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RESEARCH ARTICLE

INHIBITION EFFECT OF ACALYPHA WILKESIANA LEAF EXTRACT ON PITTING CORROSION OF FERRITIC STAINLESS STEEL IN ACIDIC MEDIUM

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ABSTRACT

The study examined the possibilityof using extract of*Acalypha wilkesiana* (*AW)*leafas green inhibitor for ferritic stainless steel (FSS).This was obtained in 0.5 M hydrochloric acid using gravimetric and potentiodynamic polarization (Tafel plots). The inhibitor, temperature and time concentration ranged from 0–10 percent v / v at 2 percent v / v interval to 30–60 ° C at 10 ° C interval at 3-18 days within a space of three days.Qualitative and quantitative analysis and Fourier Transforms Infrared (FTIR) Spectroscopy technique were used to characterize the sample. Scanning electron microscope (SEM) was used to analyze the sample surface morphology before, during and after testing. The findings showed that the corrosion rate increased with an rise in temperature and decreased with an rise in inhibitor concentration and time and acquired a peak inhibition effectiveness of 91.16 percent at an optimum 8 percent v / v concentration. The coupon's SEM without extract on the surface was rough, serious pits, cracks, and intermetallic dissolution occurred. There was an enhancement with a soft green inhibitor on the surface morphology of ferritic stainless steel. The adsorption and physisorption in nature of the extract obeysLangmuir adsorption isotherm. The inhibition effectiveness values acquired are well above a good inhibitor's minimum acceptable threshold of 70 percent. Therefore, the Acalypha wilkesiana (AW) extract was very efficient in inhibiting FSS corrosion in acidic medium.

INTRODUCTION

Stainless steels are significant class of metals and are frequently considered as the primary piece of current industry. However, stainless steel is secured with an exceptionally defensive film of chromium oxy-hydroxide and is impervious to corrosion in numerous dynamic environments (Khatak and Baldey, 2002). It experiences uniform just as setting corrosion under certain uncommon conditions, for example, acid pickling, mechanical acid cleaning, acid de-scaling and oil well acidizing (Okamoto, 1973 and Sharma &Roy, 2014). Setting corrosion is a confined corrosion processes that outcome in the development of minuscule gaps in metallic composites. Corrosionzenith outline at infinitesimal sizes and underneath, as a result of defects, scratches, breakages and splits on the uninvolved film prompting pit solutions on the metal surface particularly in areas or locales of incorporations or polluting influences (Borgioli et al;2016 and Zhang et al; 2015).These destinations become anodic while obscure, yet conceivably tremendous territory ends up cathodic. The corrosion spreads auto catalytically infiltrating the metal guilefully. Oneself enacting response systems related with setting begins at the surface in various structures and sizes relying upon the metallurgical property of the compound, the electrolyte and other electrochemical variables (Okamoto, 1973).

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Setting is more harmful and risky than general corrosion since it is hard to find out right now and to structure against. An irrelevant little pit with minuscule metal misfortune can prompt breakdown of a framework (Kadry, 2008). Crumbling and shortcoming of the constructional material can cause difficult issues that had prompted the misfortunes of lives and gear, so it winds up basic to secure materials against corrosion in such forceful conditions (Fattah Alhossein etal;2016). Security of these constructional materials from being consumed is not significant for expanding the life expectancy of materials, yet in addition significant in shielding our surroundings from dangers coming about because of the debacles (Szpowski, 2002). Notwithstanding, a significant methodology embraced for the insurance of this material against corrosion is by the utilization of inhibitors which is one of the various methods for relieving corrosion in any environments(Granese et al; 1992).The utilization of concoction inhibitors is regularly the most commonsense and financially savvy methods for corrosion moderation. Nonetheless, a large portion of these engineered inhibitors, for example, chromates, nitrates, borates, molybdates had demonstrated great enemy of destructive activity however profoundly lethal to both people and conditions as pointed by (Suleiman and Sani, 2017). An option must be looked to supplant the costly and poisonous blended corrosion inhibitors due to natural guidelines so as to elevate the practical greenness to the air. The issue of poisonous quality has prompted the utilization of normally happening substances so

as to discover ease and non-dangerous inhibitors. Plant concentrates have turned out to be significant as an ecologically worthy, promptly accessible and sustainable wellspring of materials for a wide scope of corrosion counteractive action details. In this way, discovering normally happening substances as corrosion inhibitors is a subject of extraordinary viable significance(Suleiman &Sani, 2017 and Al – Moubardi, et al; 2015). Concentrates of plants contain natural mixes, for example, N, O, P and S iotas which are viewed as viable corrosion inhibitors. The viability of natural inhibitors, in any case, relies upon the nature and the state of the metallic surface, the concoction sythesis and structure of the inhibitor (Emran, et al;2015). All plant items are natural in nature and their constituents, for example, tannins, natural and amino acids, saponins, alkaloids, flavonoids, glycosides and colors are known to show repressing activity(Pereira, 2012 and Al-Fakih, 2015).Previous works on the use of organic inhibitors to protect the materials in hydrochloric acid have been studied by (Suleiman and Sani 2016 and Adindu and Oguzie,2017). Nonetheless, there is still a need for research on other organic compounds thatcan be used as inhibitors in industrial applications. *Acalypha wilkesiana*(copper leaf, Joseph's coat) is of theEuphorbiaceae family.The plant has antimicrobial and antifungal properties and in conventional prescription, the leaves are eaten as vegetables in the administration of hypertension, being a diuretic plant. Figure 1 shows the picture of *Acalypha wilkesiana* (*AW)* leaf. The goal of this workwas to explore the corrosion inhibition of FSS in 0.5M HCl solution using *AW* extract as a novel green corrosion inhibitor by using gravitational weight loss and potentiodynamic polarization techniques, characterizations of the extract by analytical and FTIR methods and Scanning electron microscopy (SEM),

