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The Inhibitive Effect of *Carica Papaya* Leaf Extract on the Corrosion of Mild Steel in Acidic (1MHCl) Medium

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----------***ABSTRACT***----------
The effect of Carica papaya (pawpaw) leaf extract as an organic 'green' inhibitor on mild steel corrosion in 1M HClsolution was studied at ambient conditions. The biochemical species responsible for corrosion inhibition of the extract were determined both qualitatively and quantitatively by standard phytochemical methods. The species detected were alkaloids (1.93%), flavonoids (0.22%), saponins (19.74%), and tannins (3.82%). Six experimental setups were used, for the corrosion inhibition studies namely;distilled water (control 1),1M HCl (control 2), 5ml, 10ml, 15ml and 20ml extract in 1M HCl respectively. Weight loss technique of corrosion rate measurement was used for the experimental work. Results obtained showed effective corrosion inhibition of the extract on the mild steel test-specimens in the different concentrations of the extract used, with extract concentration and exposure time having some effect on the corrosion rate. The 5ml extract showed better inhibition initially while the 20ml extract showed the best overall inhibition. The results were further analyzed using the two-factor ANOVA without replication and indicated that extract concentration had more significant effect on corrosion rate than the exposure time.

Keywords: *Corrosion, Carica papaya, extract, inhibitor, phytochemical tests, mild steel, acidic medium, ANOVA*

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I. INTRODUCTION

Corrosion of metals is a serious environmental problem,[1,2] which is of great concern in the globally.Steel, an alloy of mainly iron and carbon,[3,4] is a versatile industrial metal used in different engineering structures, the manufacturing of equipment and construction. Thus, steel is exposed to different environments which are most often corrosive to the metal. There is need therefore to mitigate corrosion problems and elongate the service life of the metal.

Acid solutions are widely used in industry for several purposes, such as acid pickling, industrial acid cleaning, acid descaling and oil well acidizing[5, 6] and these are generally aggressive to metals such as steels.Although there are numerous options for controlling the corrosion of metals, like cathodic protection, material selection, protective coatings, design and process control (temperature, pressure, flow rate);[2, 11, 12] the use of inhibitors is one of the most practical methods for the protection of mild steel against corrosion especially in acidic media.[1,4 –10]

Dueto increasing concerns about the environment recently and stricter environmental regulations, low inhibitor toxicity is an important requirement for practical applications of inhibitors.[7,13,14]Consequently the current focus on corrosion inhibitor research is to identify and develop new classes of non-toxic, environmentally friendly and inexpensive alternatives.[1,5–19]

Results of previous studies on the inhibitive effect of some selected plant extracts such as the leaf extracts of *Occimumviridis (OV), Telferiaoccidentalis (TO), Azadirachtaindica (AI),Hibiscus sabdariffa (HS),Mimosa pudica (MP),Moringa oleifera* (MO),*Aspilia Africana*, tobacco, seeds of *Garcinia kola (GK)*on the acid corrosion of metals using electrochemical and weight loss monitoring methods indicate that all theextract inhibited the corrosion process by virtue of adsorption of their phytochemicalconstituents on the corroding steel surface and inhibition efficiency improved withconcentration of the active constituents.[6,7,14,16,17,19]Obviously, plant extracts are low-cost, readily available and renewable sources of materials.[1,5–7,9,12,13,15,17–20]In spite of these advantages, only very few plants has been thoroughly investigated. This prompted this investigation of *Carica Papaya,*[8,9,18,19,21,22] to further establish the effectiveness of plant leaf extract as corrosion inhibitor of mild steel in 1M HCl solution. This work furtherattempts a deduction of the inhibition mechanism and possible adsorption modes of the extract active components through a number of experimental and theoretical observations.

II. MATERIALS AND METHODS

The materials and reagents used in this work include mild steel sheet (composition shown in Table 1), *Carica papaya* leaves, 96% analytical grade n-Hexane, 99.9987% analytical grade hydrochloric acid (HCl), and distilled water.The following methods or procedures were followed:

Table 1: Chemical composition of mild steel used

Constituent Element	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**V**	**W**
% Composition	0.008	<0.0001	0.271	0.0003	0.0092	0.011	0.026	0.0014	<0.0001
Constituent Element	**Pb**	**B**	**Sn**	Zn	**As**	**Mo**	**Al**	Cu	**Co**
% Composition	0.0022	0.0008	0.0009	0.0016	<0.0001	0.0022	0.007	0.027	<0.0001
Constituent Element	**Ti**	**Nb**	**Bi**	**Ca**	**Ce**	**Zr**	**La**	**Fe**	
% Composition	<0.0001	0.0039	0.0011	0.0002	<0.0001	<0.0001	<0.0001	99.6	

2.1 Preparation of Mild Steel Coupons

Test specimens or corrosion coupons were cut from the mild steel sheet into an average rectangular size (3cm × 2cm × 0.2cm) witha 0.3cm drilled hole.A total of 24 coupons were prepared and used.
Each coupon was visually examined for surface defects, subsequently ground using silicon carbide abrasive paper (P60, P150 and P400C) to expose the surface for corrosion monitoring. They were further degreased in ethanol and dried in acetone. The treated coupons were then stored over calcium chloride in a moisture-free desiccator to prevent contamination prior to corrosion studies.

2.2 Preparation of*Carica Papaya* Leaf

Carica Papaya leaves as shown in **Plate 1**, were washed, sun dried in open air at about 30℃ to40℃ for 21days to ensure proper removal of moisture and subsequently ground using a 20kg grinding mill to near powder and its juice extracted for the corrosion inhibition study.

