0.6
12	19	5	50	40:60	0.6
23	20	4	40	50:50	0.2
7	21	3	50	60:40	0.2
3	22	3	50	40:60	0.2
17	23	3	40	50:50	0.4
24	24	4	40	50:50	0.6
18	25	5	40	50:50	0.4
Control1	26	3	30	–	–
Control2	27	3	40	–	–
Control3	28	3	50	–	–
Control4	29	4	30	–	–
Control5	30	4	40	–	–
Control6	31	4	50	–	–
Control7	32	5	30	–	–
Control8	33	5	40	–	–
Control9	34	5	50	–	–

2.6. Flourier Transform Infra Ray (FTIR) Spectra of the Guava, Fluted Pumpkin Extract and Corrosion Product

FTIR 8400s Fourier transform infrared spectrophotometer was used to determine separately the functional group of Guava Extract, Fluted Pumpkin Extract and the best performed blended inhibitor of Guava and Fluted Pumpkin Extract. The test was carried

out at National Research Institute for Chemical Technology, Zaria, Kaduna state. Guava and Fluted Pumpkin Extracts were subjected to FTIR to determine their functional group. After the corrosion studies, the corrosion products were scrapped from the metal and collected with a beaker to repeat the FTIR analysis.

3. RESULTS AND DISCUSSION

3.1. X-ray Fluorescence Spectroscopy

Table 3 shows result of X-ray fluorescence spectroscopy

3.2. Phytochemicals in Guava and Fluted Pumpkin Extracts

The result of the phytochemicals is given in Table 4. It could be seen that each extract contains

(a) Guava plant (b) Ethanol extract of guava leaves (c) Ethanol extract of FP

Figure 2: Guava plant, Ethanol extract of guava leaves and Ethanol extract of FP

Table 3: X-ray fluorescence spectroscopy.

Elements	Percentage Composition %
Ni	0.05
Cu	0.06
Mg	0.04
Al	0.13
Si	0.37
S	0.02
Ci	0.34
K	0.02
V	0.02
Cr	0.02
Mn	1.44
Fe	97.49

the same phytochemicals in different amount except steroids which was absent in FPE.

3.3. Weight Loss Result

The results of the weight loss as seen in the Table 5 shows that the corrosion rate of the mild steel was reduced when blended Guava and Fluted Pumpkin Leaves Extract was introduced in the acidic medium. Design Expert Stat Ease trial version 12 was used to analyze the result of the experiments and generate the empirical equation. The Table 4 shows the calculated corrosion rate of the mild steel coupons in the absence and presence of the blended inhibitors as obtained from the experimental data. Introduction of the blended extracts reduce the corrosion rate of the coupons. The Inhibition Efficiencies vary at different concentration of the extracts at different conditions. The above data show that blended extract reduce corrosion rate of mild steel coupons, this is as a result of the synergy between the phytochemicals present in the individual extract.

3.4. FTIR Result of Guava, Fluted Pumpkin Extract and Corrosion Product

The peaks of spectrum of the corrosion product are shown in Fig. 3a, while the peaks of spectrum of the Fluted Pumpkin and Guava Extracts are shown in Fig. 3b and 3c. The spectrum of each of the graph shows various peaks in the absorbance versus wavelength relationship. The peaks and their corresponding intensities represent the functional group of the plant extract. The shifts in peaks in the FTIR result of the corrosion product, suggest that there was interaction between the mild steel and some molecules of the blended extract. The variation of the number and the nature of the shifts indicate that there was synergy among the functional groups in the corrosion inhibition process which agrees with the work of [11].

3.5. SEM Examination of the Mild Steel Coupons

PRO X: Phehom world S/no. MVE 01570775 model no: 800-07334 was used to study the surface profile of the treated and untreated mild steel at 4 hours and 40°C in order to investigate the effects of the extract. It was observed from the surface profile of the untreated in Fig. 4a, a rough surface with porous layers full of cracks, the acid easily penetrated the steel causing it to corrode. However, in the presence of the blended inhibitor as shown in Fig. 4b at the same condition of 4 hours and 40°C, the active corrosion site was blocked by the inhibitor thereby reducing the rate at which the mild steel corroded. The reduction in corrosion rate was due to the formation of a protective layer by the blended FPE and GE on the metal surface. This shows that blended FPE and GE can be regarded as a good inhibitor for mild steel in HCl medium

From Fig. 4a, it can be observed that the metal corroded when it was exposed to the acid without inhibitor but on introduction of inhibitor, the active corrosion site on the metal was blocked which reduced the rate of the metal corrosion as can be seen on Fig. 4b.