MATERIALS AND METHODS

Preparation of the substrates: The chemicalcompound of the stainless steel utilized for this work is being displayed on Table 1. Ferritic stainless steel coupon plates of measurement steel of rectangular shape with lengths of 12.5 mm, width of 6.5 mm, and thickness of 1.5 mm were acquired for this work. The substrates were treated by solutionsoperations including the accompanying: cutting, granulating and cleaning using(500–1500) emery paper, washing and drying. The substrates were likewise treated by utilizing 10% HCl to pickle them at room temperature for 10 s, and washed with refined water, flushed in ethanol, degreased with CH3)2CO, driedand put away in a desiccator(Sulemain and Abdulwahab, 2016 and Ahmed et al;2014).

Solution Preparation: Solutions of 0.5 M HCl were set up in order to dilute systematic grade with twofold refined (distilled) water. Concentrate was dissolved in the acidsolution at the required concentration (% v/v). The solution without inhibitor was taken as clear for correlation purposes. The test solutions were newly arranged before each trial by adding *Acalypha wilkesiana* straight to the acid solution. Concentration of *Acalypha wilkesiana*extract0, 2, 4, 6, 8, and 10 % v/v. Examinations/tests were performed in triplicate to guarantee great outcomes.

Inhibitor Preparation: *Acalypha wilkesiana(AW)* used was obtained from the university of Port-Harcourt, Rivers State in Nigeria. The *AW*was extracted in 1.5 litres of 70% ethanol and 30% distilled water as solvent and half the *AW* was extracted using maceration method. The ethanol was evaporated by using a water bath and the concentration of the stock solutionexpressed in terms of (% v/v) and the concentration of2–10% v/v of the extractspreparedaccording to (Adindu and Oguzie, 2017 and Kubmarawa, et al; 2007).

Characterization of *Acalypha wilkesiana* (*AW)* by phytochemicaland FTIR analyses: The phytochemical constituents were carried out by qualitative/quantitative methods at National Research Institute of Chemical Technology, Zaria. The qualitative and quantitative results showed that the *Acalypha wilkesiana* (*AW)* leaf contains Saponins, Tannins, Alkaloids, Flavonoids, Glycosides and Volatile oil. Fourier Transforms Infrared (FTIR) analysis was carried out to determine the functional groups and chemical bonds. It was carried out using -8400S spectrophotometer Schmadzu Product Japan at National Research Institute Chemical Technology Zaria. The spectra recorded and the interpretations were done by using Standard Library. Both the phytochemical analyses and FTIR were presented in tables 2 and 3 respectively.

Figure 1. *Acalypha wilkesiana*(*AW)* copper leaf or Joseph's coat leaf

Methods used for corrosion techniques: Previously polished and degreased stored coupons were used for weight lossstudies. Specimens that have been weighed differently soaked in 500 mL of 0.5 M HCl solutionscontaining 0, 2, 4, 6, 8 and 10% v/v of *AW* extract for 3, 6, 9, 12, 15, and 18days. After sometime, when it was time, the specimenswere taken out, washed, dried and reweighed. The staged up experiments were carried out thrice while at the same time their mean values were put down. This experiment was repeated 4 times with varying temperatures of 30, 40, 50, and 60□,respectively. From the deliberate weight reduction information, thecorrosion rate (mpy) and the restraint productivity (inhibition efficiency) (IE) were determined utilizing equipments 1 - 3 (Adindu and Oguzie,2017). The corrosion rate (CR) of the material loss as a result of chemical reaction can be expressed as the thickness loss of the stainless steel per unit time:

$$CR = \frac{534W}{DAT} \qquad 1$$

Where W is the weight loss after exposure of time t, D and A are the density and exposed area while the 534 is a constant respectively. CR in mils per year (mpy) and W, D, A and t will be in units of milligrams, grams per cubic centimeter (g/cm^3), square inches and hours.

$$\left(\frac{CR_a}{CR_p}\right) x\ 100 \qquad 2$$

$$\theta = \frac{CR_a - CR_p}{CR_a} \quad 3$$

Where CR_a, $CR_p$and $\theta$are corrosion rates in the absence, presence and degree of surface coverage of the inhibitor respectively.