(a) *Carica papaya* plant showing fresh leaves

(b)*Carica papaya* leaves after drying

(c)*Carica papaya* leaf powder after drying and grinding

Plate 1: Sequence of preparation of *Caricapapaya* leaves for the extraction process

2.3 Extraction Process

The near-powder ground*Carica Papaya* leaf was soaked in a bottle with required quantity of analytical grade n-Hexane solvent for 24hrs. 250ml of the resulting solution was then poured into a round bottom flask and heated to reflux at about 70°Cfor 3hrsusing a Soxhlet extractor.[23–25] The following standard precaution was noted and observed: high temperature, stagnant water in the condenser, and high volume of solvent in the round bottom flask can lead to over floating which on further heating can lead to explosion.

2.4 Phytochemical Tests

The quantitative phytochemical tests were carried out using standard methods of analysis of alkaloids, flavonoids, saponins, and tannins.[12,26–29]

a) TEST FOR ALKALOIDS: 50mls of 10% acetic acid in alcohol was added to 2.162g of the near-powder ground*Carica Papaya* leaf in a beaker and soaked for about 12hrs; 2mls of ammonia (precipitating agent) was added to the filtrate.
A Whatman No. 42 grade filter paper was dried and pre-weighed before using it to filter the precipitate, after which the resulting filter paper is baked in an oven and immediately weighed while hot and the various weights were used for the computation of the percentage of alkaloid present in the *Carica Papaya* leaf.

b) TEST FOR FLAVONOIDS: 50mls of 2.0M HCl was added to 2.120g of the near-powder ground*Carica Papaya* leaf in a beaker and soaked for about 12hrs; 2mls of ethyl acetate (precipitating agent) was added to the filtrate.

A Whatman No. 42 grade filter paper was dried and pre-weigh before using it to filter the precipitate after which resulting filter paper was baked in an oven and immediately weighed while hot and various weights were used for the computation of the percentage of alkaloid present in the leaf.

c) TEST FOR SAPONINS: 2.0895g of the near-powder ground*Carica Papaya* leaf was tied with a filter paper and placed in a Soxhlet extractor to obtain an extract using petroleum ether as solvent for about 6hrs. The diffracted material in the filter paper was removed, air dried and subsequently weighed. The step above was repeated using methanol as the extracting solvent and the difference between the weights was used to obtain the percentage of saponins in the leaf.

d) TEST FOR TANNINS: 100ml distilled water was added to 1g of the near-powder ground*Carica Papaya* leaf in a conical flask, boiled gently on a hot plate for an hour, filtered with a filter paper into a 100ml volumetric flask. The paper is washed with distilled water and extract diluted, then cooled.
50ml of distilled water and 10ml of diluted extract was pipetted into a 100ml conical flask followed by 5ml folin-Denis reagent and 10ml of saturated Na_2CO_3solution. After thorough mixing, the solution was left to stand for about 30mins in a water bath at 25℃.

2.5 Preparation of Absolute HCl Solution

The corrosive environment (1M HCl) was prepared by adding 300ml of the 99.9987% analytical grade HCl to distilled water in a conical flask, an additional distilled water was added to the pre-diluted acid solution to obtain the required 2500ml of 1M HCl solution having a pH of 2.082 when measured with Jenway pH meter (model 3520).

2.6 Immersion of Coupons, pH and Weight Loss Measurements

The pH of each of the six media was measured using Jenway pH meter (model 3520) before immersion of coupons. At the end the corrosion studies, pH measurement was repeated for each medium after removal of coupons.

The initial weights of the coupons were taken to the nearest 0.0001g on a digital weighing balance (OHAUS Adventurer); those with uniform weights were selected for the experiment. Four coupons were completely suspended in each of the six airtight plastic containers, each containing 400ml of required test solution (i.e. distilled water serving as control 1, uninhibited 1M HCl serving as control 2, and1M HClinhibited with 5ml, 10ml, 15ml or 20ml extract) with the aid of polystyrene thread at a temperature of 25°C. Each setup stood for various periods or exposure times, i.e. 120, 240, 360, and 480 hours.
Computation of corrosion rate (in mm/yr) was done as follows:[2−4,10,30−32]

- Corrosion rate (mm/yr.) = $\frac{KW}{\rho At}$ [1]

Where, W = Weight loss (mg)
ρ = Density of specimen = 7.9g/cm^3
A = Surface area of specimen or coupon = 13.6701cm^2
t = exposure time (in hours)
K = 87.60

- Inhibitor efficiency (%) = $\frac{CR_u - CR_i}{CR_u} \times 100$ [2]

Where, CR_u = Corrosion rate of the uninhibited system
CR_i = Corrosion rate of the inhibited system

2.7Test of Statistical Significance

The two-factor analysis of variance (two-factor ANOVA) without replication tests were done at 95% confidence level (5% or 0.05 level of significance) to evaluate the separate effects of exposure time and concentration of *carica papaya* leaf extract on the weight loss, corrosion rate, and inhibition efficiency of mild steel in 1M HCl solution.[20, 34]. Two-way ANOVA is based on the Fisher's F-test and is used to determine which factors or variables have significant effect on the properties or process of interest. Usually, large *F*values imply that the factor or variable has a significant effect on the property being investigated. The factor that has the larger (or largest) F value is considered to have the more (or most) significant effect on the property. The 'P-values' are also useful for determining the level of significance of factors. Usually, 'P-values' that are smaller than 0.05 level of significance, indicate that the factor has significant effect. The smaller is the "P-value', the more significant will be the effect of the factor under consideration [35, 36]. In this test, exposure time and concentration of extract were used as the row factor and column factor, respectively; while the properties affected were weight loss, corrosion rate, and inhibition efficiency.

