ISSN : 2350-0743

www.ijramr.com

International Journal of Recent Advances in Multidisciplinary Research
Vol. 06, Issue 09, pp.5212-5216, September, 2019

RESEARCH ARTICLE

PHYTOCHEMICAL AND SPECTROSCOPY ANALYTICAL CHARACTERIZATIONS OF ACALYPHA-WILKESIANA LEAF AS GREEN CORROSION INHIBITOR

***Onyinyechi Pauline Elenwo, Israel O, Owate and Michael C, Onyeaju**

Department of Physics, University of Port Harcourt P.M.B.5323 Choba River State

ARTICLE INFO

Article History:
Received 27th June, 2019
Received in revised form
29th July, 2019
Accepted 20th August, 2019
Published online 30st September, 2019

Keywords:
Phytochemical, Spectroscopy, Analytical-Characterizations, Acalypha-Wilkesiana, Green Inhibitor.

ABSTRACT

The study examines the characteristics of the plant leaf extract of *Acalypha Wilkesiana* (copper leaf) by phytochemical analyses, Fourier transforms the techniques of infrarot spectroscopy (FT-IR) and gas chromatography-mass spectrometry (GC-MS). The leaf extract was obtained using maceration techniques in 1,5 liters of 70% ethanol and 30% distilled water as solvent. FT-IR was carried out using model-8400S Spectrophotometer Schmadzu machine whereas GC-MS model 2010 Plus Schmadzu was used to analyze the extract. The phytochemical screening shows that the extract of the leaf contains tannins, alkaloids, flavonoids, saponins, glycosides and volatile oils in varying amounts. The results of FT-IR analysis revealed the presence of some Thiocarnonyl (C=S), Sulphides compound (SxOy compounds) and C-Br Stretching of halogen derivatives. Also, it was observe that the GC-MS indicated the following: 1,3-Benzenediol, 2-chloro$C_6H_3ClN_2O_6$, 4-Ethynyl-1-methylpyrazole$C_6H_6N_2$, DifluoroamineF_2HN, 10-Azido-1-decanethiol$C_{10}H_{21}N_3S$,Diethylene glycol, 2TMS derivative $C_{10}H_{26}O_3Si_2$, Carbamodithioic acid $C_4H_9NS_2$ and (6E)-3-Chloro-6-imino-1(6H)-pyridazinol $C_4H_4ClN_3O$. Accordingly, phyto-constituents containing heteroatoms such as O, N, S, P and aromatic functional groups were found to be present in the leaf extract. These are indications of the potency for use in the formulation of organic inhibitor which is our primary aim. This suggests the use of Acalypha Wilkesiana as green inhibitor for the corrosion inhibition of materials.

INTRODUCTION

Structural materials are handled to alter their surface characteristics for decoration, enhanced hardness, wear resistance, corrosion mitigation or a basis for improving adherence to other treatments such as painting or photosensitive printing coatings (STMP, 2006). In both natural and industrial settings, these materials are volatile and inevitably return to stable chemical species similar to the chemically mixed forms from which they were obtained (Khadroui *et al.,* 2016). Most of the synthetic compounds used as corrosion inhibitors, although in most cases they have excellent anti-corrosion characteristics, are extremely toxic to humans and the environment. Synthetic chemical-based inhibitors may cause temporary or permanent harm to human organs or interfere with human biochemical procedures. The toxicity may occur during or during the synthesis of the compound (Suleiman *et al.,* 2017). The development of novel and non-toxic corrosion inhibitors from certain components of low-cost natural substances has thus been considered an financial, strategic and environmentally plausible advantage. A basic field of research is the discovery of plant products as environmentally friendly inhibitors of corrosion. In plant products, the electronic and molecular structures are similar to those of the usual inhibitor molecules (Rekkab *et al.,* 2012 and Dourna *et al.,* 2011).

Corresponding author: **Onyinyechi Pauline Elenwo,**
Department of Physics, University of Port Harcourt P.M.B.5323 Choba River State.