3.6. Optimization of the Inhibition Process using Response Surface Methodology (RSM)

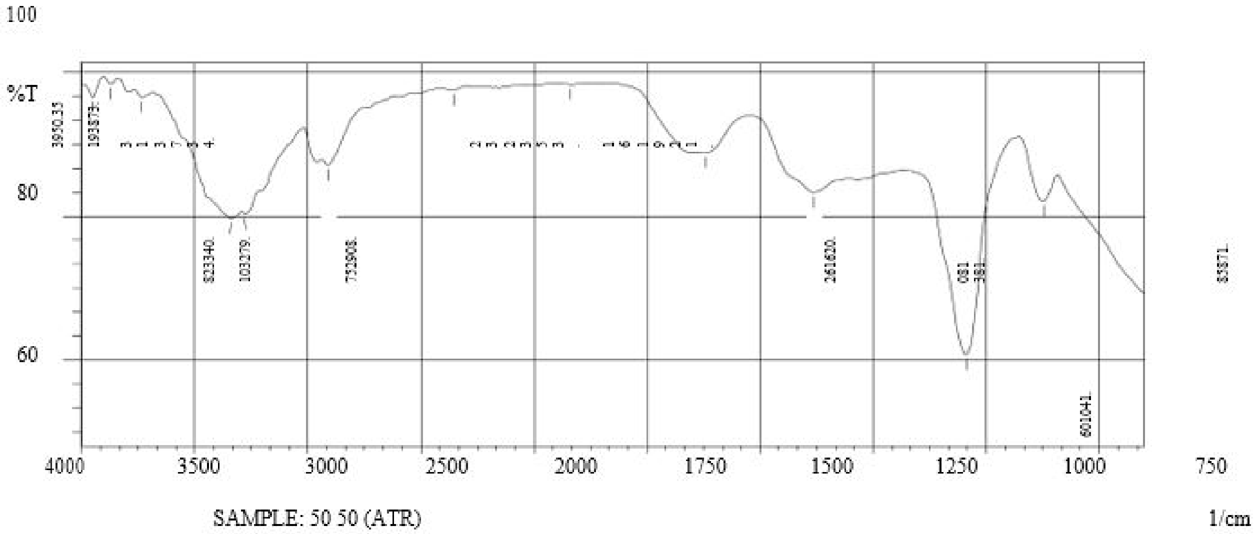
Central Composite Designs as adopted by [19] was used in the design and analysis of the result of these experiments because it can fit a full quadratic model. They are also used when the design plan calls for sequential experimentation because these designs can include information from

Table 4: Phytochemicals present in GE and FPE.

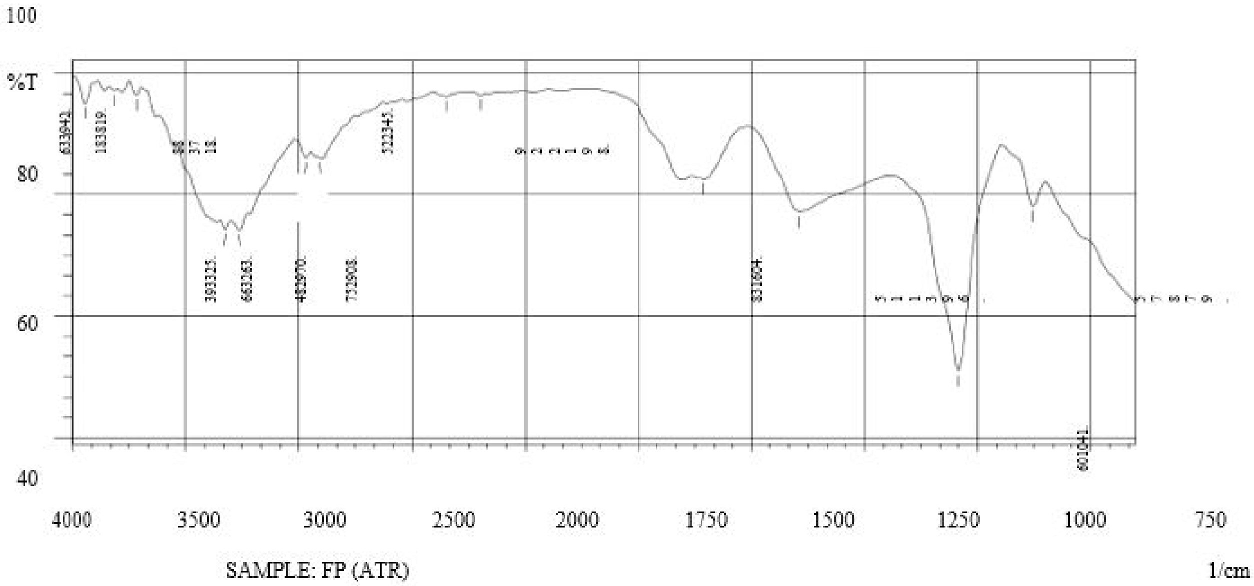
Phytochemicals	GE Qualitative	FPE Qualitative	GE Quantitative	FPE Quantitative
Glycosides	+	+		
Steroids	+	-		
Tannin	+	+	0.2348	0.2408
Alkaloid	+	+	0.2624	0.1968
Resins	-	-		
Balsams	+	+		
Flavonoid	+	+	0.2640	0.1564
Protein	-	-		
Phenols	+	+	0.2408	0.1721
Terpenoids	+	+		
Saponins			0.428	0.456