In the case of weight loss and corrosion rate, there are 4 rows and 6 columns, making the degree of freedom (*df*) for exposure time and concentration of extract to be respectively 3 and 5 (numerators in the F-

distribution table). Similarly, the interaction of row and column factors gives a '*df*' of 15, which is their common denominator in the F-distribution table.

III. RESULTS AND DISCUSSION

The results of phytochemical tests, pH measurements, weight loss, and hence corrosion rate and inhibition efficiencyare presented in Tables 2, 3 and 4 respectively. The results of inhibition efficiency are applicable to mild steel specimens immersed in 1M hydrochloric acid at the various inhibitor concentrations and exposure times; while weight loss and corrosion rate apply to both inhibited and uninhibited 1M HCl solutions as well as distilled water.

Table 2: Quantitative phytochemical analysis of Carica papaya leaf extract

Phytochemical Constituent	Alkaloid	Flavonoid	Saponin	Tannin
Quantity (%)	1.9288	0.2217	19.7368	3.8215

Table 3: pH of the various media before and after immersion

Medium inside which mild steel coupons were immersed	Distilled water (Control 1)	1M HCl (Control 2)	5ml extract in 1M HCl	10ml extract in 1M HCl	15ml extract in 1M HCl	20ml extract in 1M HCl
Initial (before immersion of coupons)	7.25	2.082	2.082	2.082	2.082	2.082
Final (after removal of coupons at end of corrosion studies)	5.361	2.524	2.364	2.374	2.366	2.374

Table 4: Weight loss in the various media

Exposure Time	**Distilled Water**	**1M HCl**	**5ml Extract in 1M HCl**	**10ml Extract in 1M HCL**	**15ml Extract in 1M HCL**	**20ml Extract in in 1M HCL**
120	15.5	492.4	11.2	22.6	43.9	26.4
240	43.2	1238.5	33.5	50.6	63.4	35.2
360	52.1	2154.0	60.3	82.2	94.8	50.5
480	71.4	3279.6	93.1	98.9	132.3	65.9
	Logarithmic values of weight loss (to shrink the range of values)					
120	1.1903	2.6923	1492	1.3541	1.6425	1.4216
240	1.6355	3.0929	1.5250	1.7042	1.8021	1.5465
360	1.7168	3.3333	1.7803	1.9149	1.9768	1.7033
480	3.5158	1.8537	1.9690	1.9952	2.1216	1.8189

3.1 Result of Phytochemical Test

Quantitative phytochemical analysis of *carica papaya*leaf extract showed that four biochemical species were detected (Table 2)as follows:alkaloid (1.93%),flavonoid (0.22%), saponin (19.74%), and tannin (3.82%). Among these, tannin is identified to be the most active biochemical inhibitor. Tannins are used for production of anti-corrosive primer, sold under brand name Nox Primer for treatment of rusted steel surfaces prior to painting, rust converter to transform oxidized steel into a smooth sealed surface and rust inhibitor.[30]

3.2 Result of pH Measurement

The pH values are presented in Table 3. The inhibited setups (5ml, 10ml, 15ml, and 20ml extracts in 1M HCl) as well as the uninhibited medium (1M HCl) generally experienced an increase in pH (decreasing acidity) at the end of the corrosion studies with the 1M HCl medium having the highest discrepancy. Conversely, the distilled/de-ionized water showed a reduction in pH measurement (increasing acidity) at the end of the corrosion study. Theacidic pH reading as observed in both the inhibited and uninhibited1M HCl solutions can be attributed to the presence of Cl^- ions while the neutral to mildly alkaline pH reading shown by distilled water is due to OH^- ions.

3.3 Weight Loss

The result of weight loss measurement is presented in Table 4 and Figures 1 and 2. The mild steel coupons immersed in distilled water (control 1 or best-case scenario) had minimal weight loss,that is; 15.5, 43.2, 52.1 and 71.4 mg respectively after 120, 240, 360 and 480 hours of exposure.In the case ofmild steel coupons immersed in 1M HCl solution without inhibitor (control 2 or worst-case scenario); significant weight loss was recorded within the duration of the experiment. That is 492.4, 1238.5, 2154, and 3279.6 mg respectively after exposure times of 120, 240, 360 and 480 hrs. In comparison, the mild steel coupons immersed in 1M HCl solution to which was added various concentrations of the extract experienced minimal weight lossagain (Table 4). This is a clear indication thatCaricapapaya leaf extract had inhibiting effect on the corrosion of mild steel in acidic

environment as shown by the reduced rate of weight loss. The 5 ml extract in 1M HCl appear to have the best inhibiting effect below 240 hours while 20 ml extract had the best effect above 240 hours (Figures 1 and 2). The lowest inhibiting effect (in this case, the extent to which weight loss is reduced) occurred with the 15 ml extract in 1M HCl, followed by 10ml extract. This shows that the inhibitor can perform at low concentrations, which is economically desirable. The 20 ml extract had the best overall inhibiting effect with a weight loss of 65.9 mg after 480 hours of exposure compared to distilled water in which the weight loss was 71.4 mg after 480 hours.