Acalypha wilkesiana is a plant belonging to the Euphorbiacaece family. The genus Acalypha crops are discovered all over the globe, particularly in the tropics of Africa, America, Asia, and from other areas of the globe have been brought into West Africa. It was grown in gardens and greenhouses as leaf crops (Petchiamal *et al.,* 2013). It gives a bronze red to muted red splash of color in the landscape, the leaves appear as heart-shaped. Acalyphawilkesiana has been reported to be used in hypertension therapy, particularly in the management of abnormal sodium and potassium metabolism accompanying hypertension (Rajendran and Karthikeyan, 2012). Plant material extracts constitute significant amount of atoms as contained in the organic compounds like P, N, S, O. These atoms coordinate with the corroding metal atom (ions) resulting in the formation of protective films on the corroding metal surface. Plant / extract source corrosion inhibitors are called organic inhibitors. Organic inhibitors, commonly referred to as film formers, safeguard the metal by forming a hydrophobic film on the metal surface and are thought to inhibit adsorption corrosion (Oguzie *et al.,* 2010). It is widely recognized that by adsorbing the metal-solution interface, the organic molecule inhibits corrosion. The most common types of hydrogen and nitrogen containing compounds are long chains (C18).

Aim and Objectives: This study aims at investigating the characteristics of *Acalypha wilkesiana* for possible use as a green inhibitor. The following are the objectives

To

- Study effectiveness of *Acalypha wilkesiana* (AW) as green inhibitor of materials
- Characterize the plant extract by qualitative and quantitative analyses, Fourier Transforms, Infrared Spectroscopy (FT-IR), and Gas Chromatography-Mass Spectrometry (GC-MS) techniques.
- Identify if the components that aid greenhouse inhibitors are present.

MATERIALS AND METHODS

Extract of leaf employed for this study was *Acalypha Wilkesiana* (copper leaf, Joseph's coat, and fire dragon). *Acalypha wilkesiana* is a member of the Euphorbiaceae family. The plant has antimicrobial and antifungal characteristics and the leaves are consumed as vegetables in traditional medicine in the management of hypertension, being a diuretic plant. Figure 3.1 shows the picture of *Acalypha wilkesiana* (*AW)* leaf. The major equipment used in the characterization of the plants extract include Ethanol distillation unit, complete units of Fourier Transforms Infrared Spectroscopy (FT-IR) and Gas Chromatography–Mass Spectrometer (GC-MS) machines.

Materials and extraction of phytoconstituents of the plants: Leaves used for this study were collected from University of Port-Harcourt, Rivers State in the Southern parts of Nigeria. The leaf samples were identified and collected by Herbarium Staff of the University. The leaves were washed with water to remove dust particles and cut into small pieces. A temperature of about 30 degrees was used to dry the leaves whereby the plants were pulverized using mortar and pestle. About 900gm of powder of sample leaves was extracted in 1500 ml (1.5 litres) of 70% ethanol and 30% distilled water as solvent using Maceration Method at the Department of Pharmacognosy, University of Nigeria, Nsukka.

Determination of Phytoconstituents of the leaf extract: Qualitative / quantitative techniques were used to determine the phytochemical constituents. They were conducted at the National Chemical Technology Research Institute in Zaria.

Fourier Transforms Infrared Spectrophotometer (FT-IR) Analysis: At the National Research Institute of Chemical Technology Zaria, Fourier transforms infrared spectroscopic analysis was performed using a-8400S spectrophotometer Schmadzu Product Japan; the spectroscopic analysis was used to define the existence of chemical bonding and functional groups in the sample. The spectra generated for the extract was registered and analyzed using the FTIR machine's standard library Standard Library (Gur *et al.,* 2011).

Gas Chromatograph- Mass Spectrometry (GCMS) analysis: A gas chromatograph-mass spectrometer (GC-MS) model 2010 Plus Schmadzu was used for the analysis of the extract of the leaf extract. The machine was directly coupled to a QP 2010 Plus Auto-system XL equipped with two fused-silica capillary columns (60 m x 0.22 mm, film thickness 0.25 µm), Rtx-1 (polydimethylsiloxane) and Rtx-Wax (polyethylene glycol). The GC conditions used include Ion source temperature: of 150 °C and energy ionization of 70 eV. The GC-MS mass spectra and data generated were analyzed and used to identify the compounds and chemical functional groups presence in each extract (Gur *et al.,* 2011).

RESULTS AND DISCUSSION

The Phytochemical analyses of the leaf extract: The Quantitative phytochemical screenings of the leaf extract (*Acalypha wilkesiana, AW*) in percentage (%) and mg/100mg results are presented in table 1. and table 2 showed the qualitative results indicating that the leaf extract contains tannins, alkaloids, flavonoids, saponins, glycosides and volatile oil.

