NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY
[IJIERT] ISSN: 2394-3696 Website: ijiert.org
VOLUME 10, ISSUE 4, April -2023

CHARACTERIZATION OF TELFAIRIA OCCIDENTALIS STEM AND BANANA LEAF AND ITS APPLICATION TO CORROSION INHIBITION OF MILD STEEL IN HCL

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Abstract
This work is focused on the application of fluted pumpkin stems (FPS) extract and Banana leaves (BNL) extract as corrosion inhibitors in mild steel in HCL. The extract from FPS and BNL were extracted using 99.7 % v/v ethanol. Characterization of the sample was done using Fourier transform infrared (FTIR), gas chromatography-flame ionization detection (GC-FID) and scanning electron microscopy (SEM). Batch study was employed to evaluate the process variables such as effect of concentration of extract, effect of concentration of HCL and effect of temperature. The FTIR result reveal the presence of heterocyclic compounds which is the anti-corrosion inhibition compound responsible for corrosion inhibition. The phytochemical analysis revealed the presence of alkaloids, flavonoids, phenol, saponins, tannins, steroids, phytates and glycoside. The leaves extract establishes their inhibitive action through adsorption of phytochemical components molecules on the metal surface. The SEM result revealed that the metal surfaces were strongly damaged owing to corrosion in the absence of the inhibitor, but in the presence of inhibitor, there is a much smaller damage on the surface. The effect of temperature showed that increase in the temperature of the system increase the percentage weight loss of FPS and BNL. The effect of inhibitor concentration showed that increase in concentration of the inhibitors resulted to a decrease in the % weight loss of the sample (decrease in rate of corrosion). The effect of acid concentration reveal that increase in concentration of acid resulted in a corresponding increase in corrosion rate (weight loss) of the samples. Thermodynamic parameters showed that the ΔH values of BNL (26.51 KJ/mol) and FPS (13.171 KJ/mol) were positive and remain constant with rise in temperatures. The positive values of ΔH show the endothermic nature of the process. The ΔS values for BNL (59.40 J/mol.K) and FPS (17.199 J/mol.K) were positive and remain constant for all temperatures. The results obtained showed that FPS and BNL demonstrated high potential in enhancing the corrosion inhibition of a mild steel.

Keywords: Inhibition, telfairia, occidentalis, corrosion, banana.

1.0 Introduction

Metals and alloys are critical to the operation of many industries. In industries, one of the toughest challenges is to see that these metals and alloys are protected from corrosion due to their exposure to the environment. Steel is a valuable alloy due to its flexibility, it is used in a variety of industries. Steel is an alloy of iron with definite percentage of carbon ranges from 0.15-1.5%, plain carbon steels are those containing 0.1-0.25%. Steel is mainly an alloy of iron and carbon, where other elements are present in quantities too small to affect the properties (Alawode, A.J., 2002; Rao. P.N, 2011; Ahmad, 2006). Mild steel, also known as plain carbon steel has become the most popular type of steel due to its inexpensive cost and ability to meet the needs of wide range of applications. (Singh et al, 2016).However, it has a low corrosion resistance, which is especially

problematic in acidic settings (Alaneme et al, 2016). Acidic solutions are used extensively in industrial processes such as acid cleaning, pickling, descaling, and drilling operations in oil and gas exploration, therefore iron and steel vessels or surfaces utilized in these conditions are prone to corrosion (Olusegun & Adelowo, 2016).

After the protective barrier in these metals is breached, corrosion begins immediately and is followed by a series of reactions that alter the composition and properties of both the metal surface and the surrounding environment**.**