Table 5: Weight loss result with calculated corrosion rate and inhibition efficiencies.

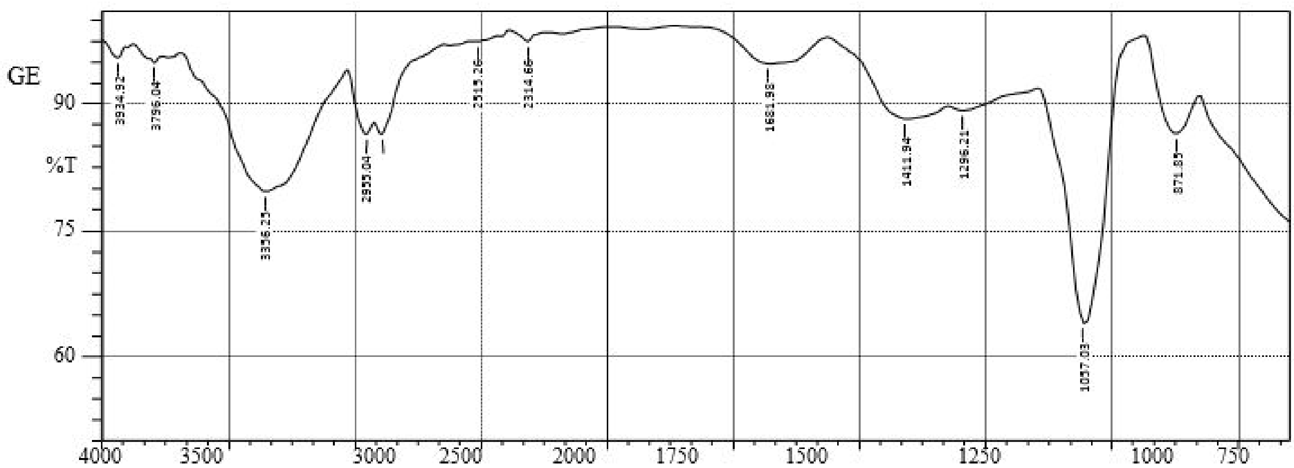
Run	Time (Hrs.)	Temp (°C)	Ratio GE:FP	Qty (g)	W_0 (g)	W_1 (g)	W_t (g)	CR ($gcm^{-2}h$-1)	IE. (°C)
1	3	30	40:60	0.2	63.49735	63.4939	0.001948092	0.0001038	75.77
2	5	50	60:40	0.2	61.9604	61.9534	0.007	0.000224	89.079
3	4	40	60:40	0.4	61.9437	61.9395	0.0042	0.000168	93.103
4	3	30	40:60	0.6	61.4866	61.4857	0.0009	0.000048	88.75
5	5	30	40:60	0.2	62.6998	62.6968	0.003	0.000096	75.409
6	4	40	50:50	0.4	60.5346	60.5134	0.004200273	0.0001680	93.103
7	4	40	30:70	0.4	61.1996	61.1963	0.0033	0.000132	94.58
8	5	50	40:60	0.6	62.52818	62.5131	0.00658307	0.0002106	89.73
9	5	50	60:40	0.6	62.6399	62.6346	0.0053	0.0001696	91.73
10	4	40	50:50	0.6	62.80519	62.7947	0.00829458	0.0003317	86.38
11	4	50	50:50	0.4	62.64422	62.6399	0.00432	0.0001728	84
12	3	40	50:50	0.4	62.13029	62.1155	0.000693	0.0002304	93
13	4	40	50:50	0.2	61.72267	61.6947	0.024969	0.0009987	59
14	5	40	50:50	0.4	61.20283	61.1839	0.001027	0.0000328	93.5
15	3	50	60:40	0.2	61.70461	61.688	0.01111085	0.0006088	83.71
16	3	50	40:60	0.6	62.6801	62.6966	0.0035	0.000186	95.007
17	3	30	60:40	0.2	61.3567	61.3545	0.0022	0.000117	72.5
18	5	30	40:60	0.6	61.5980	61.5958	0.0022	0.0000704	81.96
19	5	30	60:40	0.6	62.0377	62.0363	0.0014	0.0000448	80.52
20	3	50	40:60	0.2	62.27189	62.2351	0.01418824	0.0007774	79.76
21	3	50	60:40	0.6	61.9668	61.9632	0.0036	0.000192	94.86
22	4	30	50:50	0.4	61.71432	61.7	0.0124215	0.0004968	63.25
23	3	30	60:40	0.6	62.0037	62.0025	0.0012	0.000064	85
24	4	40	70:30	0.4	62.6980	62.695	0.003	0.00012	95.073
25	5	50	40:60	0.2	62.6760	62.6681	0.0079	0.0002528	87.67
26	5	30	60:40	0.2	61.9193	61.9156	0.0037	0.0001184	69.67
27	3	30	Control 1	Nil	62.1269	62.1189	0.00804	0.0004	-
28	3	40	Control 2	”	61.1255	61.1156	0.0099	0.0005	-
29	3	50	Control 3	”	59.9805	59.9104	0.0701	0.0037	-
30	4	30	Control 4	”	62.0853	62.0515	0.0338	0.0013	-
31	4	40	Control 5	”	62.2077	62.1468	0.0609	0.0024	-
32	4	50	Control 6	”	62.1826	62.1556	0.027	0.0010	-
33	5	30	Control 7	”	62.7078	62.6956	0.0122	0.0003	-
34	5	40	Control 8	”	60.4053	60.3895	0.0158	0.0005	-
35	5	50	Control 9	”	61.9327	61.8986	0.0641	0.0020	-