Potentiodynamic Polarization (Tafel plots): All test have been completed in open circuit potential (OCP-T) under barometrical conditions at a temperature of 30°C utilizing three-cathode frameworks including a calomel reference terminal, a platinum plate as the helper anode and ferriticstainless steel tests as working anode that drenched in 0.5 M HClsolutions. In Tafel test, after a deferral of around 15 minutes, the potential was expanded with 1 mV/s filtering rate. The required information were gotten utilizing the above programming. From the exploratory estimations, the estimations of corrosion potential (Ecorr), corrosion current thickness (Icorr) anodic and cathodicTafel slope constants (ba and bc) can be assessed from the anodic and cathodic points of Tafel plots. However, the extrapolation of the linear Tafel portion of the anodic and cathodic plot to corrosion potential was done to obtain corrosion current densities (I*corr*). The inhibition efficiency (IE %) of the inhibitor was calculated using equation 4 (Adindu and Oguzie, 2017):

$$IE\ \% = \frac{i_{corr} - i'_{corr}}{i_{corr}} x\ 100\% \quad 4$$

wherei_{corr} and i'_{corr} are the rust current densities of ferritic stainless steel in the absence and occurrence of the inhibitor respectively as described (Suleiman and Abdulwahab, 2016).

SEM investigations: The stainless-steel surface was prepared for SEM by keeping the specimens for one hour in the electrolyte, with and without the ideal fixations ofthe inhibitor. The treated steel examples were then washed with refined water,dried and broken down utilizing SEM. A Philips model XL30SFEG examining electronmicroscope was utilized for surface examination. The stainless-steel surface, as described by Suleiman et al; (2018).

RESULTS AND DISCUSSION

Chemical Composition of ferritic stainless steel: Table 1 showed thechemicalcomposition of the as-received ferritic stainless steel which was determined by spark analysis at Federal University of Technology, Owerri, Nigeria.

Characterization of *Acalypha wilkesiana* (*AW*) Phytochemical analyses: The Quantitative and qualitative phytochemical screenings of the leaf extract (*Acalypha wilkesiana, AW*) in percentage (%) and mg/100mg results are presented in Tables 2 and 3. The results also indicated that the leaf extract contains tannins, alkaloids, flavonoids, saponins, glycosides and volatile oil.

Fourier Transforms Infrared (FTIR) Spectroscopic methods: Table 4 showed the peaks and intensity while table 5 showed the outstanding peak obtained from reflectance for *AW* extract reflectance FT-IR spectroscopy. The IR absorption bands between 524.66 to 3402.54 cm^{-1} for *Acalypha wilkesiana* indicated the presence of Suphides compound (SxOy compounds, P=O vibration for stretching vibrator organic phosphorustion, CH_2, R–CH=CH–R, C=CH_2 mono, 1,1, C=C stretch, –N=C=S, C≡N, CH_2, NH_2, X≡Yand X≡Y≡Z, NH_2 functional groups which fit well with these constituents.

Table 1.Elementalcompositionofferritic stainless steel employed for the study

S.No.	Metal	(Wt. %) Elemental Composition
1	Fe	Balance
2	C	0.0880
3	Si	0.471
4	Mn	9.230
5	P	0.112
6	S	0.0294
7	Cr	17.42
8	Ni	1.15
9	Mo	<0.001
10	Cu	0.791
11	Al	0.0061
12	Ti	0.0137
13	V	0.0968
14	Co	0.129
15	Nb	0.029
16	Sn	0.0195
17	Pb	0.0208
18	Mg	0.0103
19	As	0.0887
20	Ce	0.0111
21	Ta	0.150
22	Zn	0.273
23	N	0.0414

Figures 2 and 3 presented the results of chemical bonds/functional groups of IR absorption spectrum of *AW* extract from the tables.

Weight loss (WL) measurements: The corrosion rate was displayed on Figure 4, as well as the time for the corrosion of ferriticstainless steel (FSS) in 0.5 M HCl containing various concentrations of *AW* at 30°C. From the figure, it is evident that the corrosion rate of ferriticstainless-steeldecreases with increase in the concentration of *AW*. The corrosion rate of the FSS in the absence of the inhibitor (blank) solution was higher than those obtained for solutions of HCl containing various concentrations of *AW*. The viability of the concentrate is focus ward and corrosion rate then again diminishes as grouping of the concentrate increments. The decline in the corrosion rates can be ascribed to a portion of the constituents that were contained in the extract such as functional groups, hydroxyl, aromatic / heterocyclic rings compounds present and the metallic elements that reacted with some cations to form protective films on the samples.Similar trends have been reported in the study by (Al-Fakih et al; 2015 and Suleiman and Abdulwahab, 2016). Table 6 analysis on the optimum concentration for *Acalypha wilkesiana* (*AW)*was 8% v/v with utmostreticencecompetence (inhibition efficiency) of 91.16% for the period of 12 days of immersion time. This result indicated that the plant extract could act as effective corrosion inhibitor for FSS in the hydrochloric acid medium. This indicated that the reaction of the inhibitor on the surface of the FSShas reached the state of equilibrium. The decrease in corrosion was also attributed to the compounds/elements obtained from the phytochemical and FTIR results as shown above contain some hetero-atoms. The thin cover of the oxides comply to the metal surface leading to a reduction in corrosion rate thereby increasing the efficiencies and similar results had been reportedby(Umoren,and Mohammed, 2016 and Sulieman 2018).