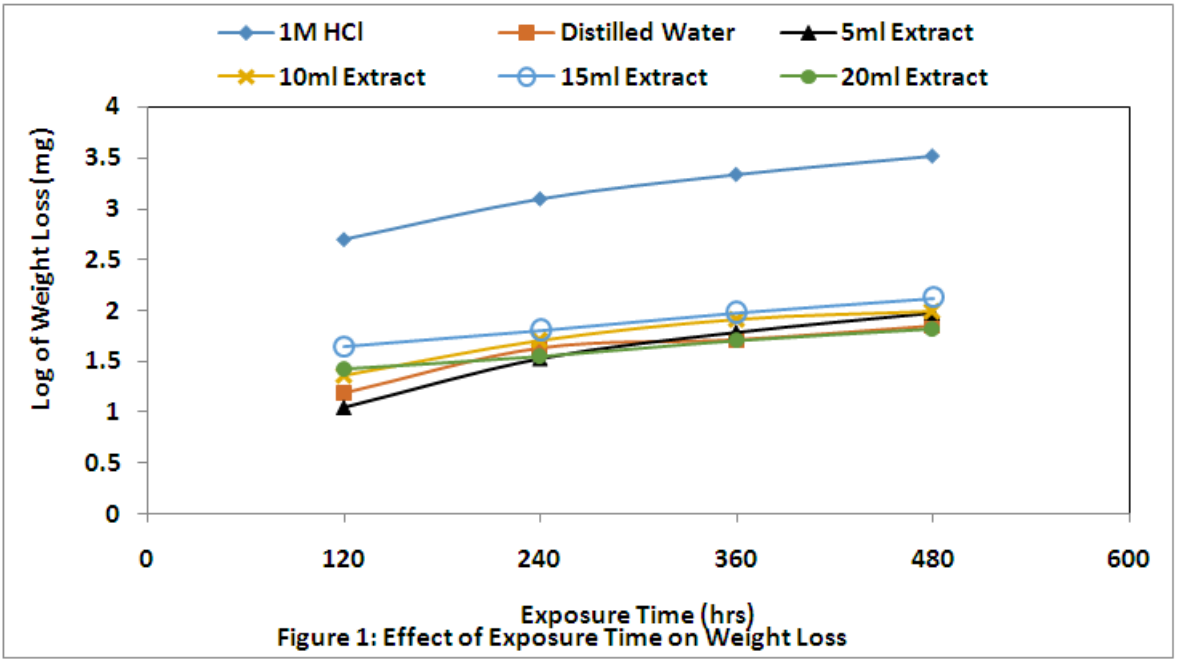

Figure 1: Effect of Exposure Time on Weight Loss

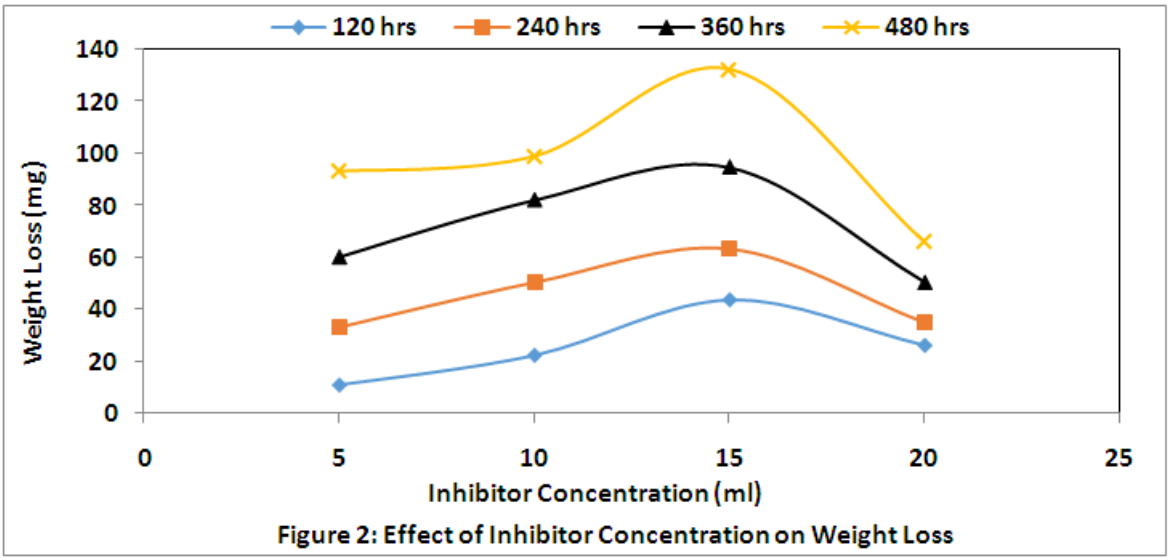

Figure 2: Effect of Inhibitor Concentration on Weight Loss

3.4 Corrosion Rate

The corrosion rates of the mild steel samples are as presented in Table 5 and Figures 3 and 4. The 1M HCl solution (without inhibitor) had the highest corroding effect on the specimen throughout the experiment, with a corrosion rate of 5.5422 mm/yr in 480 hours.The specimens in distilled water andthose in inhibited 1M HCl solution all had low corrosion rates. The least corrosion rate (i.e. best inhibiting effect) of approximately 0.1114 mm/yr was observed in the case of specimen immersed in 1M HCl solution inhibited with 20ml extract for 480 hours. This was followed by 0.1207 mm/yr for specimen in distilled water. The least inhibiting effect was observed in the case of 1M HCl solution with 15ml extract. This high corrosion rates as observed in theuninhibited 1M HCl solution can be attributed to the presence of Cl^- ions while the presence of Carica papaya leaf extract inhibited the corrosiveness of Cl^- ions in the case of 1M HCl solutions with various

concentrations of inhibitor. In the case of distilled water (being neutral),the presence of OH^- ions caused a relatively low corrosion rate as mild steel resists corrosion by OH^- ions.Again, it is seen that the 5ml and 20ml extracts had better inhibiting effect within the exposure period than the 10ml or 15ml extracts (Figures 3 and 4).