(a) FTIR result for best performed blended extract

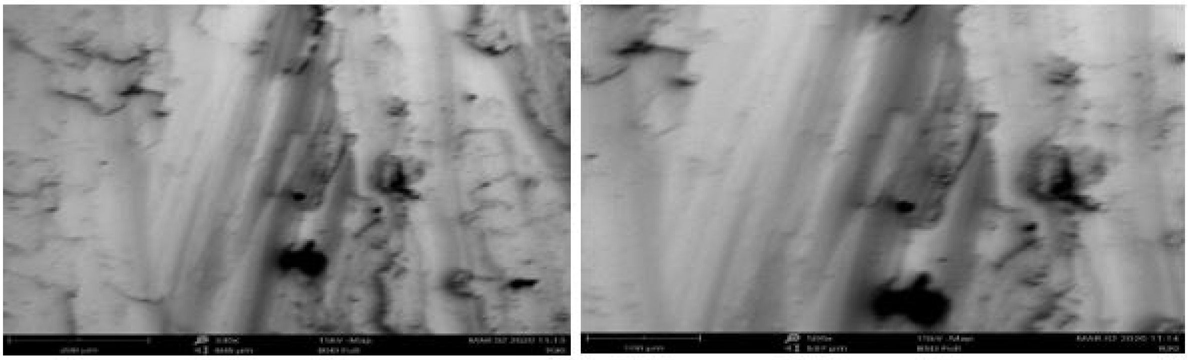


(b) FTIR result for FP extract

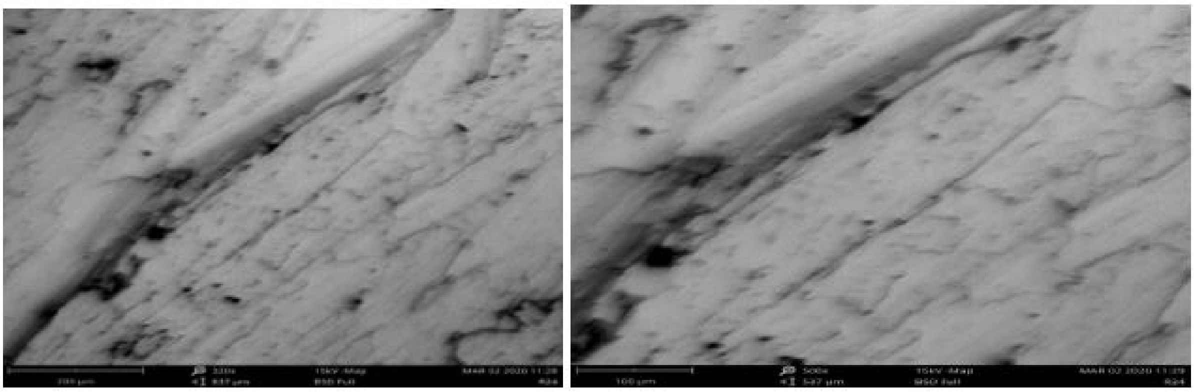


(c) FTIR result for GE

Figure 3: FTIR results for (a)best performed blended extract, (b)FP extract and (c) GE.