Corrosion inhibition is the most cost-effective, practical, and convenient way for controlling corrosion on metals in an aqueous environment (Solomon & Umoren, 2015). Corrosion inhibitors regulate both metal dissolution and acid consumption. Many inorganic inhibitors, especially those containing phosphate, chromate, and other heavy metals, are now being gradually restricted or banned by various environmental regulations, particularly in the marine industry, where aquatic life is at risk, due to their toxicity and difficulties in disposal (Roy, Adbikari and Sukul, 2014). Synthetic organic inhibitors have also been widely used, although their toxicity and high manufacturing costs have hampered their utilization, this has motivated researchers to look into other areas in order to develop green corrosion inhibitors that are environmentally benign, inexpensive, and biodegradable to replace inorganic and synthetic organic inhibitors.Plant extracts, amino acids, proteins, and biopolymers have been reported to be efficient corrosion inhibitors (Tuken & Erbil, 2016). Plant extracts are thought to be a significant source of naturally generated chemical substances that may be extracted using simple, low-cost processes (Krishnavari & Ravichandran, 2014). Inhibitors are adsorbed on the metal surface, establishing a protective barrier, and interact with anodic or cathodic reaction sites, reducing oxidation and/or reducing corrosion processes (Singh et al, 2016). Plant extracts as corrosion inhibitors could be the answer to all of the concerns and issues about synthetic corrosion inhibitors that have been raised in the media. Plant extracts have phytochemical that are environmentally friendly and have structures that are similar to synthetic corrosion inhibitors. Heteroatoms like oxygen, sulfur, phosphorus, and nitrogen, as well as conjugated carbon chains containing aromatic rings, are found in them. (Umoren *et al.* 2008).According to the initial phytochemical analysis done on the plants, the stem of fluted pumpkin and the leaf of banana were found to contain phytochemical components which are rich in heteroatoms including alkanoids, tannins, and saponins.This work however focuses on the characterization of ethanol extract of Fluted pumpkin (Telfairia Occidentalis) stems and Banana leaves (Musa Spp) extract against the corrosion of mild steel in HCL acid media.

2.0 Materials and Methods

2.1The Extraction of fluted pumpkin stems and Banana leaves

Leaves of banana and the stems of fluted pumpkin were collected and were separately sun dried for three days. After sun drying, the dried leaves were separately ground with mortar and pestle to increase the surface area and stored in close containers. The powdered extracts were Maceration extracted using ethanol. 30 grams of the ground banana leaves and fluted pumpkin stems were measured separately and soaked in 1000ml of ethanol (99.7% v/v) for 48 hours. At the end of the 48 hours, each plant mixture were filtered. The filtrate obtained were a mixture of the plant extract and the ethanol. The plant extract obtained in ethanol solvent were concentrated by evaporating the ethanol from the mixture using rotary evaporator at 80°C to obtain a solution free of ethanol. Each of the plant extract weighed and stored for the corrosion inhibition study.

2.2. Metal Preparation

The mild steel used were cut into coupons (5 cm x 4 cm x 0.1 cm). The coupons were cleaned followed by polishing with emery paper to expose shining polished surface. To remove any oil and organic impurities, the coupons were degreased with acetone and finally washed with distilled water, dried in air and then stored in. Accurate weight of each coupon were taken using electronic weighing balance and the initial weight were recorded. The coupons were labeled in a manner to avoid any mix up.

2.3 Characterization of the Plant Extracts

2.3.1 Fourier Transform Infrared Spectroscopy (FTIR) Analysis of the Plant Extracts

Fourier transform infrared spectrometer (SHIMADZU, Model: IR affinity –I; S/N A2137470136 SI) were used for the determination of the functional groups of the plant extracts. The plant extracts were extracted using ethanol extract. The FTIR spectroscopic technique were used to obtain spectrum of each plant extract. The FTIR spectrophotometer simultaneously collected high spectral resolution data over a wide spectral range. Fourier transform (a mathematical process) will convert the raw data into actual spectrum. Analysis of various FTIR to produce peaks were carried out so as to determine the appropriate functional groups.

Fourier transform infrared spectrophotometer were used to study the functional groups of the pure extracts and corrosion products in the presence of the plant extracts. The plant extracts were extracted using ethanol solvent. Then the solvent were evaporated at 80 ^{0}C to obtain the pure extract. The metals were immersed in the media, in the presence of the plant extracts. At the end of the corrosion study, the corrosion products in the beaker were collected with the aid of sample bottles. Comparative analysis of various FTIR produced peaks were carried out so as to determine the appropriate functional groups for the corrosion inhibition process.