Table 5: Corrosion rate (mm/yr) in the various media

Exposure Time	Distilled Water	1 M HCl	5ml Extract in 1M HCl	10ml Extract in 1M HCL	15ml Extract in 1M HCL	20ml Extract in in 1M HCL
120	0.1048	3.3285	0.0757	0.1528	0.2967	0.1785
240	0.1460	4.1859	0.1132	0.1710	0.2143	0.1190
360	0.1174	4.8534	0.1359	0.1852	0.2136	0.1138
480	0.1207	5.5422	0.1573	0.1671	0.2236	0.1114
	Logarithmic values of weight loss (to shrink the range of values)					
120	-0.9797	0.5222	-1.1209	-0.8160	-0.5276	-0.7485
240	-0.8356	0.6218	-0.9461	-0.7670	-0.6690	-0.9246
360	-0.9304	0.6860	-0.8669	-0.7323	-0.6704	-0.9439
480	-0.9184	0.7437	-0.8032	-0.7769	-0.6506	-0.9533

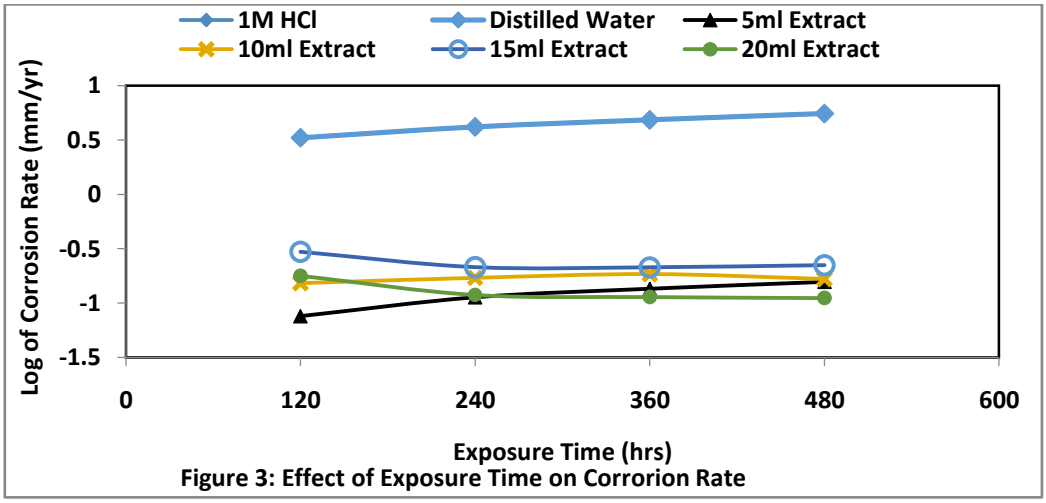

Figure 3: Effect of Exposure Time on Corrorion Rate

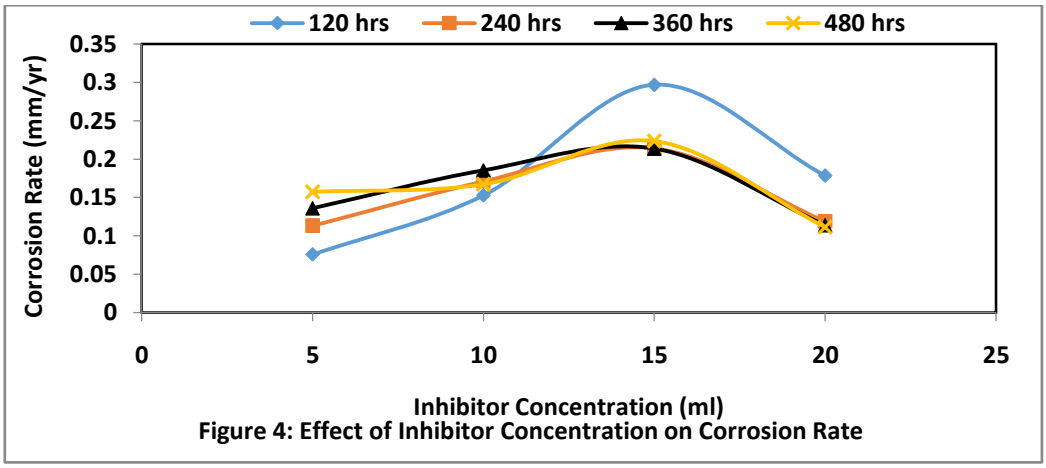

Figure 4: Effect of Inhibitor Concentration on Corrosion Rate

3.5 Inhibition Efficiency

The results of inhibition efficiency obtained for various concentrations of the inhibitor in 1M HCl solution are given in Table 6 and Figures 5 and 6. The 5ml extract showed the best or highest inhibition efficiency at the early stages (0 – 240 hrs) while the 20ml extract gave better efficiency at later stages (240 – 480 hrs). The inhibition efficiency of the 5ml extract reached 97.73% after 120 hours and decreased with time to

97.30, 97.20 and 97.16% after 240, 360 and 480 hours respectively. In the case of the 20ml extract, the inhibition efficiency reached 94.64% after 120 hours and increased with time to 97.16, 97.66 and 97.99% after 240, 360 and 480 hours respectively. As shown in Figures 5 and 6, the use of low concentration (e.g. 5ml) or high concentration (e.g. 20ml) of the extract produced better inhibition efficiency than using average concentrations such as 10ml or 15ml. The extract caused corrosion inhibition by beingeasily adsorbed on the surface of the metal, thus depressing or hindering metal dissolution and other reduction reactions.