Figure 1. Plant used for preparing *Acalypha wilkesiana* leave extract

The phytochemical constituents can be adsorbed onto the metallic sample by blocking the active corrosion site or reduce the evolution of hydrogen gas at the cathode. This may be attributed to the facts that some of these phytoconstituents contain heteroatom such as O, N, S, P and both aromatic and functional groups. This agrees with earlier research reported by (Suleiman and Sani'2018 and Suleiman et al; 2016). The chemical bonds and functional groups identified by FT-IR Spectroscopy and Gas Chromatography and Mass Spectrometry (GC–MS) were performed on the extract to identify the likely constituents responsible for the inhibition. The structural allocation of GC compound retention information was based on spectral correspondence with the NIST library (National Institute of Standards and Technology). The *Acalypha wilkesiana* extract showed the presences of phytochemical constituents (alkaloids, tannins, saponins, flavonoids, glycosides and volatile oils) by analytical method and were supported by the FT-IR spectra as shown in tables 3 and 4. 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 phosphorus ion, 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≡Y and XY≡Z, NH_2 functional groups which fit well with these constituents. The inhibitor showed an efficient anticorrosion potential and the findings obviously stated that the inhibition mechanism involved the adsorption of the inhibitor molecules blocking the surface of the structural materials. Overall, the adsorption phenomenon was influenced by the metal's nature and surface charge, the aggressive electrolyte type, and the inhibitor's chemical composition (Oguzie, 2006). Because of the acidity of the corrosive medium, in its free base state, the leaf extract containing the phytochemical components could

Table 1. 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 2. 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: −

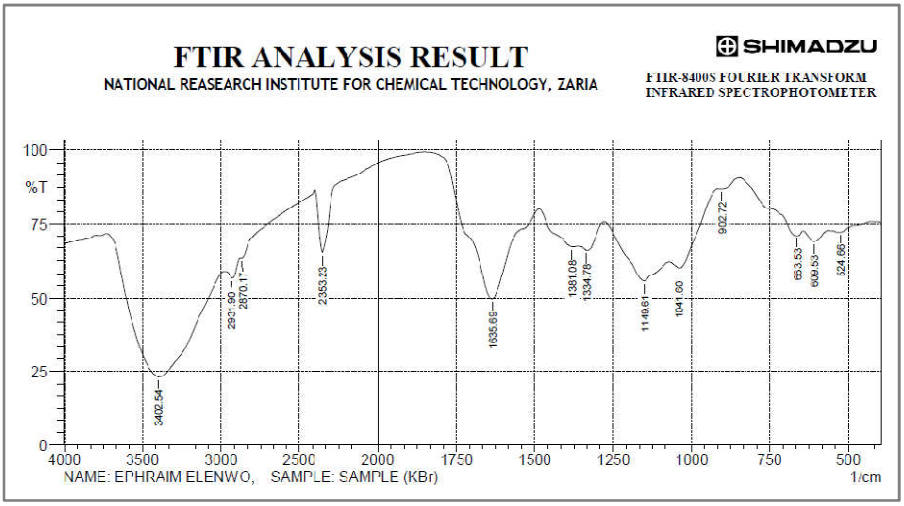

Figure 1. IR absorption spectrum of *AW leaf* extract

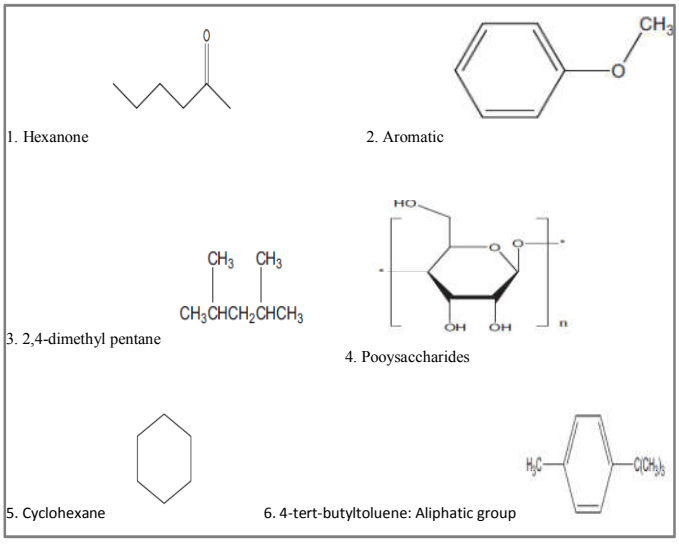

Figure 2. Chemical bonds/Functional groups of IR Absorption Spectrum of *AW leaf* extract