Potentiodynamic polarization: The results presented in Figure 5 demonstrated the impact of *AW* extract on both cathodic and anodic polarization curve of ferritic tempered steel in 0.5 M HCl. It could be seen that both the cathodic and anodic responses were stifled with the expansion of explored green inhibitor extricate, which proposed that *AW* concentrate decreased anodic disintegration and furthermore hindered the hydrogen advancement response.

Table 2. Quantitative analysis of Acalypha *wilkesiana (AW)* leaf

S/No	Leaf	Alkaloids (%)	Tannins (mg/100 g)	Saponins(%)	Flavonoids (%)	Glycosides (mg/100 g)	Volatile oil (%)
1	*AW*	10.04	1281	6.98	6.32	870	3.03

Table 3. Qualitative analysis of *Acalypha wilkesiana (AW)* leaf

S/No	Leaf	Alkaloids	Tannins	Saponins	Flavonoids	Glycosides	Volatile oil
1	*AW*	++	+++	++	+	+++	+

Heavily present: +++; slightly present: ++; present: +; absent: −

Table 4. Peaks and intensity for *AW* extract from reflectance FT-IR spectroscopy

No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	524.66	72.150	1.261	547.0	486.00	0.439	0.239
2	609.53	68.801	4.029	640.39	563.23	11.624	1.021
3	663.53	71.006	3.654	848.71	640.39	20.266	1.391
4	902.72	86.953	0.878	918.15	848.71	3.77	0.198
5	1041.6	80.157	7.059	1072.46	918.15	23.783	3.248
6	1149.61	55.623	11.653	1280.78	1072.46	42.042	8.074
7	1334.78	65.883	3.955	1357.93	1280.78	12.377	1.095
8	1381.08	67.031	2.511	1489.1	1357.93	19.126	1.511
9	1635.69	19.735	38.148	1851.72	1489.1	49.14	31.158
10	2353.23	65.141	22.624	2399.53	1867.16	26.252	8.966
11	2870.17	63.372	0.443	2877.89	2399.53	55.43	-5.714
12	2931.9	56.587	4.666	2985.91	2877.89	24.764	1.739
13	3402.54	23.246	1.136	3734.31	3394.83	130.488	-1.385

Table 5. Prominent peaks obtained from reflectance FTIR spectroscopy for *AW extract*

No.	Frequency (cm^{-1})	Band assignment
1	524.66	Metal –O- metal group
2	609.53	C-I Stretching of iodol compounds
3	663.53	C-Br Stretching of halogen derivatives
4	902.72	Thiocarbonyl (C=S)
5	1041.6	Sulphides compound (SxOy compounds)
6	1149.61	Symmetric stretching of amino acids
7	1334.78	P=O Vibration for stretching vibrator organic phosphorustion
8	1381.08	$C(CH_3)_3$
9	1635.69	N-H in =plane bending mainly proteins
10	2353.23	PH acids) stretches (Phosphoric
11	2870.17	CH_2 Symmetric stretching of amino acids
12	2931.9	C-H stretching mainly lipids
13	3402.54	N-H stretching amine

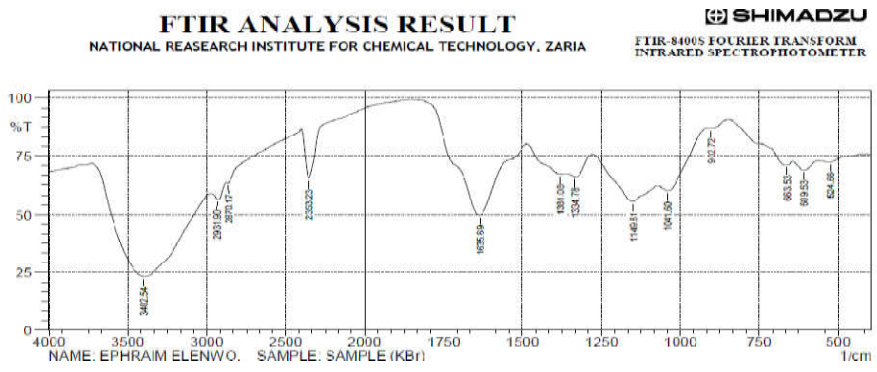


Figure 2. IR absorption spectrum of *AW* bark extract

Electrochemical corrosion energy parameters, for example corrosion potential (Ecorr), cathodic and anodic Tafel slants (βa, βc) and corrosion current thickness (icorr) got from the extrapolation of the polarization bends, were additionally given in table 7were calculated using equation 4. The values given in the tables show that, corrosion current (i_{corr}) decreases noticeably in the occurrence of the extract. The magnitudes of change increase with increasing extract inhibitor concentrations.