Table 6: Inhibition efficiency of the various concentrations of extract

Exposure Time	Distilled Water	1M HCl	5ml Extract in 1M HCl	10ml Extract in 1M HCL	15ml Extract in 1M HCL	20ml Extract in in 1M HCL
120	–	–	97.73	95.41	91.08	94.64
240	–	–	97.30	95.91	94.88	97.16
360	–	–	97.20	96.18	95.60	97.66
480	–	–	97.16	96.98	95.97	97.99

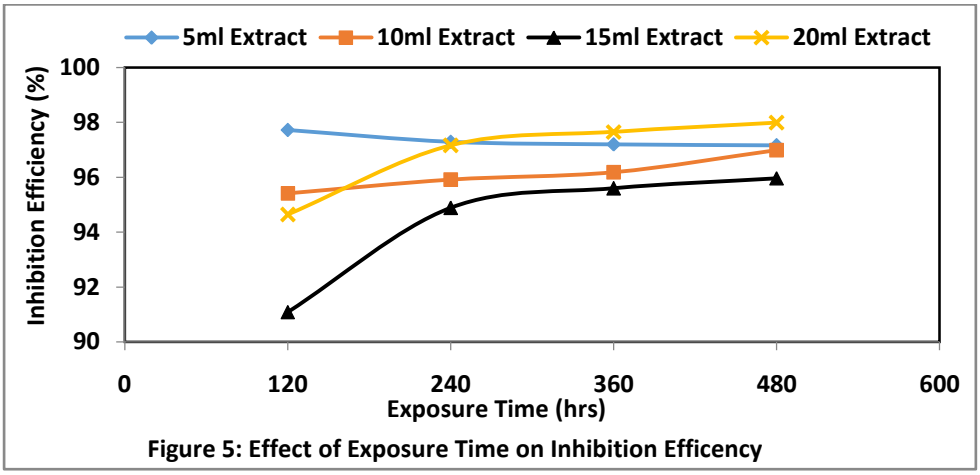

Figure 5: Effect of Exposure Time on Inhibition Efficency

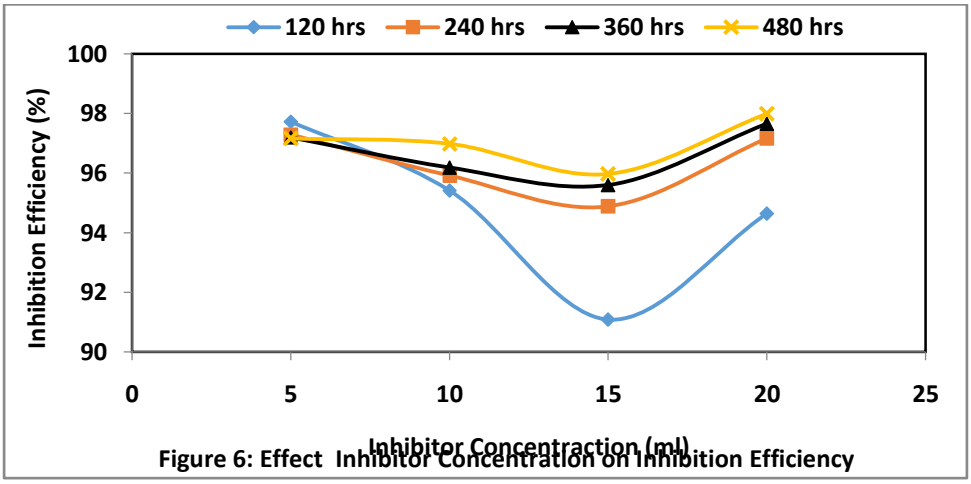

Figure 6: Effect Inhibitor Concentration on Inhibition Efficiency

3.6 Two-Factor ANOVA Outputs

The ANOVA outputpresented in Table 7 shows that exposure time has F value of 1.32 which is less than F critical of 3.29. Values of F critical can be confirmed from the F-distribution table for 0.05 or 5%-level of significance. Similarly, concentration of extract has F value of 8.73 which is greater than F critical of 2.9. Therefore, it can be concluded with 95% confidence that the exposure time does not significantly affect weight loss,but concentration of extract is the major factor affecting the weight lossof mild steel in 1M HCl environment. The ANOVA output also shows 'P-values' for the row factor (exposure time) and the column factor (extract concentration). While the 'P-value' for exposure time (0.3) is greater than 0.05; the 'P-value' for concentration of extract (~0.0005) is far less than 0.05. This supports the hypothesis that concentration of

extract has significant effect on the weight loss. Therefore, it is statistically acceptableto say that concentration of extract has more significant effect than exposure time and is the major factor affecting the weight loss ofmild steel in 1M HCl environment.

Table 7: Two-factor ANOVA output for weight loss measurements in 1M HCl

ANOVA: Two-Factor Without Replication						
SUMMARY	*Count*	*Sum*	*Average*	*Variance*		
120 hrs	6	612	102	36706.876		
240 hrs	6	1464.4	244.0666667	237455.6947		
360 hrs	6	2493.9	415.65	725554.219		
480 hrs	6	3741.2	623.5333333	1693681.227		
0 ml in H_2O (control 1)	4	182.2	45.55	539.8833333		
0 ml in HCl (control 2)	4	7164.5	1791.125	1446439.036		
5 mls	4	198.1	49.525	1246.829167		
10 mls	4	254.3	63.575	1147.349167		
15 mls	4	334.4	83.6	1493.753333		
20 mls	4	178	44.5	302.6866667		
ANOVA						
Source of Variation	*SS*	***df***	*MS*	***F***	***P-value***	***F crit***
Rows (Exposure Time)	910811.3246	**3**	303603.7749	**1.322816455**	**0.303939**	**3.287382**
Columns (Conc. of Extract)	10024292.79	**5**	2004858.559	**8.735266527**	**0.000478**	**2.901295**
Error	3442697.288	**15**	229513.1525			
Total	14377801.41	23				