(a) SEM for mild steel without inhibitor at 4 hours and 40°C temperature



(b) SEM for mild steel with inhibitor at 4 hours and 40°C temperature

Figure 4: SEM for mild steel with and without inhibitor at 4 hours and 40°C temperature

a correctly planned factorial experiment. The design plan was used to optimize the corrosion Inhibition Efficiency of the blended guava and fluted pumpkin leaves extract on mild steel in HCI medium. The coded and uncoded values of the test variables were used to optimize the variables namely quantity of inhibitor, exposure time and temperature. The result of corrosion Inhibition Efficiency depends on significant variation for combination of process parameters. The empirical relationship between corrosion Inhibition Efficiency (Ygravimetric method) and three variables in coded values was obtained by using the statistical package Design-Expert trial Version 12 (Stat-Ease, Inc.) for determining the levels of factors which gives optimum corrosion Inhibition Efficiency was given by the equation 4 as adopted by [19] in their studies. The software uses the theory of the coded values for the analysis of the significant terms; hence, to study the effect of the variables on the responses, equation in coded values was used. Empirical equation is represented as shown in equation 4:

$$Y = \beta_0 + \int_{i=1}^{4} \beta_i X_i + \int_{i=1}^{4} \beta_{ii} X_i^2 + \int_{i=1}^{4} \int_{j=i+1}^{4} \beta_{ij} X_i X_{ij} \quad (4)$$

Empirical quadratic equation with coefficient is given as

$$\begin{aligned} &Y_{\text{inhibition efficiency}} \\ &= 93.10 - 0.3762A + 5.161B – 0.2317C \\ &= +5.35D + 1.18AB – 0.0621AC – 1.18AD \\ &= +1.37BC – 0.7633BD – 0.0079CD + 0.0784A^2 \\ &= –4.83B^2 + 0.4725C^2 – 5.06D^2 \end{aligned} \quad (5)$$

P-values less than 0.0500 indicate model terms are significant. In this case B, D, AB, AD, BC, B^2, D^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. Therefore, A, C, AC, BD, CD, A^2 and C^2 are insignificant model terms which are not included, resulting to a model reduction and gives Eq. 6 as the improved model.

$$\begin{aligned} &Y_{\text{inhibition efficiency}} \\ &= 93.10 + 5.16B + 5.35D + 1.18AB \\ &- 1.18AD + 1.37BC – 4.83B^2 – 5.06D^2 \end{aligned} \quad (6)$$

Equation (6) represents the quantitative effect of the factors (A, B, C, and D) upon the response ($Y_{gravimetric}$ method). Coefficients with one factor represent the effect of that factor while the coefficients with more than one factor represent the interaction between those factors. Positive sign in front of the terms indicates synergistic effect while negative sign indicates antagonistic effect of the factor. This finding agrees with the work of [19, 20].

The adequacy of the above proposed model was tested using the Design Expert sequential model sum of squares and the model test statistics. From the statistics test, the regression coefficient (R^2 = 0.9812) is high, and the adjusted RR^2 (0.9636) is in close agreement with the predicted RR^2 (0.8915) value. This showed that the experimental data obtained for the Inhibition Efficiency are statistically consistent and the second order polynomial model selected was suitable for modelling the second-order polynomial equation in final equation terms of the coded values of the process parameters as showed above. This agrees with the work of [16]. Table 6 and Fig. 5 show ANOVA table and the relationship between the actual and the predicted values.

Table 5 shows that the single factors of significant effects are Temperature (B) and quantity of Inhibitor (D) and for interaction factors are B^2 and D^2.

It can be seen from Fig. 5 that the data points on the plot were reasonably distributed near to the straight line, indicating a good relationship between the experimental and predicted values of the response as also shown by [20] in their studies and that the underlying assumptions of the above analysis were appropriate. The result also suggests that the selected quadratic model was adequate in predicting the response variables for the experimental data as reported by [2, 19].

3.7. Surface Response Plots for Mild Steel with blended FP and GE

The interactive effects of the process variables on the corrosion rate were studied by plotting a three-dimensional surface curve against any two-independent variable, while keeping the other variable constant as adopted by [15]. The 3D curves are shown in Figs. 6 – 8. Figure 6 indicates that the Inhibition Efficiency is about 95 percent at 50°C and 5 hours. The graph shows the actual value of the blending ratio C and Quantity of Inhibitor D. In Fig. 7 Time increases the IE up to 0.4 g combination of inhibitors. It only decreases above 0.4 g. while Fig. 8 indicates that temperature is the only significant factor. At 50°C, the IE was at 95%. The graph also shows the actual value of time (A) 4 hr. and quantity of inhibitor (D) 0.489g.