Table 3. 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	72.158	1.261	547.8	486.08	8.439	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	60.157	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	49.735	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	-6.714
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 4. 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 iodo compounds
3	663.53	C-Br Stretching of halogen derivatives
4	902.72	Thiocarnonyl (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

Table 5. The chemical compounds identified in the ethanol distillate of *AW* leaf extract by GC-MS analysis

Peaks	Extract	Chemical Names	Molecular Formula:	Molecular Weight g/mol
1	*Acalypha wilkesiana (AW)*	Methane, chloromethoxy-	C_2H_5ClO	80.523
2		1,3-Benzenediol, 2-chloro-	$C_6H_3ClN_2O_6$	234.5
3		3-Vinyl-1-cyclobutene	C_5H_8	80.13
4		4-Ethynyl-1- methylpyrazole	$C_6H_6N_2$	106.128
5		1-Buten-3-yne	C_4H_4	52
6		Difluoroamine	F_2HN	53
7		2,4-Pentadienenitrile	C_5H_5N	79
8		1,2,4,5,9,10-Triepoxydecane	$C_{10}H_{16}O_3$	128
9		1-Methyl-3-butenyl 3-methyl-3-hydroxybutyl ether	$C_{10}H_{20}O_2$	171.26
10		10-Azido-1-decanethiol	$C_{10}H_{21}N_3S$	215.35
11		3-Hexen-1-OL	$C_6H_{12}O$	100
12		1-Heptene, 4-methyl-	C_7H_{14}	98
13		Hexahydro-1,3-benzodioxol-2-one	$C_7H_{10}O_3$	142.5
14		Butylamine	$C_4H_{11}N$	73.1
15		1,5-Heptadiene, (Z)-	C_7H_{12}	96.17
16		1-azabicyclo(3.1.0)hexane	C_5H_9N	83.13
17		5-Nitro-1-pentene	$C_5H_9NO_2$	115.13
18		11-(2-Cyclopenten-1-yl) undecanoic acid, (+)-	$C_{16}H_{28}O_2$	252.39
19		11-(2-Cyclopenten-1-yl) undecanoic acid, (+)-	$C_{16}H_{28}O_2$	252.39
20		Chlorine dioxide	ClO_2	67.45
21		3-Aminopropionitrile	$C_3H_6N_2$	70.09
22		Oxirane, 2,2'-(1,4-butanediyl)bis-	$C_8H_{14}O_2$	142.19
23		Glycine, N-acetyl-	$C_4H_7NO_3$	117.10
24		3,4-Altrosan	$C_6H_{10}O_5$	162.14
25		(6E)-3-Chloro-6-imino-1(6H)-pyridazinol	$C_4H_4ClN_3O$	145.54
26		5-(Hydroxymethyl)-1,4-dioxan-2-yl]methanol	$C_6H_{12}O_4$	148.15
27		Pentane, 2,2,4-trimethyl-	C_8H_{18}	114.22
28		D-Mannoheptulose	$C_7H_{14}O$	114.23
29		Triepoxydecane	$C_{10}H_{16}O_3$	184.23
30		Carbamodithioic acid, dimethyl-, methyl ester	$C_4H_9NS_2$	135.25
31		IUDWIAICWHVSQF-UHFFFAOYSA-N	$C_{15}H_{26}O$	222.37
32		Nonanoic acid	$C_9H_{18}O_2$	158.23
33		Cyclopropanetetradecanoic acid, 2-octyl-, methyl ester	$C_{26}H_{50}O_2$	394.67
34		alpha-Methyl-d-galactoside	$C_7H_{14}O_6$	194.18
35		Methyl d-glycero-.beta.-d-gulo-heptoside	$C_7H_{14}O$	114.13
36		Methyl 6-O-sec-butylhexopyranoside	$C_{11}H_{22}O_6$	250.29
37		Methylfructoside	$C_7H_{14}O_6$	194.18
38		2,3,4,5,6-Pentahydroxy-7-methoxyheptanal	$C_8H_{16}O$	128.12
39		11-(2-Cyclopenten-1-yl) undecanoic acid, (+)-	$C_{16}H_{28}O_2$	252.39
40		Diethylene glycol, 2TMS derivative	$C_{10}H_{26}O_3Si_2$	250.48
41		Methyl d-glycero-.beta.-d-gulo-heptoside	$C_7H_{14}O$	114.13
42		11-Cyclopentylundecanoic acid	$C_{16}H_{30}O_2$	254.41
43		7-Octenoic acid	$C_8H_{14}O_2$	142.19
44		Cyclopentaneundecanoic acid	$C_{16}H_{30}O_2$	254.41
45		Methyl-4,6-O-benzylidene-α-D-galactopyranoside	$C_{14}H_{18}O_6$	282.29
46		Lactose	$C_{12}H_{22}O_{11}$	342.3
47		7-Octenoic acid	$C_8H_{14}O_2$	142.19
48		Glucose	$C_6H_{12}O_6$	180.12
49		11-Cyclopentylundecanoic acid	$C_{16}H_{30}O_2$	254.41
50		6-Ethyldecan-3-yl prop-2-enoate	$C_{15}H_{28}O_2$	240.38