2.3.2 Phytochemical Analysis of the Plant Extracts.

0.2g of extract was weighed and transferred in a test tube and 25ml of ethanol was added. The test tube was allowed to react in a hotplate at 60^{0}c for 90mins. After the reaction time, the reaction product contained in the test tube was transferred to a separator funnel. The tube was washed successfully with 20ml of ethanol, 10ml of cold water, 10ml of hot water and 3ml of hexane, which was all transferred to the funnel. This extracts were combined and washed three times with 10ml of 10%v/v ethanol aqueous solution. The solution as dried with anhydrous sodium sulfate and the solvent was evaporated. The sample was solubilized in 1000ul of pyridine of which 200ul was transferred to a vial for analysis.

2.3.3 Quantification by GC-FID

The analysis of phytochemical was performed on a BUCK M910 Gas chromatography equipped with HP-5MS column (30 m in length × 250 μm in diameter × 0.25 μm in thickness of film). Spectroscopic detection by GC–MS involved an electron ionization system which utilized high energy electrons (70 eV). Pure helium gas (99.995%) was used as the carrier gas with flow rate of 1 mL/min. The initial temperature was set at 50 – 150 °C with increasing rate of 3 °C/min and holding time of about 10 min. Finally, the temperature was increased to 300 °C at 10 °C/min. One microliter of the prepared 1% of the extracts diluted with respective solvents was injected in a split less mode. Relative quantity of the chemical compounds present in each of the extracts ofwas expressed as percentage based on peak area produced in the chromatogram.

2.3.4 Identification of chemical constituents

Bioactive compounds extracted from different extracts were identified based on GC retention time on HP-5MS column and matching of the spectra with computer software data of standards (Replib and Mainlab data of GC–MS systems).

3.1 Characterization of the plant leaf Extracts

3.1.1 Phytochemical analysis of plant leaf extracts

Qualitative and quantitative analysis were carried out on the Banana leave extract (BNL) and fluted pumpkin stem extract (FPS) and the results are shown in Tables 3.1-3.5. According to Table 1.0 and 3.2, the phytochemical composition of FPS and BNL only shown significant results with ethanol extractions but shown no significant results with aqueous solution. This simply shown that these phytochemical constituents of FPS and BNL are soluble in ethanol because of the presence of hydroxyl group (OH^-). The phytochemical analysis of FPS and BNL was done withgas chromatography-flame ionization detection (GC-FID) and the results are shown in Tables 3.3 and 3.4, respectively. According to Table 3.0, several phytochemical components with their respective composition either in ppm (mg/l) or $\mu g/ml$were isolated from the FPS extract. They are; alkaloid compounds (scopolamine and Epihedrine), phenolic compounds (resveratol), flavonoid compounds (Anthocyanin, Flavon3ol, Naringenin, Rutin, Flavonones, Kaempferol, Flavone, Epicatechin and Catechin), Cardiac glycoside (cardiac glycoside, Cyanogenic glycoside) and Saponin compounds (sapogenin).

The phytochemical composition of the BNL and its respective compositions are shown in Table 4.0. It shows that BNL is composed of phenolic compounds (Resveratol), flavonoid compounds (Naringin, Anthocyanin, Flavon3ol, Naringenin, Rutin, Flavonones, Kaempferol, Flavones and Epicatechin), Cardiac glycoside (cardiac glycoside, Cyanogenic glycoside), alkaloid compounds (Spatein, and berberine) and Saponin compounds (sapogenin).

The qualitative analysis of the samples (FPS and BNL) are shown in Table 5.0. It showed that flavonoid (54.17mg/l), Cardiac glycoside (21.93mg/l), alkaloid (10.35mg/l) and steroids (15.33mg/l) were the dominant compounds found in FPS. It also reveal that the dominant compounds isolated in BNL were Saponin (9.26 mg/l), flavonoids (66.51 mg/l), phytate (9.26 mg/l), Cardiac glycoside (25.06 mg/l) and steroids (13.66mg/l). This phytochemical analysis revealed the presence of alkaloids, flavonoids, phenol, saponins, tannins, steroids, phytates and glycoside (Adesegun et al 2008, Nana et al 2013). The leaves extract establish their inhibitive action through adsorption of phytochemical components molecules on the metal surface.

