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Corrosion Inhibition of Mild Steel in Acid Environment using *Telfairia occidentalis* Leaves Extract

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ABSTRACT

Extract of Telfairia occidentalis leaves, as organic corrosion inhibitor of mild steel in corrosive medium of sulphuric acid (H2SO4) has been investigated at room temperature of 320C using gravimetric technique. Mild steel coupons of 25mm by 25mm with thickness of 0.8mm were suspended in acidic medium in the absence and presence of the leaves extract for a duration of 2 hours in 10MH2SO4 acid solution. The concentrations of leaves extract used were 0.625g/L, 1.250g/L, 2.500g/L and 3.750g/L. The results show that corrosion rate dropped as the concentration of telfairia occidentalis leaves extract increases. It also shows that the leaves extract has good adsorption properties as experimental data fit the Langmuir and Temkin adsorption isotherm with calculated correlation coefficient of 0.9995 and 0.9977 respectively. The lateral interaction parameter was calculated to -6.5922. Also, the adsorbed molecules of the extract showed inhibitory action on dissolution process of mild steel in sulphuric acid. Thus, telfairia occidentalis leaves extract whose plants are bountiful in the Southern Province of Nigeria and in many West African nations, provides good corrosive inhibition in mild steel.

Keywords: *Corrosion Inhibition; Acidic Environment, Telfairia occidentalis Leaves Extract*

1. Introduction

Nowadays, most important considerations in industry are reduction of overall costs by protection and maintenance of materials, and equipment used. The corrosion of metals remains a worldwide scientific problem as it affects the metallurgical, chemical, construction and oil industries. Studies on preventing the corrosion of mild steel in acidic environments and the problematic chemical process that arise have attracted the attention of researchers from a wide range of industrial sectors (Rani et al., 2012). Corrosion is a common problem for steel and directly impacts its cost and safety. The corrosion of iron, or rust, can cause structural damage and lead to changes in the mechanical and chemical properties of plants, vessels, pipes, and other processing equipment. These effects demonstrate that corrosion would produce considerable costs if an effective solution is not identified from its study and research. Preventing the corrosion of steel has played an important role in various industries, especially in the chemical and petrochemical processing industries that employ the use of steel (Shukla et al, 2012; Bin et al., 2014; Kosari et al., 2014; Bobina et al., 2013; Fragoza et al., 2012). Iron and steel are the metallic materials mostly used in structures that are exposed to the atmosphere and often, to the aggressive environments in industrial applications due to their availability and low cost (Bentis et al., 2002). Acidic solutions are extensively used in acid cleaning, pickling, and descaling processes, as well as, for drilling operations in oil exploration (Bothi and sethuraman, 2008). Iron and steel surfaces deployed in service in these environments undergo considerable corrosion. Significant reductions in corrosion rates has been achieved by various means including reduction of the metal impurity content, application of several surface modification techniques, as well as, incorporation of suitable alloying element. However, the use of corrosion inhibitors is about the most practical and economical method for corrosion prevention of unexpected metal dissolution in aqueous aggressive media (Satapathy et al., 2009; De-Souza and Spinelli, 2009; Da Rocha et al., 2010). A good number of the efficient corrosion inhibitors are organic compounds that contain nitrogen, oxygen, sulphur, phosphorus, and multiple bounds or aromatic rings in their structure (Jia-Jun et al., 2010; Shukla et al., 2009; Shukla and Quraish, 2009; Sinko, 2001). The molecular electronic structures and electron densities around these functional groups are the key structural features that determine the effectiveness of inhibition (Bothi and Sethuraman, 2008; Ketsetzi et al., 2008; Umoren et al., 2009).