3.8. Predicted and Actual Optimal Levels

The Design Expert software predicted the following optimized conditions: time, 4.036hr, temperature, 49.481°C, blending ratio 59.214:40.786, quantity of inhibitor 0.487g, IE 96.085%. Four different experiments were conducted for Cronox CGW80437 (Industrial Inhibitor), Fluted Pumpkin Extract, Guava Extract and the Blended Extract to validate the optimal conditions predicted by the software. The IE results of the four experiments show that Industrial inhibitor has 95.18%, FPE, 78.14%, GE 63.7% while the blend 93.70%. This shows that the equation 6 above can be used to predict the IE of the inhibitors and Blended Extract is a good substitute for Cronox CGW80437 (industrial inhibitor) considering the environmental, cost and health implications of using industrial inhibitors.

4. CONCLUSION

The following conclusions were drawn:

1. The Phytochemical compounds in the leaves extract of blended Guava and Fluted Pumpkin inhibited the corrosion of mild steel in varying concentration.

2. Using the Central Composite Design of Response surface methodology in Design Expert trial version 12 to analyze, model and optimize the inhibition process of the Blended Guava and Fluted Pumpkin inhibitor, the optimized conditions predicted by the software was immersion time 4.036 hr., temperature 49.481°C, ratio of inhibitor 59.21: 40.79, inhibitor quantity 0.487g, Inhibitor Efficiency 96.085%

3. The IE obtained from the experiment for Cronox CGW80437 (industrial inhibitor) (95.18%) compared well with that of Blended Extract (93.70%) under optimized conditions. These were very close to the predicted value (96.085%).

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Table 6: ANOVA for Quadratic model (Response: Inhibition Efficiency).

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	2739.61	14	195.69	55.81	< 0.0001	Significant
A-Time	3.40	1	3.40	0.9687	0.3406	
B-Temperature	639.71	1	639.71	182.43	< 0.0001	
C-Ratio of lnh	1.29	1	1.29	0.3675	0.5535	
D-Qty of lnh	685.97	1	685.97	195.63	< 0.0001	
AB	22.31	1	22.31	6.36	0.0234	
AC	0.0616	1	0.0616	0.0176	0.8963	
AD	53.75	1	53.75	15.33	0.0014	
BC	29.84	1	29.84	8.51	0.0106	
BD	9.32	1	9.32	2.66	0.1238	
CD	0.0010	1	0.0010	0.0003	0.9867	
A^2	0.1686	1	0.1686	0.0481	0.8294	
B^2	639.31	1	639.31	182.32	< 0.0001	
C^2	6.12	1	6.12	1.75	0.2061	
D^2	702.71	1	702.71	200.40	< 0.0001	
Residual	52.60	15	3.51			
Lack of Fit	52.60	10	5.26			
Pure Error	0.0000	5	0.0000			
Cor Total	2792.21	29				