Table 1.0: Phytochemical composition of FPS extract

Phytochemical	Aqueous extract	Ethanol extract
Alkaloid	-	++
Flavonoid	-	++
Reducing sugar	-	-
Tannin	-	++
Cardiac glycoside	-	+
Steriods	-	++

Table 2.0: Phytochemical composition of BNL

Phytochemical	Aqueous extract	Ethanol extract
Alkaloid	-	++
Flavonoid	-	++
Reducing sugar	-	-
Tannin	-	++
Cardiac glycoside	-	+
Steriods	-	++

Table 3.0 phytochemical analysis of FPS usinggas chromatography-flame ionization detection (GC-FID)

Component	Retention	Area	Height	External	Units
Lunamarin	0.206	6102.8514	493.551	2.6806	µg/ml
Cardiac glycoside	2.390	12421.8376	963.612	4.8716	µg/ml
Anthocyanin	4.120	6544.0460	511.833	5.8930	µg/ml
Flavan 3 ol	6.016	18238.4729	1390.783	10.5945	ppm
Tannin	7.470	8487.2413	661.982	4.9287	ppm
Ribalinidine	10.366	19619.6586	1493.612	24.6508	µg/ml
Naringenin	12.970	6253.5744	489.557	5.4502	µg/ml
Rutin	15.460	4978.4178	390.100	3.0893	µg/ml
Resveratol	17.963	11350.8426	881.534	7.3315	µg/ml
Flavonones	20.316	12766.2143	888.829	9.8539	ppm
Steriods	22.730	9584.2142	738.648	15.3298	ppm
Kaempferol	25.650	10090.3523	784.201	7.9195	ppm
Cyanogenic glycoside	27.536	11537.7968	889.916	17.0586	µg/ml
Phytate	29.860	5485.4772	430.055	5.5297	ppm
Flavone	32.993	14339.2342	1096.698	8.8981	µg/ml
Epicatechin	34.600	6057.7184	474.697	8.3531	µg/g
Oxalate	36.876	6997.3518	539.543	7.1935	µg/ml
Catechin	39.200	10236.5203	788.825	2.4720	µg/ml
scopolamine	40.699	10567.6785	835.657	5.3741	µg/ml
Sapogenin	42.276	3509.9406	275.546	2.4531	µg/ml
Epihedrine	44.170	10548.9686	819.790	4.9759	µg/ml

Table 4.0 phytochemical analysis of Banana leaf using gas chromatography-flame ionization detection (GC-FID)

Component	Retention	Area	Height	External	units
Lunamarin	0.190	5184.3944	427.802	2.2772	µg/ml
Naringin	1.583	4709.7496	369.572	4.3788	µg/ml
Cardiac glycoside	2.633	12170.5138	945.575	4.7730	µg/ml
Anthocyanin	3.550	393.4112	306.580	3.5151	µg/ml
Flavan 3 ol	4.400	10229.5051	797.090	5.9422	ppm
Ribalinidine	12.620	6505.2012	510.587	8.1733	µg/ml
Naringenin	12.990	7261.1404	564.292	6.3284	µg/ml
Spartein	13.273	5414.6802	430.677	2.6889	µg/ml
Rutin	13.973	3725.9862	292.790	2.3121	µg/ml
Resveratol	15.620	5351.2845	419.380	3.4564	ppm

Flavononones	18.950	6368.0202	498.244	4.9153	ppm
Steriods	22.456	8539.726	666.846	13.6592	ppm
Kaempferol	25.563	4875.0349	382.357	3.8262	µg/ml
Cyanogenic glycoside	27.910	13725.1531	1063.342	20.2926	ppm
Phytate	28.276	9186.5206	716.488	9.2606	µg/ml
Flavone	33.810	18147.5364	1384.596	11.2613	µg/ml
Epicatechin	35.650	17427.5578	1329.989	24.0311	Ug/g
Oxalate	36.526	5159.9954	404.908	5.3047	µg/ml
Sapogenin	42.706	13247.6644	1026.936	9.2587	µg/ml
Berberine	44.234	7671.3452	765.123	3.3412	µg/ml

Table 5.0: Quantitative analysis of phytochemicals

Phytochemicals	**FPS**	**BNL**
Saponin	2.4531	9.2587
Tannin	4.9287	
Flavonoid	54.1705	66.5105
Phytate	5.5297	9.2606
Cardiac glycoside	21.9302	25.0656
Alkaloid	10.35	6.0301
Phenol	7.3315	
Steriods	15.3298	13.6592
Oxalate	7.1935	5.3047