The final choice of an appropriate inhibitor for a particular application is, however, constrained by such considerations as cost, environmental and toxicity issues (due to increasing concerns about the environment), as well as, the vast variety of possible corrosion systems, which often necessitate the use of combinations of additives to provide the multiple services required for effective corrosion inhibition. By 21st century, a large volume of literature was available about plant leaves extracts as effective corrosion inhibitors of iron or steel in acidic media. Interestingly, extracts from natural products (biomass) contains several phytochemical consistent, including alkaloids, tannins flavonoids, saponins, amino acids, ascorbic acid, phenolic acids, pigments resins, tritpenoids which possess electronic structures akin to those of conventional organic corrosion inhibitors as described above. Accordingly, the present report continues to focus on the broad application of biomass extracts for metallic corrosion control and reports on the inhibiting effect of the leaf extract of *Telfairia occidentalis* (T.O.) on the acid corrosion of mild steel. *Telfairia occidentalis* is a tropical vine grown in West Africa as a leaf vegetable and for its edible seeds (Akoroda, 1990). In this study, the adsorption and inhibitory proportion of *Telfairia occidentalis* of leaves extracts on the corrotioin of mild steel in H2S04 mediums was investigated.

2. Materials And Methods

The materials/apparatus used in this mild steel of corrosion inhibition include sulphuric acid (H_2SO_4), ethanol, methanol, butanol, distilled water, wagner's reagent, sodium hydroxide (NaOH), *telfairia occidentalis* leaves extract, beakers, measuring cylinder, electronic weighing balance, venier caliper, micrometer screw gauge, retort stand, wire cable, mortar and pestle, filter, filter paper, burner plate, masking tape and desiccators.

2.1 Materials Preparation

The leaves of *telfairia occidentalis* were harvested freshly from a local farm in Amaechi, Enugu State of Nigeria. The leaves were washed with water to remove dust and other particles that may act as contaminants. The washed leaves were sun dried under open air to reduce moisture content. The dried leaves were size reduced to increase surface area using mortar and pestle. The leave extract was extracted by cold extraction method (i.e according to Anna). The solvents used were methanol, butanol and water. The extract was concentrated by gentle heating in a flat bottom beaker using burner plate. The sheet of mild steel was obtained from a local market, near Enugu and was mechanically press cut into coupons of 25mm by 25mm with thickness of 0.8mm. A hole of uniform diameter was drilled in each coupon to facilitate its suspension in the test solution. The coupons were mechanically cleaned, degreased in ethenol, washed with distilled water, dipped in acetone and dried in air. The accurate weight of each dry coupon was taken using electronic weighing balance of modern FA2104A and recorded as initial weight, Wi. The coupons were labeled in a manner to avoid any mix up.

2.2 Phytochemical Analysis

Phytochemicals are chemical compounds that occur naturally in plant (phyto means "plant"). The phytochemical constituents which contributed to the corrosion inhibition include alkaloid, saponin, Quinine, phenol, flavonoid glucoside and others.

Test for alkaloids: 1ml of wagner's reagent was added separately to 1ml of each of the extracts in different test tubes and the slight reddish precipitate observed show the presence of alkaloids.

Test for saponin: 8mls of distilled water was used to dilute 2mls of each of the extracts in different test tubes and the content was vigorously shaken. Persistence foam (a mass of small bubbles escape on the surface of a liquid) formed, showing the presence of saponin.

Test for quinine: 1ml of acidified potassium iodide solution was added separately to 1ml of the extract in different test tubes. Blue-black color was observed, indicating the presence of quinine.

Test for phenol: A small portion of extract (1ml) was added to 1ml of water and 0.5ml of 5% NaOH. The colour changes from yellow to bright orange, indicating the presence of phenol.

Test for glucosides: 2mls of each extract in different test tube was added to 5mls of distilled water, 2mls of H2SO4 and was boiled together in a water bath for 15 minutes. It was allowed to cool and each was neutralized with 1ml of 20%KOH after which 1ml of fehling solution was added and boiled for another 15 minutes and brick red precipitate was observed indicating the presence of glucoside.

Test for flavonoids: 2 drops of 10%NaHO solution was added separately to 1ml of each extract in 3 different test tubes resulting to yellow ppt. 2 drops of AlCl3 was added to the above solution, followed by addition of concentrated H2SO4. Yellow colouration produced by each of the extract disappears on addition of conc. H2SO4.