This confirms the inhibitive action of the *AW* on ferritic stainless steel in hydrochloric. The current densities decrease with increase in the extract concentrations from 2-10% v/v, which suggests that passive layer on the surface of ferritic stainless steel is strengthened in the presence of extract due to blockage of active sites on the electrode surface and agreed to (Ahmed et al;2014 and Anupama, et al;2016). This decrease in $\boldsymbol{i_{corr}}$was relatedto the adsorption of the inhibitor on ferritic stainless steel/acid solution interface and confirmed to the

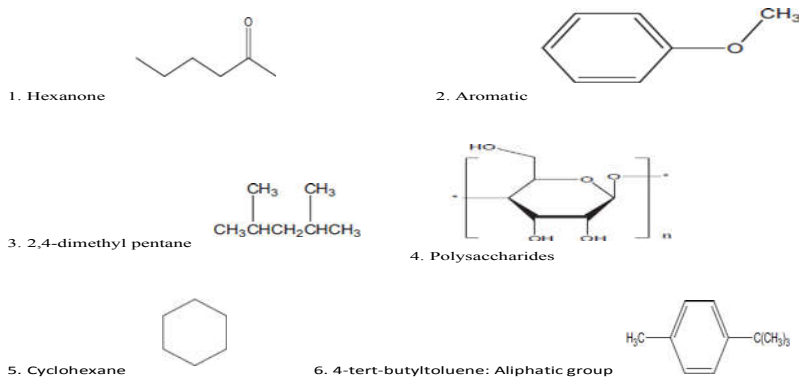


Figure 3. Chemical bonds/Functional groups of IR Absorption Spectrum of *AW* Extract

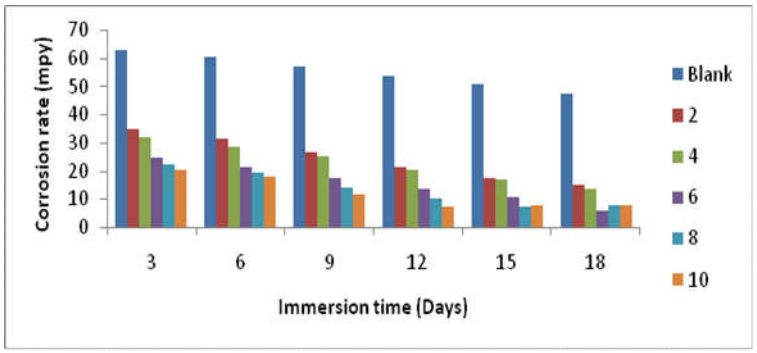


Figure 4. Variation of Corrosion rate with immersion time of *AW* extract for stainless steel in 0.5 M HCl solution at 30 °C

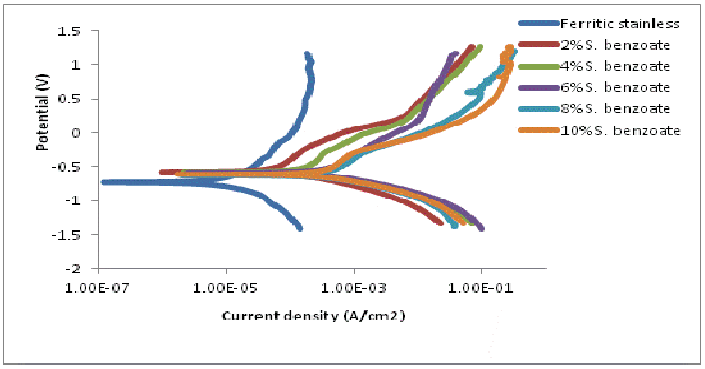


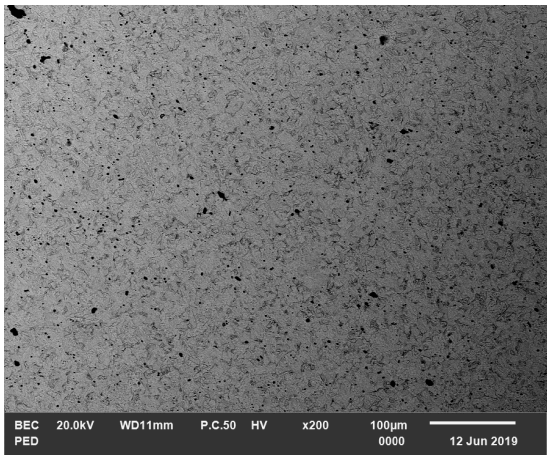
Figure 5. Potentiodynamic polarization curves for the dissolutionofferritic stainless steel in 0.5 M HCl in the absence and presence of *AW* extract concentrations at 30°C

Table 7. Potentiodynamic polarization parameters for ferritic stainless steel in 0.5M HCl containing different concentrations of *AW*extract at 30°C

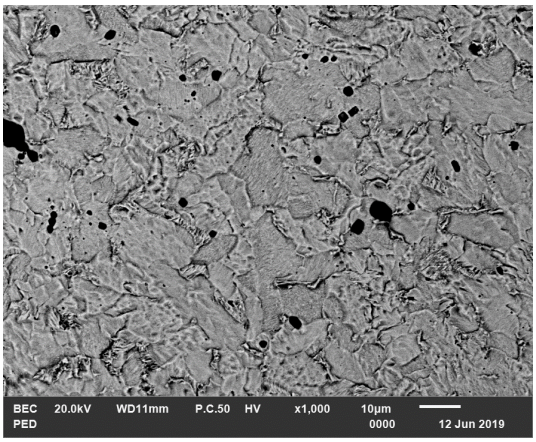
AW (%v/v)	-E_{corr} (SCE) (mV)	Iorr (mA/cm^2)	Tafel slopes (mV/decade)	b_ab_c	Inhibition efficiency (IE %)
Control	0.512	9.86	62	87	-
2	0.526	3.08	65	86	68.70
4	0.528	2.76	68	88	72.00
6	0.557	1.62	65	86	83.57
8	0.529	1.25	68	85	87.32
10	0.554	0.50	73	88	92.01