not stay in solution. It may exist as or in its cationic form as neutral species, as shown in figures 1 and 2 (John, 2000).

Gas Chromatography- Mass Spectrometry (GC-MS) analysis of *Acalypha wilkesiana* extract: The analysis of *Acalypha wilkesiana* by GC-MS permitted the classification of fifty mechanism, that comprises of 100% in the total of the extract. Table 5 showed the chemical compounds recognized in the ethanol distillate of *Acalypha wilkesiana (AW)* leaf extract by GC-MS analysis. The table revealed the presence of 1,3-Benzenediol, 2-chloro, 4-Ethynyl-1- methylpyrazole, 1-ethenyl-1-methyl-2, methyl ester, 2,4-Pentadienenitrile, and other phenolic compounds followed by methyl ester which are major constituents. The results also revealed the functional groups which are good corrosion inhibitors as reported by (Petchiamaletal; 2013 and Suleiman and Sani, 2018,). This extract contains oxygen atoms, hydroxyl, aromatic rings and hydrocarbon which are the centers of adsorption as reported by (Somaz, 2014 and Oguzie 2006).

Conclusion

You can draw the following findings from the research.

- The analyses revealed the presence of phytochemical and phytoconstituents in the *Acalypha wilkesiana* such as saponins, alkaloids, flavonoids, tannins etc.
- The results of FT-IR analysis revealed the presence of Thiocarnonyl (C=S), Sulphides compound (SxOy compounds), C-Br Stretching of halogen derivatives etc.
- The GC-MS also revealed the following structures 1,3-Benzenediol, 2-chloro$C_6H_3ClN_2O_6$, 4-Ethynyl-1-methylpyrazole$C_6H_6N_2$, DifluoroamineF_2HN, 10-Azido-1-decanethiol $C_{10}H_{21}N_3S$,Diethylene glycol, 2TMS derivative $C_{10}H_{26}O_3Si_2$, Carbamodithioic acid $C_4H_9NS_2$, (6E)-3-Chloro-6-imino-1(6H)-pyridazinol$C_4H_4ClN_3O$ etc.
- The extract of the leaf is found to contain many functional groups and hence can be consider as potentials materials for formulation of green corrosion inhibitor which can be proposed for materials surface modification in environments.

REFERENCES

Abiola O. K., Oforka N. C., Ebenso E. E., Nwinuka N. M. 2007. *Anti-Corros Methods & Mats.* 54 , 219.

Ahamad, I., Khan, S., Ansari, K. R., Quraishi, M. A. (2011). Primaquine: A Pharmaceutically Active Compound as Corrosion Inhibitor for Mild Steel in Hydrochloric Acid Solution. *Journal Chemical Pharmaceutical Resources,* 3(2), 703-717.

Dourna, Asefi, Mokhtar, Arami., Niyaz, Mohammad Mahmoodi. 2011. Organic Materials as Corrosion Inhibitors for Aqueous Medium: A Review. *The Electrochemical Society Meeting*, 23-56.

David Staut 2007. Eurek alert. Studies force New view on biology of flavonoids. Adapted from a new release issued by Oregon state university URL 541-737-0787.