2.3 Corrosion Study

The *telfairia occidentalis* leaves extract from metanol solvent was further heated to dryness. 80ml each of prepared 10M H2SO4 acid solution was measured into five beakers. 0.05, 0.1, 0.2, and 0.3 gram of the processed leave extract were added into four of the beakers respectively. The fifth beaker (blank) was set as control without any extract added to it. Five of the mild steel metals coupons of known initial weights, Wi in each case, were suspended in the five beakers, one per beaker by means of cable wire. The coupons were suspended freely (without touching the walls of the container) and were totally submerged in solution. The set up was allowed to stand for 2hours after which the mild steel metal coupons were withdrawn for their solutions, washed, scrubbed with brush to remove corrosion product, rinsed in distilled water and dipped in acetone and dried on air. Again their final weights, Wf in each case was obtained and recorded. Weight loss, ▯W=Wi-Wf was calculated. A parameter (θ) which represents the part of the metal surface covered by the inhibitor molecules, the percentage inhibition efficiency (%IE) and corrosion rate (CR) were also calculated using the following equations.

$$\theta = 1 - \frac{W_{add}}{W_{free}} \quad ------------------- \quad (1)$$

$$\%IE = \left[1 - \frac{W_{add}}{W_{free}}\right] 100 \quad ------------------- \quad (2)$$

$$CR = \frac{K\Delta W}{\vartheta \Delta T} \quad -------------------- \quad (3)$$

Where W_{free} and W_{add} are the weight loss of mild steel coupons in free and inhibited acid solution, respectively.

3. Phytochemical Result

The phytochemical analysis of *telfairia occidentalis* leaves extract has the followings; Alkaloids, saponin, Quinine, phenol, glucosides and flavonoids as summarized in Table 1.

Table 1: The phytochemical analysis result of *telfairia occidentalis* leaves extract using different extracting solvents.

Extract Constituent	Water	Methanol	Butanol
Alkaloid	+	-	-
Saponin	-	+	-
Quinine	-	+	++
Phenol	++	-	-
Glucoside	+	-	-
Flavonoid	++	-	-

Where; - = Absent
+ = Present
++ = strongly present

3.1 Corrosion Study Result

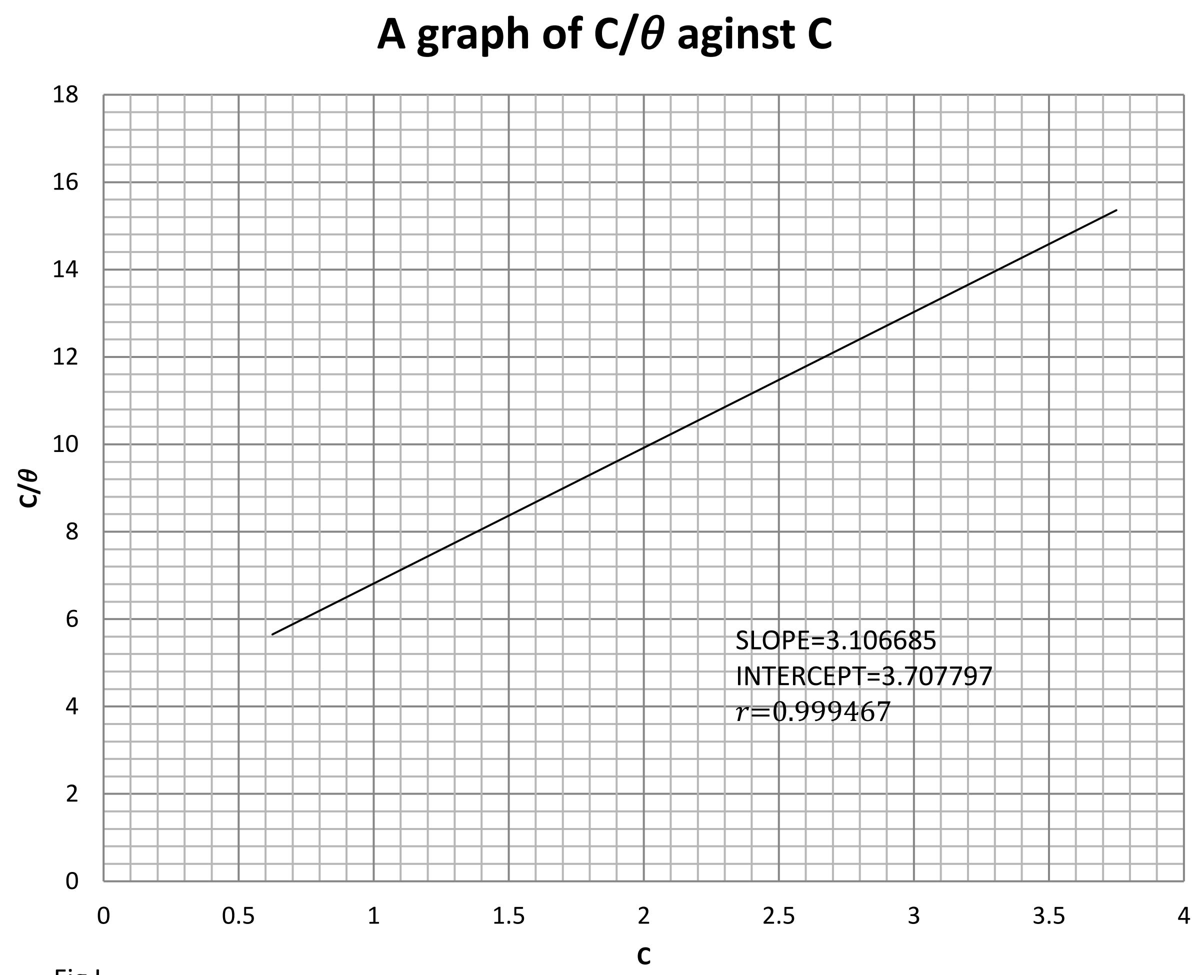
The inhibitive action of the extract on the dissolution process of the mild steel coupon was observed from the calculated corrosion rates in the presence of the leave extract compared to the blank (control) as described by Umoren. The adsorption properties were also investigated by subjecting experimental data to Langmuir adsorption isotherm (Metcalf, 2003; Buchweishaija, 2008); using fraction surface coverage parameter, the inhibition efficiency was also calculated (Umoren, 2008). The results are presented in Tables II and III. The regression plots of the adsorption parameters are shown in figures I and II.