Table 8. Parameters from Langmuir Isotherm for *AW* at 30 - 60°C in 0.5 M HCl solution

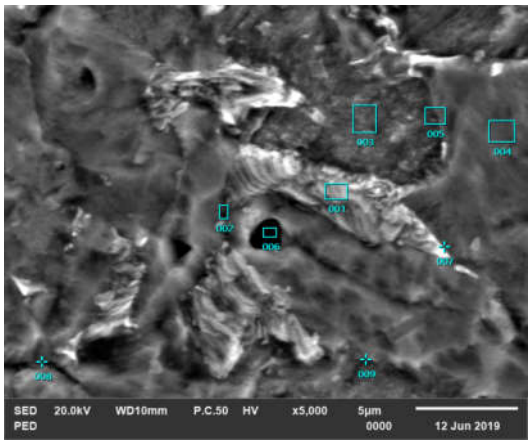
Inhibitor	Temp.	LANGMUIR ISOTHERM			
	(°C)	ΔGcorr, KJ/mol	Slope	R^2	K_{ads}
	30	-11.278	1.223	0.989	1.585
	40	-11.767	1.175	0.996	1.441
	50	-12.166	1.097	0.998	1.284
	60	-12.321	1.067	0.997	1.154
AW (0.5 M HCl)					



(A)



(B)



(C)

Figure 6. SEM micrographs of stainless-steelsurface (a) free surface of ferritic stainless steel, (b) after immersion in 0.5 M HCl and (c) after immersion in 0.5 M HCl + 8% v/v of*AW*.

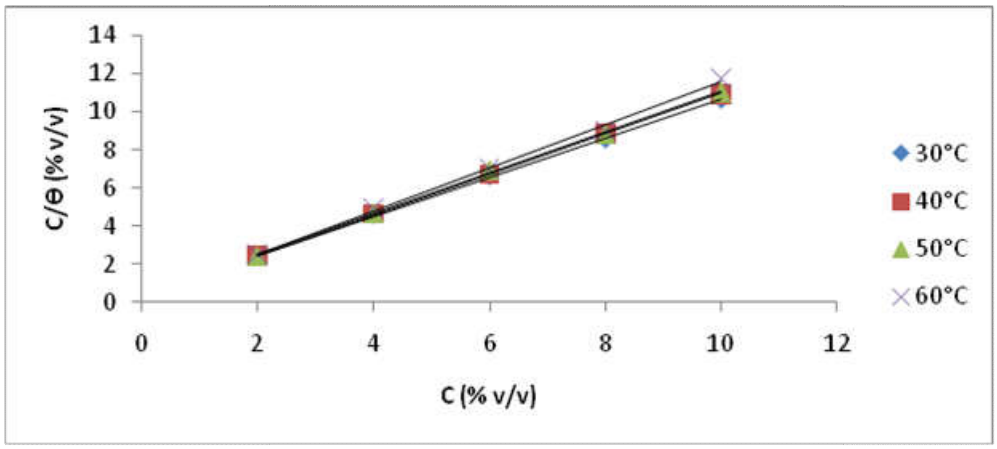


Figure 7. Langmuir adsorption isotherm as (C/Θ) versus C of *AW* extract for corrosion of FSS in 0.5M HClsolutionat 30, 40, 50, and 60°C

Table 9:Activation parameters Ea,Δ*Hads* and Δ*Sads* for FSS dissolution in 0.5M HCl in the absence and the presence of *AW* at 30, 40, 50, and 60°C

System/concentration	Ea (kJmol^{-1})	Δ*Had*skJ/mol	Δ*Sads*(J/mol. k)
Blank	6.89	10.68	-19.65
2% v/v AW	8.18	11.71	-18.91
4% v/v AW	14.55	13.29	-18.62
6% v/v AW	15.24	13.84	-17.97
8% v/v AW	19.63	14.90	-17.52
10% v/v AW	21.29	15.23	-16.81