Gür Emre Güraksın, UçmanErgün and ÖmerDeperlioğlu 2011. The Analysis of Heart Sounds and a Pocket Computer Application via Discrete Fourier Transform, Fourier

Trans- New Analytical Approaches and FTIR Strategies, Prof. GoranNikolic (Ed.).

John Coates 2000: Interpretation of Infrared Spectra, A Practical Approach in Encyclopedia of Analytical Chemistry.R.A. Meyers (Ed.) pp. 10815–10837 Wiley & Sons Ltd, Chichester.

Khadraoui A, Khelifa M, Hadjmeliani R, Mehdaoui K, Hachama A, Tidu Z, Azari IB, Obot A., Zarrouk A. 2016. Extraction, characterization and anti-corrosion activity of Mentha pulegium oil: weight loss, electrochemical, thermodynamic and surface studies. J Mol L 216:724–731.

Kubmarawa, D., Ajoku, G. A., Enwerem, N. M., Okorie, D. A. 2007. Preliminary Phytochemcial and Antimicrobial Screening of 50 Medicinal Plants in Nigeria. *Africa Journal of Biotechnology,* 6(14), 1690-1696

Oguzie, E. E., Enenebeaku, C. K., Akalez,i C. O., Okoro, S. C., Ayuk, A.A., Ejike, E. N. 2010. Adsorption and Corrosion-Inhibiting Effect of DacryodisEdulis Extract on Low-Carbon-Steel Corrosion in Acidic Media.*Journal of Colloid and interface Science,* 349 (1), 238-252.

Oguzie, Emeka E. 2008. Corrosion Inhibitive Effect and Adsorption Behaviour of Hibiscus Sabdariffa Extraction Mild Steel in Acidic Media. *Portugaliae ElectrochimicaActa,* 26, 303-314.

Petchiammal A., Selvaraj S. and K. Kalirajan, 2013. Influence of Hibiscus Esculenta Leaves on the corrosion of Stainless Steel in acidic medium., International Journal of Universal

Pharmacy and Bio Science 2(1).236-246.

Rekkab, S. Zarrok, H., Salghi, R., Zarrouk, A., Bazzi, Lh.,Hammouti, B., Kabouche, Z, Touzani Zougagh M. R. 2012. Green Corrosion Inhibitor from Essential Oil of Eucalyptus globulus (Myrtaceae) for C38 Steel in Sulfuric Acid Solution", *Journal of Materials Environmental Sciences,* 3: 613-627.

Rajendran A. and Karthikeyan C. 2012. The inhibitive effect of extract of flowers of *Cassia Auriculata*in 2 M HCl on the corrosion of aluminium and mild steel. *Int. J. Plant Res.* 2:9-14.

Surface Treatment of Metals and Plastics 2006. Reference Document on Best Available Techniques for the European Commission, pp. 2.

Suleiman IY., OchuRufai Suleiman, Rasheed AA., Ogheneme OC., Emokpaire OS. 2017. Adsorption and thermodynamics properties of acacia tortilis as corrosion inhibitor of aluminum metal matrix composites in acidic medium. Metall Mater Eng 23:153–166.

Singh, R., Kumar, A., Giri, D. D., Bhuvaneshwari, K., Pandey, K. D. 2012. Gas Chromatography - Mass Spectrometry Analysis and Phytochemical Screening of Methanolic Fruit Extract of Momordicacharantia.*Journal of Recent Advances in Agriculture.* 1(4), 122-127

Solmaz R 2014 Investigation of corrosion inhibition mechanism and stability of Vitamin B1 on mild steel in 0.5 M HCl solution. CorrosSci 81:75–84.

Suleiman I. Y. and Sani. A. Salihu 2018. Characterizations of Plant Extract by AAS and GC–MS as Green Inhibitor for Mild Steel in 1.0 M HCl. Iran J SciTechnol Trans Sci.,42:1977-1987.

Suleiman, I. Y., Yaro S. A and Abdulwahab M. 2016. Inhibitive Behaviour of *Acacia senegalensis*on Corrosion Resistance of Mild Steel-Acidic Environment. *Asian Journal of Chemistry;* 28(2):242-248.

Zucchi, F., Oma, I. H. 1985. Plant Extracts as Corrosion Inhibitors of Mild Steel in HCl Solutions.*Surface Technology,* 24(4), 391–399.

****