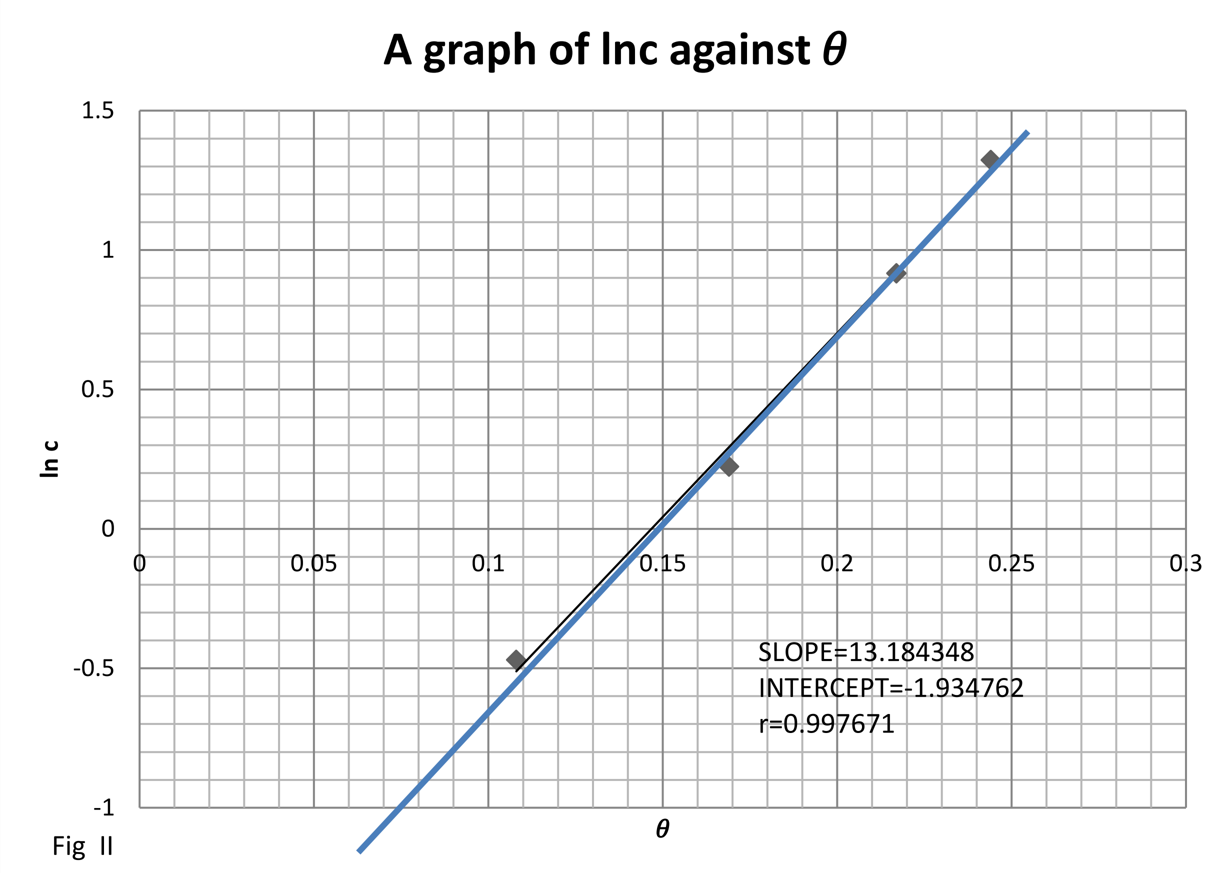
TABLE II: Effect of Telfairia occidentalis leaves extract on mild steel corrosion in 10MH2SO4 at 320C for 2hours