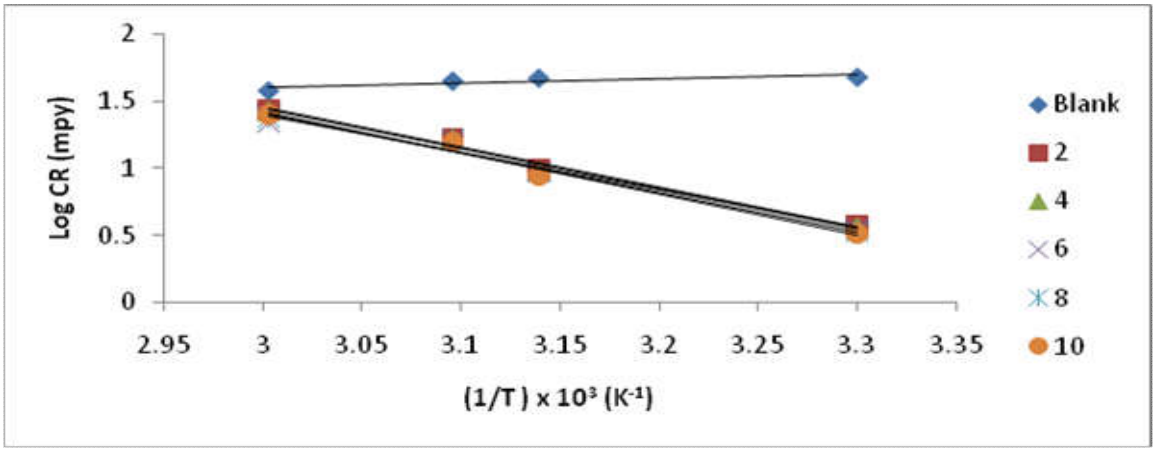


Figure 9: Variation log CR with 1/T for FSS in 0.5 M HCl in the presence and absence of *AW* concentration at 30, 40,50, and 60°C

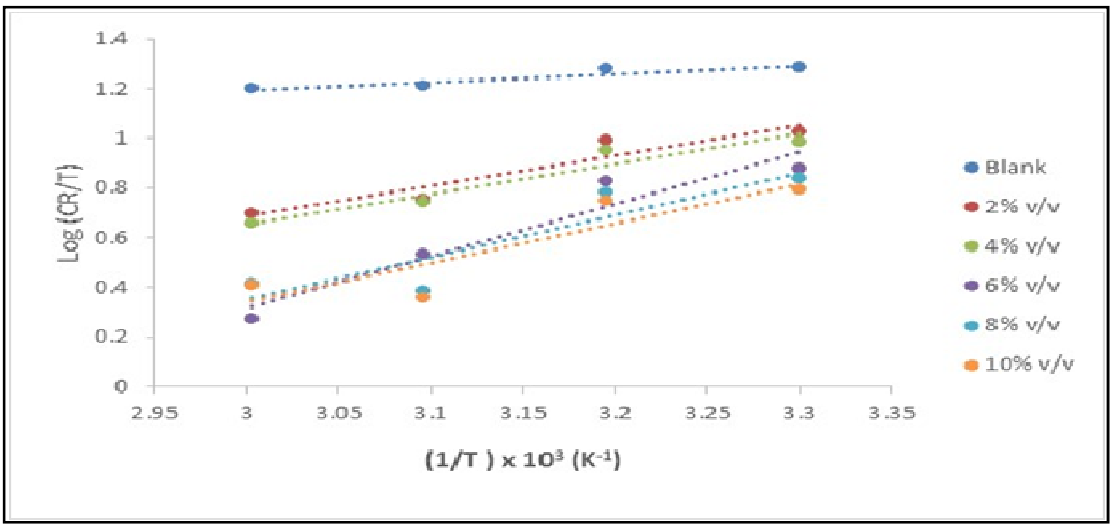


Figure 10: Variation log CR/T with 1/T for FSS in 0.5 M HCl in the presence and absence of *AW* concentration at 30, 40,50, and 60°C

previous works (Suleiman and Abudlwahab,2016 and Verma, et al;).

Surface characterization: The morphology of the examples without and with inhibitor of *Acalypha wilkesiana* (*AW*)was inspected and the outcomes exhibited in figure 6a-c. It just uncovered the cleaned/scratched surface. From the surface morphology of uninhibited FSS in 0.5 M HCl interface in figure 6b, serious pits, cracks and particular disintegration of inter-metallic happened at the surface. In figure 6c, there was an improvement in thesurface morphology of FSSin the nearness of Acalypha wilkesiana (AW). From the SEM assessment, it is clearthat a portion of the dynamic constituents in the phytochemical and the FTIR such as CH_2, R–CH=CH–R, C=CH_2 mono, 1,1, C=C stretch, –N=C=S, C≡N, CH_2, NH_2, X≡Yand XY≡Z, NH_2act as reaction centre leading to the formation of film on the surface of FSS (Suleiman and Sani, 2017 and Ahmed et.al; 2014). The inhibitor therefore forms a protective thin layers and complexes on the FSS surface. This leading a reduction in contact between FSSand the forceful process experienced on the inhibition effect arranged in sequence according to Suleiman et al; (2018) and Verma et al; (2016).

Adsorption isotherms: Adsorption isotherm gives the connection between the coverage of an interface with the adsorbed species and the concentration of species in solutions. The utilization of adsorption isotherms gives valuable understanding into the corrosion reticence system. The estimations of the level of surface inclusion (θ) were assessed at various centralizations of the inhibitor in0.5 M HClsolution. Efforts were formed to fit θ values tovarious adsorption isotherms (El-Awady, Freundlich, Frumkin, Temkin and Langmuir models) as depicted by (Szpowski, 2002 and Emran et al; 2015): The inhibitor was found to obey Langmuir isotherm with a plot of C/θ versus C which was direct. From Figure 7, the adsorption of various groupings of Acalypha wilkesiana (AW)extract on the outside of FSS was found to obey Langmuir adsorption isotherm. The phytochemical constituents of Acalypha wilkesiana (AW)showed that these compounds were hydrolysable and can without much of a stretch be adsorbed on the metal surface by means of the solitary pair of electrons present on their oxygen particles and make a boundary for charge and masstransfer prompting decline inthe collaboration of the metal withthe destructive condition and thus, the corrosion rateof the metal diminished with increment in the concentrate (Pereira, 2012 and Doner, et al; 2012). The development of film layer basically squares release of H+ and disintegration of metal particles was then fulfilled. Acid pickling inhibitors containing natural N, S and OH− gatherings act also to restrain corrosion (Al-fakih et al; 2015 and Suleiman and Sani, 2016). It pursues that hindrance proficiency (IE) is legitimately corresponding to the portion of the surface secured by the adsorbed particles (θ).