3.2 Instrumental analysis

3.2.1 FTIR graphical analysis

Fourier transform infrared spectrophotometer is a powerful technique used by scientist in determination of the functional group of the plant extracts. Comparative analysis of various FTIR produced peak were carried out to ascertain the appropriate functional group responsible for the corrosion inhibition process. The FTIR spectrum is presented in Table 6.0 and 7.0. The peak numbers represent the functional groups in the FPS and Banana Leaf Extracts. Further close examination reveal that anti corrosion protection of FPS and Banana leaf is due to the heterocyclic compounds existing in them.

Table 6.0: FTIR Spectroscopy Studies on FPS Extract

SL. No	PEAK (cm^{-1})	FUNCTIONAL GROUP
1	3324.8	Hydroxyl compound
2	2929.7	Methyl group
3	2832.8	Cyclo alkane
4	2035.4	Cyclo alkane
5	1744.4	Carbonyl compound
6	1654.9	Carbonyl compound
7	1449.9	Phenol ring
8	1408.9	Aromatic ring
9	1088.4	C-O-C group
10	1021.3	C-O-C group
11	879.7	C-H

Table 7.0: FTIR Spectroscopy Studies on BNL Extract

SL. No	FREQUENCY (cm^{-1})	FUNCTIONAL GROUP
1	3339.7	Hydroxyl compound
2	2944.6	Methyl group
3	2832.8	Cyclo alkane
4	2031.4	Clyco alkane
5	1654.9	Carbonyl compound
6	1449.9	Phenol ring
7	1408.9	Aromatic ring
8	1088.4	C-O-C group
9	1021.3	C-O-C group
10	879.7	C-H

3.2.2 Metal Surface Study Using Scanning Electron Microscopy (SEM)

Scanning electron microscopy (SEM) provides a pictorial representation of the metal surfaces studied. To understand the nature of the surface film in the absence and presence of inhibitors and the extent of corrosion of the metals. The micrographs of the corroded metals in the corrosive media (absence) and in the presence of the plant extracts are presented in Plate 1.0-4.0. Looking at the corroded metals for all media used, there were significant differences in the morphology of the metal surface in the presence and absence of the plant extracts. This is attributed to the formation of a good protective film on the metal surfaces by the inhibitors (Shanthi and Rajendran, 2013). The micrographs have close correlation with the results obtained from the weight loss method. This is in agreement with the previous study by Loto and Popoola, (2012). The surface nature of the corroded metals in the presence and absence of the plant extracts shows that the inhibitors suppressed the corrosion process.

The morphology of the mild steel surface in plate 1.0 reveals that, in the absence of inhibitors, the surface is highly damaged, with area of typical uniform corrosion on the mild steel surface. Although, in the presence of green inhibitors plate 1.0, the rate of corrosion was suppressed, due to the formation of an absorbed film of the inhibitor on the mild steel surface. Plate 4.0 shows the protected mild steel surface after addition of green inhibitors, whereby the surface damage has diminished in comparison to the blank material. This is attributed to a good protective film on the mild steel surface.