S/No	Mass of extract (g)	Extract conc.(g/l)	W_i(g)	W_f	Δ w(g)	θ	%IE	CR
1	Blank	Blank	5.0906	4.9535	0.1371	-	-	12.23
2	0.05	0.625	4.8429	4.7206	0.1223	0.108	10.8	10.91
3	0.10	1.250	5.0719	4.9580	0.1139	0.169	16.9	10.16
4	0.20	2.500	4.8226	4.7152	0.1074	0.217	21.7	9.58
5	0.30	3.750	5.0906	4.9870	0.1036	0.244	24.4	9.24

Table III: Parameters for deduction of adsorption isotherms at 32C

S/No	Extract Conc. C(g/L)	Surface Coverage, θ	$\frac{C}{\theta}$	lnC
1	0.625	0.108	5.787	-0470
2	1.250	0.169	7.396	0.223
3	2.500	0.217	11.521	0.916
4	3.750	0.244	15.369	1.322


A graph of C/θ aginst C
C/θ
C
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
SLOPE=3.106685
INTERCEPT=3.707797
r=0.999467
Fig I


A graph of lnc against θ
1.5
1
0.5
0
-0.5
-1
ln c
0
0.05
0.1
0.15
0.2
0.25
0.3
θ
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INTERCEPT=-1.934762
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Fig II