Table 8: Two-factor ANOVA output for corrosion rate measurements in 1M HCl

ANOVA: Two-Factor Without Replication						
SUMMARY	*Count*	*Sum*	*Average*	*Variance*		
120 hrs	6	4.137	0.6895	1.677281052		
240 hrs	6	4.9494	0.8249	2.712491096		
360 hrs	6	5.6193	0.93655	3.683572431		
480 hrs	6	6.3223	1.053716667	4.836741814		
0 ml in H_2O (control 1)	4	0.4889	0.122225	0.000298163		
0 ml in HCl (control 2)	4	17.91	4.4775	0.89337282		
5 mls	4	0.4821	0.120525	0.001217243		
10 mls	4	0.6761	0.169025	0.000177496		
15 mls	4	0.9482	0.23705	0.001602163		
20 mls	4	0.5227	0.130675	0.001026609		
ANOVA						
Source of Variation	*SS*	***df***	*MS*	***F***	***P-value***	***F crit***
Rows (Exposure Time)	0.43585719	**3**	0.14528573	**0.965470746**	**0.434672**	**3.287382**
Columns (Conc. of Extract)	62.29320567	**5**	12.45864113	**82.79170673**	**2.22E-10**	**2.901295**
Error	2.25722629	**15**	0.150481753			
Total	64.98628915	23				

The ANOVA output showing the effect of exposure time and concentration of extract on the corrosion rate is presented in Table 8. The F value of 0.96versus F critical of 3.29 (for exposure time) compared with F value of 82.8 versus F critical of 2.9 (for concentration of extract) shows that exposure time has no significant effect on corrosion rate. It can be concluded with 95% confidence that concentration of extract is the major factor affecting the corrosion rate of mild steel in 1M HCl environment. Again, the 'P-values' of 0.4 (for exposure time) and2.22×10^{-10} or 0.000000000222 (for extract concentration) shows that the effect of exposure time is statistically insignificant.On the contrary, the 'P-value' of 0.000000000222 being very far less than 0.05 shows that concentration of extract has more significant effect than exposure time and is the major factor affecting the corrosion rate of mild steel in 1M HCl environment.

The two-factor ANOVA output showing the separate effects of exposure time and concentration of *Carica papaya* leaf extract on the inhibition efficiency of mild steel in 1M HCl solution is given in Table 9.There are 4 rows and 4 columns which imply that 3 is the degree of freedom (*df*) for both exposure time and concentration of extract. The '*df*' for the denominator is therefore 9, as shown in Table 9. Again, it can be concluded with 95% confidence that the concentration of extract with an F value of 5.45(compared with F critical of 3.86) is the major factor affecting the inhibition efficiency of mild steel in 1M HCl environment, while the exposure time with an F value of 3.34(compared with F critical of 3.86) has lesser effect on the corrosion rate. Similarly, the 'P-values' of 0.07 (for exposure time) and 0.02 (for extract concentration) compared with the significance level of 0.05 shows that it is statistically acceptable to state that concentration of extract is the major factor affecting the inhibition efficiency of mild steel in 1M HCl.

Table 9: Two-factor ANOVA output for inhibition efficiency measurements in 1M HCl

ANOVA: Two-Factor Without Replication						
SUMMARY	*Count*	*Sum*	*Average*	*Variance*		
120 hrs	4	378.86	94.715	7.597366667		
240 hrs	4	385.25	96.3125	1.302491667		
360 hrs	4	386.64	96.66	0.881866667		
480 hrs	4	388.1	97.025	0.688166667		
5 mls	4	389.39	97.3475	0.068491667		
10 mls	4	384.48	96.12	0.430466667		
15 mls	4	377.53	94.3825	5.052158333		
20 mls	4	387.45	96.8625	2.311758333		
ANOVA						
Source of Variation	*SS*	***df***	*MS*	***F***	***P-value***	***F crit***
Rows (Exposure Time)	12.43277	**3**	4.144256	**3.343383548**	**0.069571**	**3.862548**
Columns (Conc. of Extract)	20.25382	**3**	6.751273	**5.446597275**	**0.020649**	**3.862548**
Error	11.15586	**9**	1.23954			
Total	43.84244	15				

Figures 7, 8, and 9 are graphical plots of F values showing the influence of exposure time and concentration of extract on weight loss, corrosion rate, and inhibition efficiency, respectively.In each case, it is shown that concentration of extract is the dominant factor affecting the weight loss, corrosion rate, and inhibition efficiency of mild steel in 1M HCl environment.