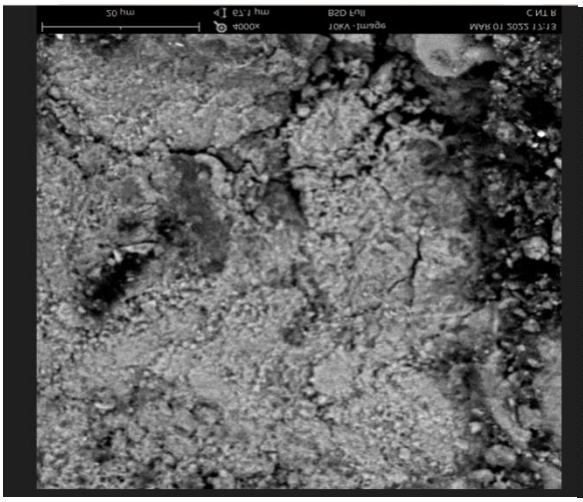

Plate 1.0: The micrograph of corroded mild steel surface in HCL without FPS

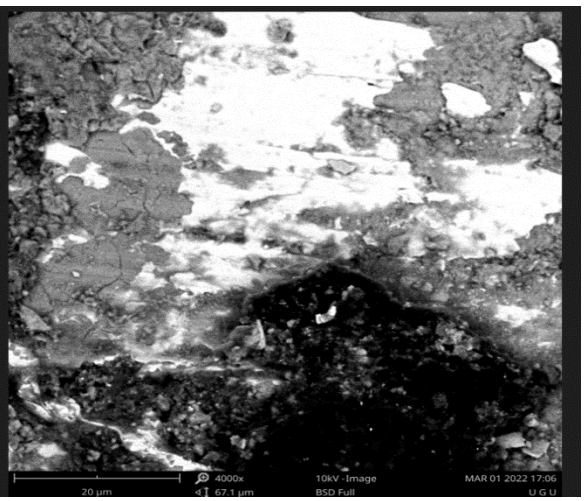

Plate 2.0: The micrograph of corroded mild steel surface in HCL with FPS

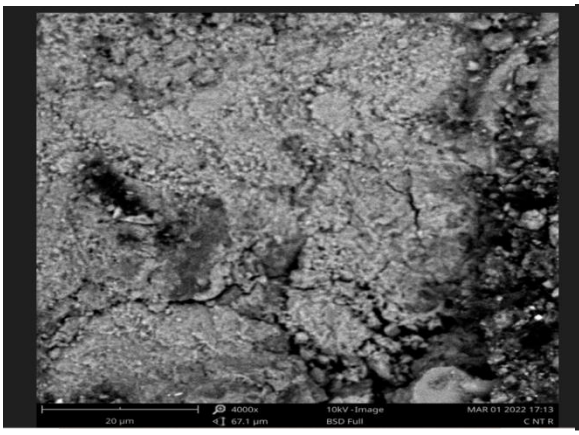

Plate 3.0: The micrograph of corroded mild steel surface in HCL with FPS

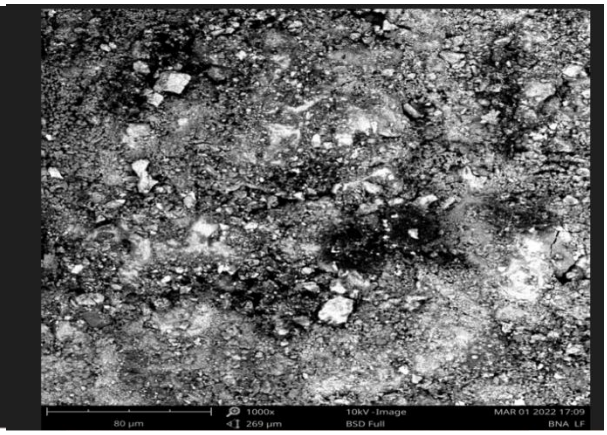

Plate 4.0: The micrograph of corroded mild steel surface in HCL

3.3 Effect of Process Variables

3.3.1 Effect of Temperature and Corrosion Rate

The effect of temperature on corrosion inhibitions of mild steel from BNL and pumpkin extract is shown in Fig. 1.0. As shown in Fig. 1.0, increase in the temperature of the system increase the percentage weight loss of the samples (Banana and Pumpkin). At 30 ^{o}C, the weight loss of the samples obtained were 18.457 and 23.893% for BNL and pumpkin extract respectively. Increasing the temperature to 35 ^{o}C produced a corresponding increase in weight loss of the sample to 23.616 and 24.586 %, respectively. Furthermore, at 50 ^{o}C, the weight loss percentage obtained were 36.558 and 30.136 % respectively. The optimum weight loss obtained for banana and pumpkin were 43.412 and 37.454, respectively and this occurred at 60 ^{o}C as shown in Fig. 1.0. Generally, corrosion rate increases as temperature increases as shown in Fig. 1.0. According to Fig. 2.0, the corrosion rate (CR) of banana and pumpkin extract shows that increase in the temperature of the reaction resulted in higher corrosion rate. At higher temperature, the rate of chemical reaction is increased and oxygen solubility is reduced. This allows the cathodic reaction to occur. Furthermore, the viscosity of water decreases with increases in temperature. The reduction in viscosity of water leads to increased diffusion, which in turn allow for increase in the transport of reactant (dissolved oxygen or electron acceptors) and product (Fe^{+2} species) on the mild steel surface. From Fig. 2.0, it could be seen that under the same operating conditions that BNL has higher corrosion rate than pumpkin extract. Hawraa et al., (2018) reported similar observation with acid solution.