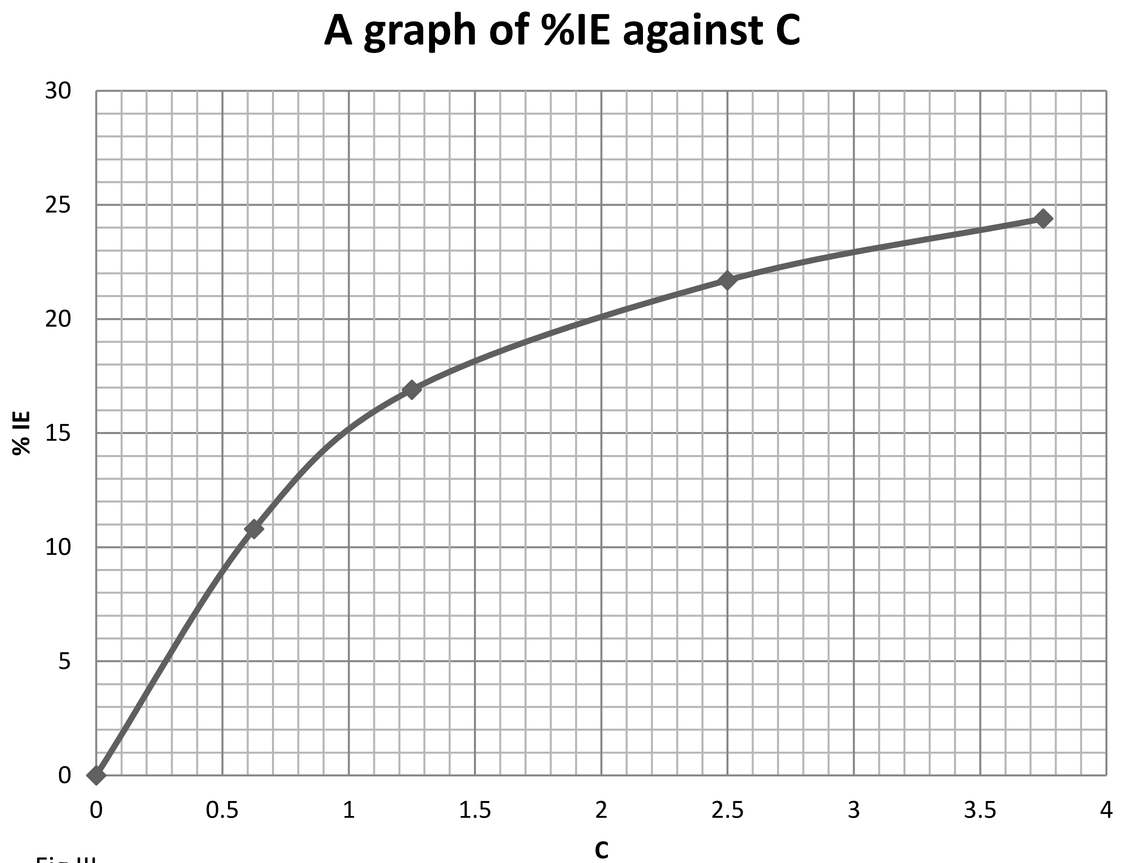

Fig III

4. Discussion

Organic molecules are known to attach on metal surfaces through adsorption. The preferred adsorption mode (chemical or physical) depends on structure of metal surface, structure of organic molecule and process conditions. Adsorption isotherms are frequently used to confirm adsorption processes in a given interaction. Adsorption isotherms show relationship between fractional surface coverage, θ and concentration of adsorbate, C in the environment. In this study, the adsorbate is *Telfairia occidentalis* leaves extract and the substrate (adsorbent) is mild steel metal coupon.

The data in Table II shows the effect of *Telfairia occidentalis* leaves extract concentration on mild steel metal corrosion inhibition. Result indicates that presence of the leaves extract reduced the rate of corrosion in all cases compared to the blank (control). Increasing the extract concentration reduced the corrosion rate progressively within the trial concentrations tested. This implies that increase in the extract concentration increased its inhibitory performance on the acid corrosion of mild steel. The observed inhibition could be due to formation of a passivating thin film layer of the extract on the metal surface, which protects the metal from further attack, depending on the decree of surface covered. The ratio of surface covered θ to that not covered, (1- θ) increases with increase in extract concentration. Therefore, the mechanism of inhibition is satisfactorily explained by adsorption.

If adsorption is assumed to be a mechanism of inhibition, then the plot of fractional surface coverage, θ against extract concentration, C must fit a known adsorption isotherm equation. Trial plot was made with Langmuir isotherm equation given as $C/\theta = C + 1/K$. where K is a constant. A plot of C/ θ against C gave a straight-line graph with slope as unity and intercept 1/K. The regression plot is presented in fig. 1 using data in Table III with slop, intercept and sample correlation coefficient (r) as 3.1067, 3.7078, 0.9995 respectively. The sample correlation coefficient close to unity (0.9995), suggests that data fit Langmuir isotherm. Langmuir isotherm generally implies chemical adsorption, which in turn implies that there is reaction between functional groups present in the leave extract and the valence electrons present in the mild steel metal, leading to the formation of mild steel-leaf extract complex.

Trial plot was also made with Temkin adsorption isotherm equation given by (Metcalf and Eddy, 2003) as -2a θ = Inc + Ink, where 'a' is the later interaction parameter describing the adsorbate molecule interaction in the adsorption layer and the heterogeneity of the metal surface. A plot of Inc against θ (from Inc = 2a θ-Ink) will give a straight-line graph with slope as -2a and intercept as -Ink. The regression plot is presented in fig. II using data in Table III, with slope, intercept and sample correlation coefficient (r) as 13.1843, - 1.9348 and 0.9977 respectively. The interaction parameter,' a' is calculated from slope and the value is -6.5922. This value being negative reveals that the interaction is repulsive.