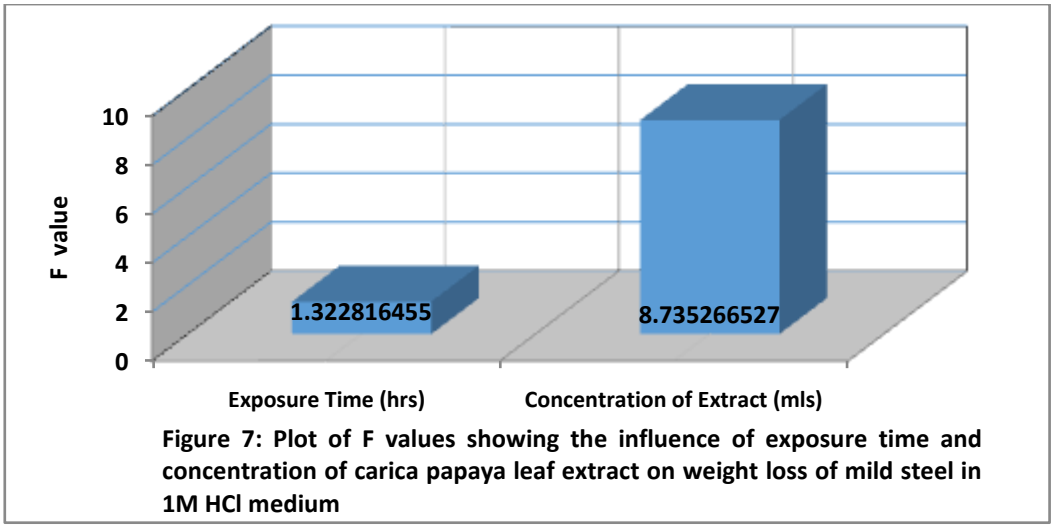

Figure 7: Plot of F values showing the influence of exposure time and concentration of carica papaya leaf extract on weight loss of mild steel in 1M HCl medium

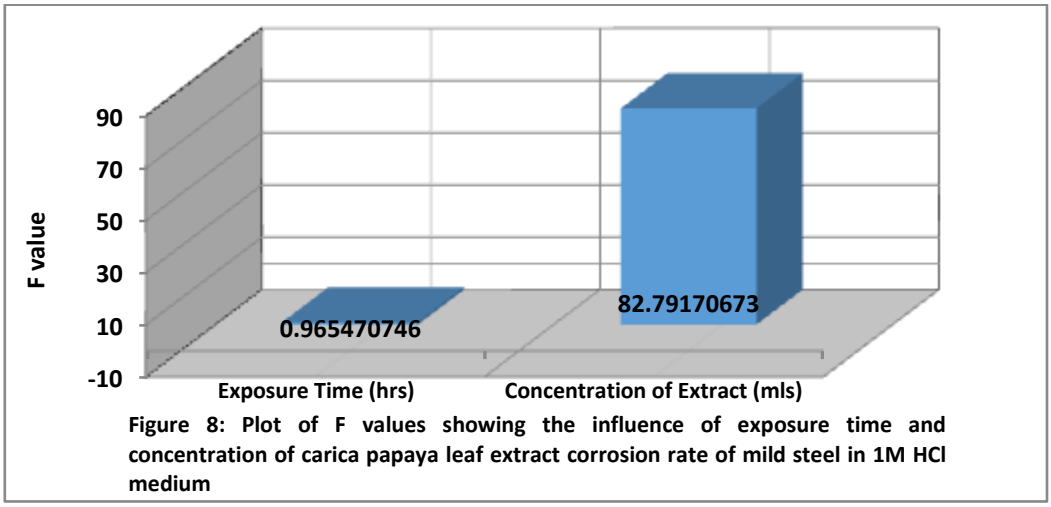

Figure 8: Plot of F values showing the influence of exposure time and concentration of carica papaya leaf extract corrosion rate of mild steel in 1M HCl medium

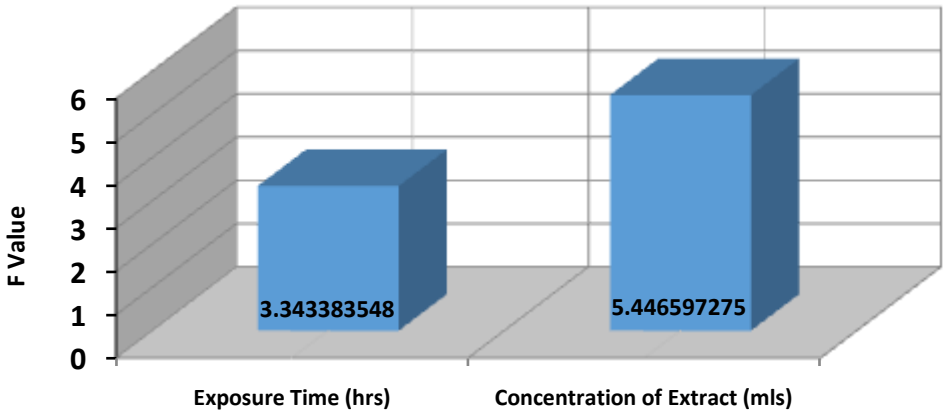

Figure 9: Plot of F values showing the influence of exposure time and concentration of *carica papaya* leaf extract corrosion rate of mild steel…

IV. CONCLUSION

The following conclusions have been drawn from this study:

1. *Carica papaya* (pawpaw) leaf extract can be used as an organic inhibitorfor mild steel corrosion in1M HCl acid medium.
2. Carica papaya leaf extract is an effective inhibitor at low concentrations, since 5ml extract in 400 ml of 1M HCl solution was more effective than 10ml and 15 ml. This means that the organic inhibitor will not only be eco-friendly but cost-effective as well.
3. The biochemical species present in *Caricapapaya* leaf are alkaloid (1.93%), flavonoid (0.22%), saponis (19.74%), and tannins (3.82%), with tannin being the most active corrosion inhibitingspecie.
4. ANOVA test confirmed that at 95% confidence level, the exposure time and concentration of *Caricapapaya*leaf extract partially affect the corrosion rate of mild steel in 1M HCl medium, with concentration of extract being the more significant factor.
5. It is recommended that based on the eco-friendliness, cost-effectiveness and inhibition efficiency of Carica papaya leaf extract (over 97%), further studies should be done to harness this organic resource, particularly the bio-synthesis of the biochemical species detected for the commercial application of *Caricapapaya* leaf as a source of industrial green corrosion inhibitor of mild steel in 1M HCl medium.

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