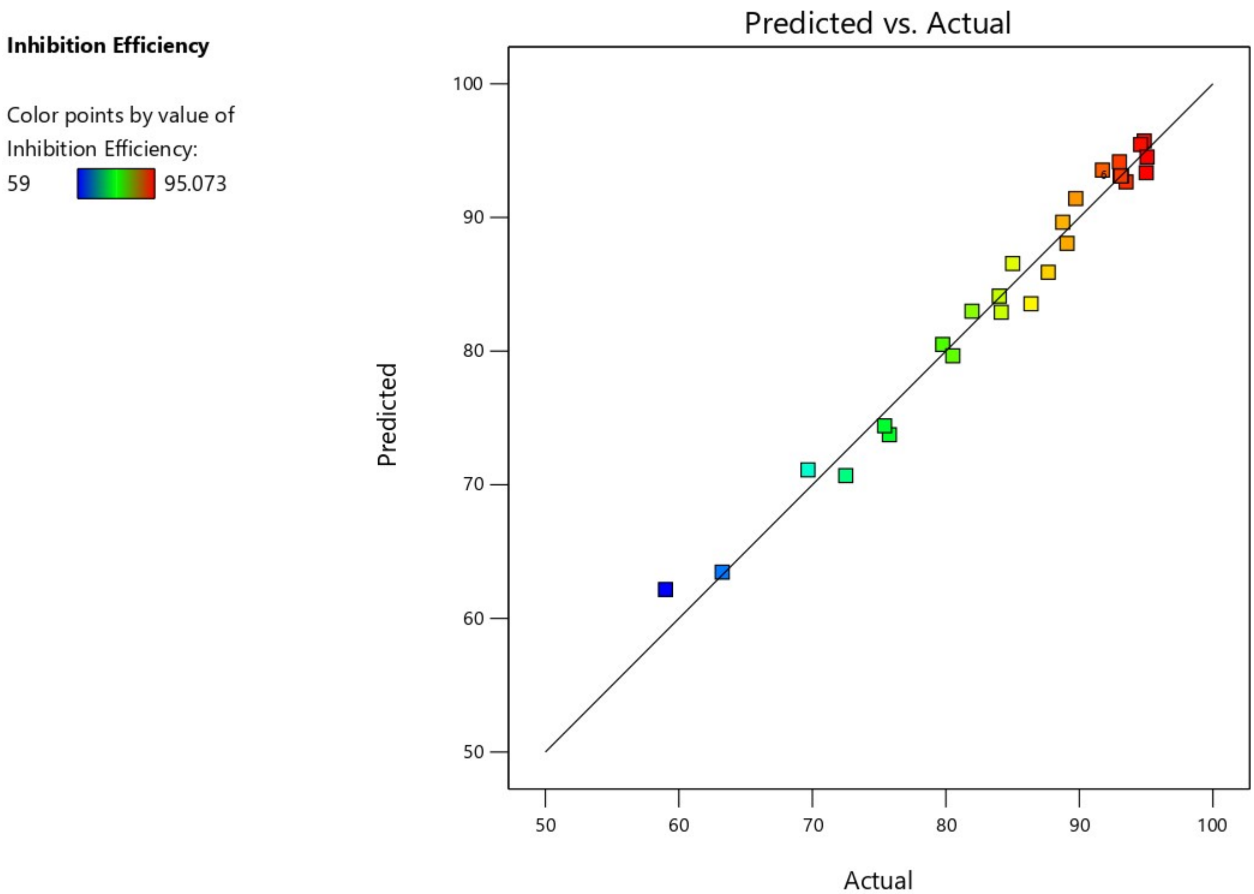

Figure 5: Predicted vs actual.

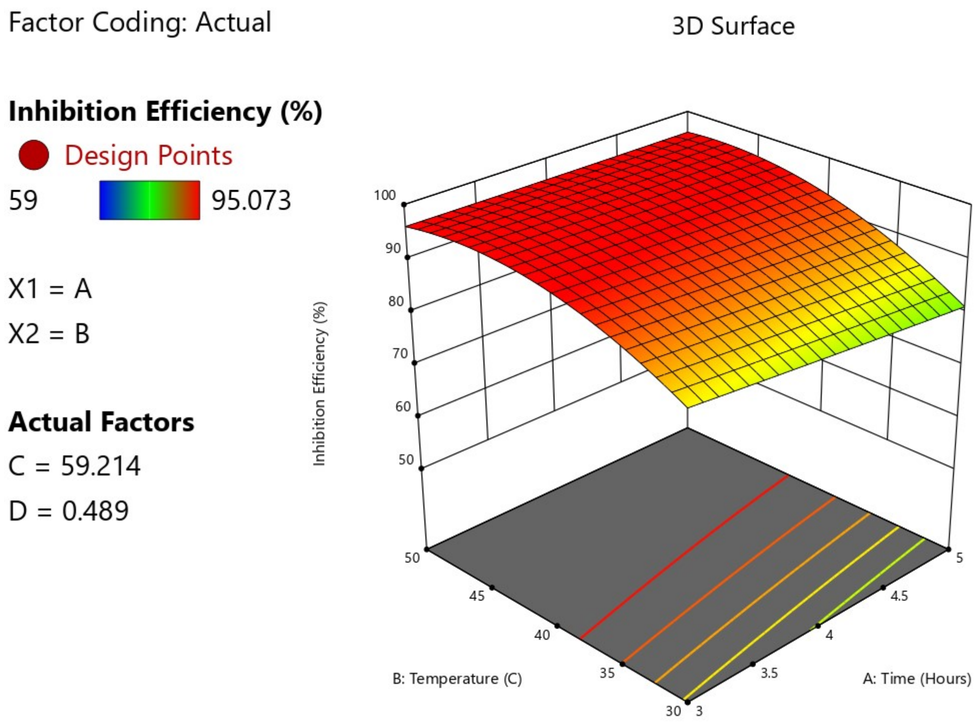

Figure 6: 3D Surface plot of IE, Temperature and Time.