Thusly, (θ) with the concentrate focus indicates the adsorption isotherm that depicts the system(Khadraoui et al; 2014). The thermodynamic parameters for the adsorption of the concentrate on FSS surface in 0.5 M HCl at various temperatures were exhibited in table 8. From the table, it was discovered thatthe negative estimations of ΔG°adsreflect that the adsorption was unconstrained procedure and ΔG°adsvalues increment (become more positive) with an expansion in temperature. Kads diminishes as the temperature expands which likewise affirm that the green inhibitor was adsorbed and repressed the corrosion. This demonstrated the event of exothermic procedure whereby, adsorption was ominous with expanding response temperaturewas the aftereffect of the concentrate desorption from the FSS surface (Pereira, 2012).

Kinetics/Thermodynamics Consideration: To examine the impact of temperature on the hindrance adsorption system of Acalypha wilkesiana (AW)in acidic solutions in the nonattendance and nearness of fixation from 0–10% v/v, ponders were completed at various temperatures (303–333 K) by weight reduction estimations at eighteen (18) days of inundation time. It was seen that the corrosion rate increments both in the uninhibited and hindered with increment in temperature. The nearness of inhibitor prompts decline in the corrosion rate and restraint productivity additionally decline with increment in temperature, implying that the corrosion procedure is temperature dependant(Khadraoui et al; 2014 and Hong , et al; 2013). The decline might be because of increment in the pace of disintegration procedure of FSS and incomplete desorption of the inhibitor from the metal surface with increment in temperature(Ahmed, et al; 2014and Suliema, et al; 2018) and been presented in Figure 8.

Figure 8: Variation of inhibition efficiency of extract with temperature in 0.5 M HCl solution

The corrosion rate in acidic solution is associated with Arrhenius equation of temperature provided in equation 5 (Verma et al; 2016 and Xhanai et al;2016):

$$CR = A\exp(-Ea/RT) \quad 5$$

A weight loss assessment log of the corrosion rate versus 1/T showed a straight line with a path of-Ea/2.303R) (shown in figure 9. Table 9 also presents the activation energy values. The data show that in the presence of extract, the activation energy (Ea) of FSS corrosion is higher in 0.5 M HCl solution than in uninhibited. In this research, the rise in the evident activation energy for FSS dissolution in inhibited solution can be viewed as physical adsorption that supports our previous results from the job and comparable to the job of FSS (Umoren and Eduok, 2016) and Suleiman et al; 2018). An alternative formulation of Arrhenius equation was used to calculate the ΔH_{ad}s and ΔS_{ads} in equation 6(Suleiman et al; 2018 and Verma et al; 2016):

$$\text{Log}(CR) = -Ea/2.303RT + A \quad 6$$

The plots of log (CR / T) versus 1/T were shown in Figure 10 as a straight row with slope and interval equal to-Hads/2.303R and (log(R / Nh)+Sads/2.303R) respectively from which the values of the slope and intercept had been calculated. Table 9 presented the calculated values for the green AW inhibitor in 0.5 M HCl for the activation energy, standard free energy change, Ea, ambigads, ambigads, and ambigads for the green AW inhibitor. From the figure, the slope and intercept equals–Hads/2.303R and (log(R / Nh)+Sads/2.303R) respectively from which the values of Sads and Hads were then evaluated. The values of Sads and Sads are positive and negative, the positive sign of Hads indicates that the adsorption of the inhibitor molecules is an endothermic process, while the values of Sads in the presence of AW are negative, m. The values of Ea in table 9 were greater in the presence of AWis (21,29 kJ / mol) than in the presence of uninhibited solution (6,89 kJ / mol). It has been created that the value of the activation energy (Ea) > 80 kJ / mol means chemical adsorption while Ea< 80 kJ / molimplies (physical adsorption)(Qian et al; 2017 and Rubaye et al; 2015). Consequently, the rise in the activation energy can be viewed as physical adsorption that still satisfies previous claims.(Rocha et al; 2014 and Deyab, 2015).

Conclusion

The following conclusions can be drawn from the study investigated:

- The isothermic adsorption of Langmuir corresponds to the experimental data acquired in this research. Thus, on the ferritic stainless steel surface, a monolayer film was formed by the extract and the values of Ea, Gads, Hads and Sads obtained proposed physical adsorption phenomena for inhibitor adsorption.
- The mechanism engaged in this research was the phytoconstituents of the green powder that was adsorbedon the surface of the FSS which formed a protective thinfilm layer that prevents hydrogen ion (H+)ion release.
- The adsorbed protective film's SEM morphology on the FSS surface verified elevated performance of the green extract's inhibitive impact.
- The findings achieved using various analysis of corrosion (gravimetric and potentiodynamic polarization) are inappropriate contracts.

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