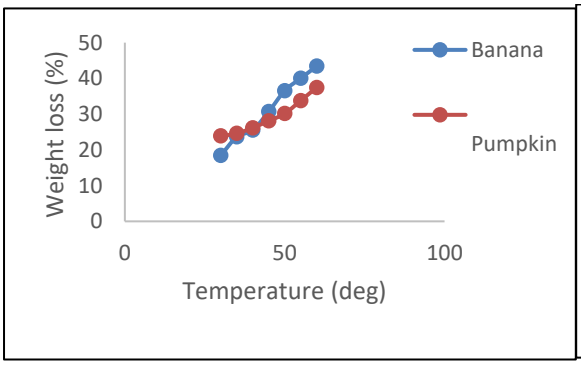

Fig. 1.0: Effect of Temperature on Corrosion of steel

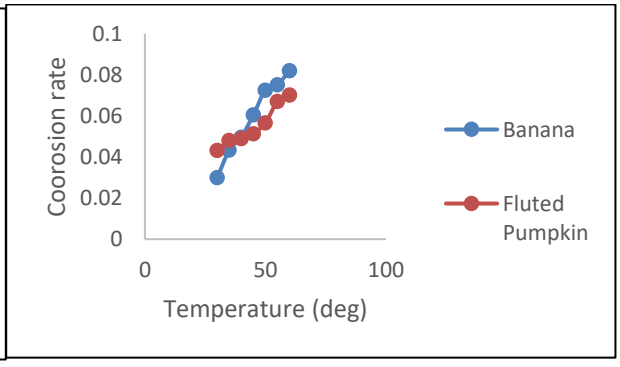

Fig. 2.0: Corrosion rate of steel

3.3.2 Effect of inhibitor Concentration on Corrosion of steel

The effect of inhibitor concentration on corrosion of mild steel were done at these operating conditions: Temperature of 30 ^{o}C and acid concentration of 0.5m and are shown in Fig. 3.0. According to Fig. 3.0, increase in concentration of the inhibitors resulted to a decrease in the % weight loss of the sample (decrease in rate of corrosion). At inhibitor concentration of 0.1m, the % weight loss of the samples were 14.324 and 12.347 % for BNL 1 and Pumpkin extract respectively. Also, at inhibitor concentration of 0.15m, the weight loss obtained were 10. 682 and 10.333 % respectively. This reduced to 8.294 and 6.231 % respectively at inhibitor concentration of 0.3m (Fig.3.0). This is due to the increase in surface coverage by increasing the inhibitor concentration. The same observation was reported by Sudhish and Eno (2011) with Streptomycin on mild steel in hydrochloric acid medium.