5. Conclussion

Telfairia occidentalis leaves extract is an excellent inhibitor for corrosion of mild steel in acid environment at room temperature. Inhibition efficiency of mild steel in sulphuric acid media increases with increase in the concentration of the inhibitor. Corrosion inhibitor is afforded by both physical and chemical adsorption components of *Telfairia occidentalis* leaves extract on mild steel surface. Langmuir and Temkin adsorption isotherms are obeyed with correlation coefficient 0.9995 and 0.9977 respectively. Results from the technique employed are in reasonably good agreements and point to the fact that *telfairia occidentalis* leaves extract is a good and efficient inhibitor within the range of concentrations investigated

References

Ababi, O.Y. (2000). New School Chemistry: *Senior Secondary Science Series,* New Edition. African First Publisher; Onitsha, Nigeria. ISBN: 9971 1 0398 2. Page 77-80.

Acid: en.m Wikipedia org/wiki/acid.

Akalezi, C.O., Enenebaku, C.K., Oguzie, E.E. (2012). Application of Aqueous Extracts of Coffee Senna for Control of Mild Steel Corrosion in Acidic Environments. *Int Journal in Chem.,* 3:13.

Akoroda, M.O. (1990). Ethnobotary of Telfairia occidentalis (Curcurbitacae) among Igbos of Nigeria. *Economic Botany:* 29-39.

Basics of Corrosion Control: A Short Introduction to Corrosion and its Control; Corrosion of Metals and its Prevention. Available in pdf.

Bentis, F., Lagrence, M., and Traisnel, M. (2002). 2,5-bis (n-pyridy 1) 1,3,4-oxadizoles as Corrosion Inhibitors for Mild Steel in Acidic Media. *Corros. Sci. 56*, 733-742.

Bin, X., Wenzhong, Y., Ying, L., Xiaozhuang, Y., Weinan, G., and Yizhong, C. (2014). Experimental and Theoretical Evaluation of two Pyridinecou Boxaldehyde Thiosemicarbozone Compounds as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid Solution. *Corros. Sci 78*, 260-268.

Bobina, M., Kellenberger, A., Millet, J., Muntean, C., and Vaszilcsin, N., (2013). Corrosion Resistance of Carbon Steel in Weak Avid Solutions in the Presence of L-histidine as Corrosion Inhibitor. *Corros Sci. 69,* 389-395.

Bothi, R.P. and Sathuramen, M.G. (2008). "Inhibitive effect of black paper extract on the sulphuric acid corrosion of mild steel". mater lett 62:2977-2979.

Bothi, R.P., and Sethuraman, M.G. (2008). Natural products as corrosion inhibitors for metals in corrosive media. *A review mater lett 62*, 113-116.

Corrosion fundamentals: Why metals corrode: forms of corrosion. Available in corrosion.ksc.nasa.gov/corr-metal.htm; corrosion.ksc.nasa.gov/corr-forms. htm.

Corrosion inhibitor; en.m.wikipedia.org/wiki/corrosion.inhibitor

Da Rocha, J.C., Gomes, DC P., and Delia, E. (2010). Corrosion inhibition of carbon steel in hydrochloric solution by fruit peel aqueous extracts. *corros Sc. 52*, 2341-2348.

De-Souza, F.S., and Spinelli, A. (2009). Caffeic acid as a green corrosion inhibitor for mild steel Coros. Sic. 52, 1845.

Difference between rust and corrosion; Available in www.differencebetween.net/science/chemistry-science/difference.between-rust-and–corrosion.

Echegi, U.S. (2009). Chemical Reaction Engineering. *Benalice int'l Publication*, No 6A Medical Road Phase six Trans Ekulu Box 8587 Enugu ISBN: 978-978-906-773-2 Pg 291-316.

Factors which affect corrosion; www.emedicalprep.coml.study–material/chemistry/electro-chemistry/factor–affectin–corrosion htm.