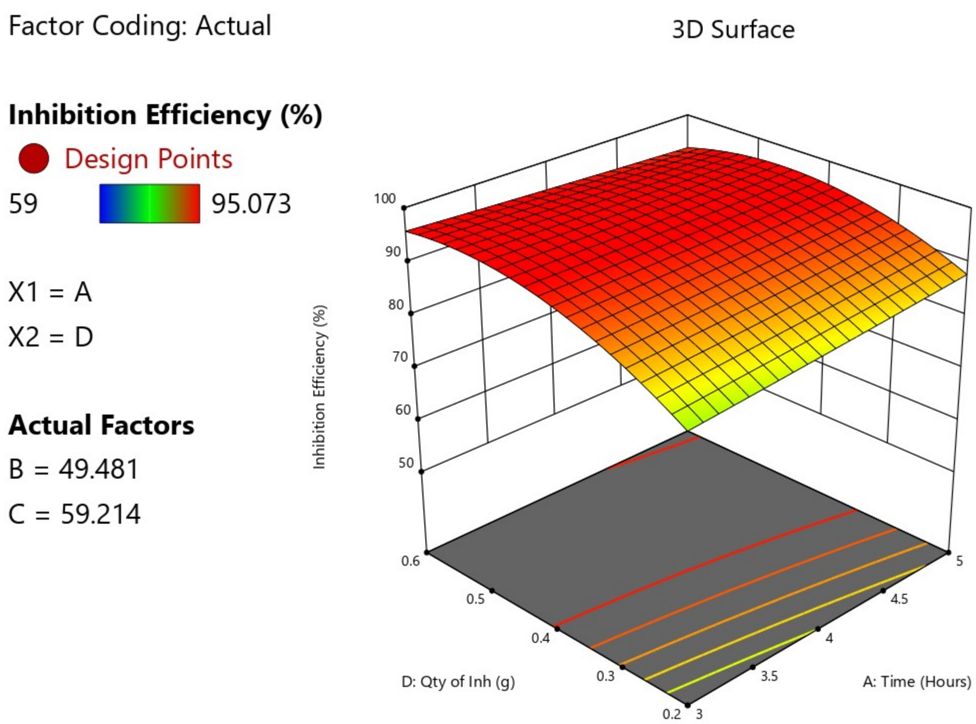

Figure 7: 3D Surface Plot of IE, Qunatity of inhibitor and Time.

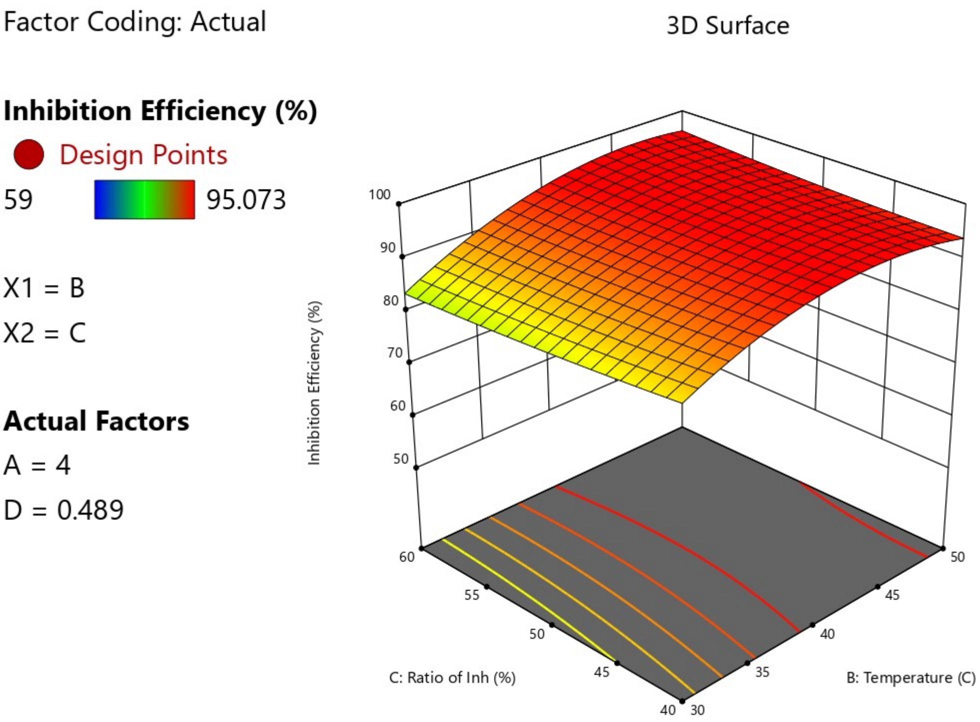

Figure 8: 3D Surface Plot of IE, Ratio of Inhibitor, Temperature.

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