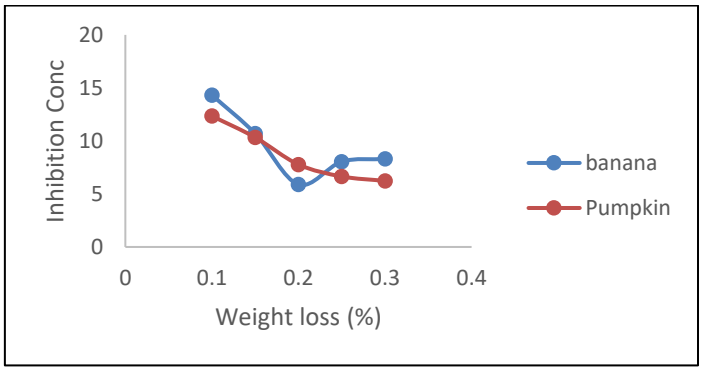

Fig. 3. 0: Effect of inhibitor Concentration on Corrosion of steel

3.3.3 Effect of Acid Concentration on Corrosion of steel.

The effect of acid concentration on corrosion of mild steel were done at these operating conditions: Temperature of 30 ^{o}C and inhibitor concentration of 0.2g and the plot is shown in Fig. 4.0. According to Fig.4.0 increase in concentration of acid resulted in a corresponding increase in corrosion rate (weight loss) of the samples. At 0.2 M acid concentration, the weight loss of BNL and pumpkin extract were 17.43 and 18.551 % respectively. Increasing the concentration of the acid to 0.4 resulted in the increase of weight loss to 27.819 and 23.564 % respectively. The optimum percentage weight loss obtained for BNL and pumpkin extract were 33.05 and 30.766 % respectively. Beyond these points, the weight loss became stable and with insignificant weight loss observed with further increase in the concentration of the acid. This could be attributed to the deposition of corrosion products that tends to shield the corroding surface from further attack thereby reducing the rate of corrosion. Similar observationwas also reported by Raymond and Higgins (2004) andOgundare et al. (2012).

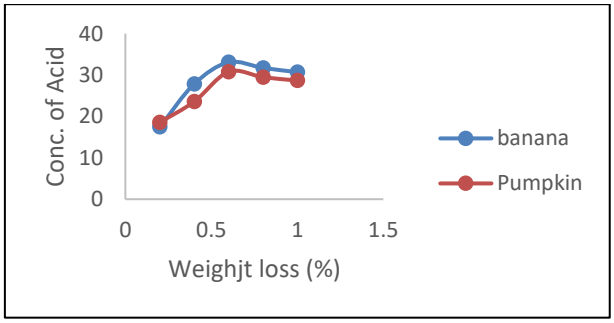

Fig. 4.0: Effect of Acid Concentration on Corrosion of steel

3.4 Thermodynamics of Corrosion of BNL and FPS

The standard thermodynamic parameters, enthalpy (ΔH) and entropy (ΔS) for corrosion inhibition process of BNL and FPS were calculated using the Van't Hoff's. The variations in Gibbs free energy (ΔG) for the different temperatures were estimated and the parameters were calculated by employing the data obtained from the temperature effects of corrosion. The data was used to plot the natural log of k against the inverse of temperature in Kelvin. These plots give a straight line and its slope represents the standard enthalpy of the system. The thermodynamic parameters of corrosion inhibition of mild steel by BNL and FPS is shown in Table 8.0. According to Table 8.0, the ΔG values for both BNL and FPS was positive and decreased with increasing temperatures. The ΔH values of BNL (26.51 KJ/mol) and FPS (13.171 KJ/mol) were positive and remain constant with rise in temperatures. The positive values of ΔH show the endothermic nature of the process. The ΔS values for BNL (59.40 J/mol.K) and FPS (17.199 J/mol.K) were positive and remain constant for all temperatures. This indicates that the activation complex represents association steps and that the reaction was spontaneous and feasible (Olasehinde et al., 2012). Similar observation was reported by Olasehinde et al., (2012).

Table 8.0: Thermodynamic parameters of corrosion inhibition of mild steel

Sample	Temp	ΔG (KJ/mol)	ΔH (KJ/mol)	ΔS (J/mol.K)
	303	8.510075		
	308	8.213032		
BNL	313	7.91599	26.51085	59.4085
	318	7.618947		
	323	7.321905		
	328	7.024862		
	333	6.72782		
	303	7.959743		
	308	7.873748		
FPS	313	7.787753		
	318	7.701758	13.17104	17.199
	323	7.615763		
	328	7.529768		
	333	7.443773		

4.1 Conclusion

Based on the result of the work, the following conclusions are drawn:

- The study shows that ethanol of FPS and BNL are good inhibitors for the corrosion of mild steel in HCL. The inhibition efficiency of BNL was the best followed by that of FPS.
- Effect of process parameters shows that increase in temperature increases the percentage weight loss (corrosion rate) of BNL and FPS. It also showed that increase in concentration of the inhibitors resulted to a decrease in the % weight loss of the sample (decrease in rate of corrosion). Increase in concentration of acid resulted in a corresponding increase in corrosion rate (weight loss) of the samples.
- The study shows that HCL is corrosive to the mild steel.

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