Fragoza-Mar, L., Oliveres-Xometl, O., Dominguez-Aguilar, M., Flores, E., Lozada, P., and Jinenes-cruz, F. (2012). Corrosion inhibitor activity of 1,3-diketone molonates for mild steel in aqueous hydrochloric acid solution. *Corros. Sci. 61,* 17-184.

Hubert, G., Elmar- Manfred, H., Hartmut, S., and Helmut, S. (2002). "Corrosion" Uumann's encydopedia of industrial chemistry, Wiley–VCH. Weinheim, Doi; 10. 1002/14356007. Bol – 08.

Jia-Jun, F., Lis-n, Wana, Y., Cool-H, and Lu-de, L. (2010). Computational and electrochemical studies of some amino acid compounds as corrosion inhibitors for mild steel in hydrochloric acid solution. *J. Mater Sci. 46*, 6255-6265.

Ketsetzi, A., Stathoulopoulon, A., and Demads, K.D. (2008). Being green in chemical water treatment technologies: Issue, Challenges and Developments. *Desalination 223,* 487-493.

Kosari, A., Moayed, M.H., Davoodi, A., Parvizi, R., Momeni, M., Eshgi, H. and Moradi, H. (2014). "Electrochemical and quantumcemcial assessment of two organic compounds from pyridine derivatives as corrosion inhibitors for mild steel in HCl solution under stagnant condition and hydrodynamic flow. *Corros. Sci. 78*, 138-150.

Merrian-webster's online Dictionary: acid.

Nwanna, E.E. (2008). "Antioxidant and hepatoprotective properties of Telfairia occidentalis leaf (Fluted Pumpkin). Thesis and Dissertations (Biochemistry): n. Pag. Web 17. Nov. 2013.
http://dspacefuta.Edu.Ng8080/jspui/handle123456789/587

Okoli, B.E. and Mgbeogu, C.M. (1983). Fluted Pumpkin, Telfairia occidentals. *West African vegetable crop.* School of Biology Science, University of Port-Harcourt 37.2: 145-149. Springed.

Omkar. P. (2012), Mild Steel Properties: www.buzzle.com/articles/mild-steel-properties.html.

Osuwa, J.C. and Okere, C. (2013). Aspilia Africana extracts as organic corrosion inhibitor of mil steel in corrosive acidic media*. J. Env. Sci, Toxi and Food Tech. 4,* 61-65.

Rani, B.E.A; Basu, B.B.J. (2012). Green Inhibitors for Corrosion Protection of Metals and Alloys: *an Overview. Int J. Corros.2*, 1-15.

Satapathy, A.K., Gunasekeran, G., Sahoo, S.C., Anit, K., and Rodrigness, P.V.; (2009). Corrosion inhibition by Justica Genderussa Plant extract in hydrochloric acid solution. *Corros Sic. 51,* 2848-2856.

Shukla, S.K. and Quraishi, M.A. (2009). Ceftriaxone: A novel Corrosion Inhibitor for mild steel in hydrochloric acid. *J. Appl Electrochem.* 39, 1517-1523.

Shukla, S.K., Singh, A.K., Ahamad, I., and Quraishi, M.A. (2009). Streptomycin: A commercially available drug as corrosion inhibitor for mild steel in hydrochloric acid. *Mater let.* 63, 819-822.

Shukla, S.K., Singh, A., and Quraishi, A.T. (2012). Efficient corrosion inhibitors for mild steel in hydrochloric acid solution. *Int J. Eletrochem. Sci*. 7, 3371-3389

Sinko, J. (2001). Challenges of Chromate inhibitor pigments replacement in organic coatings. *Prog. org. coat*. 42, 267-282.

The history of corrosion inhibitors: *www.nubiola./com/p-corrosion-inhibitors-history.asp*

Ugwu, P.U. (2003). Digestive principles and techniques of Statistics. *Rhema Publication*, 23 Neni Street, Ogui-New Layout, Enugu. ISBN: 978-36714-1-3, 231-232.

Umoren, S.A., Obot, I.B. and Obi-Engbedi, N.O. (2009). Raphia hookeri gun as a potential eco-friendly inhibitor for mild steel in Sulphuric acid. *J. Mater Sci*. **44** (1), 274-279.