Investigation into the Effectiveness of 50:50 Ratios of Blended Bitter Leaf Extract and Honey on Corrosion Inhibition of Mild Steel in HCL Medium

SADIQ A. S[1*], TOKAN A[2], OTOGOR P. U[3] and NNAMANI D. N[4]

Department of Mechanical and Production Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria

Abstract: *The paper present experimental report on the effectiveness of 50:50 ratio blended bitter leaf extract (vernoniaamygdalina) and honey on the corrosion inhibition of mild steel in HCL medium using weight lost method. Both bitter leaf extract and honey were separately used as corrosion inhibitors in HCL medium with inhibition efficiencies of 60% and 48.5% at 120 hours in 8ml concentrations of the inhibitors respectively. The inhibitive effect of either bitter leaf extract or honey on the corrosion of mild steel in HCL medium was appreciable; however this present work is an attempt to improve on the inhibition efficiencies of both bitter leaf extract and honey by blending them in the ratio of 50:50. Efficiency of 83.4% was obtained for the same concentration of the inhibitors and time of exposure. This gave improved efficiencies of 28.1% and 41.8% on bitter Leaf extract and on honey respectively. The Inhibitive effect and efficiency were found to increase with increase in the inhibitor concentration while the rate of corrosion decreases. The overall results showed that improved efficiency of organic inhibitors can be achieved when blended together than when used separately*

Keywords*: Corrosion, Corrosion inhibitor, Mild steel, Weight loss, Corrosion rate and Inhibition efficiency.*

I. Introduction

Although there are different materials (metal and non metals) available for engineering applications, ferrous metallic materials, most especially plain carbon steel (i.e. mild steel) account for a large percentage (about 87%) of metals used for diverse applications in constructions and other industrial uses. This is due to fact the materials are readily available and affordable in addition to inherent good mechanical properties suitable for many applications. Where necessary as an added advantage, their mechanical properties can be improved upon easily by convectional heat treatments such as hardening, tempering etc, [1].

Going by [2], when ferrous metals such as. Mild steel is in contact with the environment, it tends to convert to its pre-extraction state. The conversion process is faster and complex if the environment is very aggressive and contains some radicals such as sulphides, nitrides, chloride, etc. Consequently machine components, devices and process equipment made of these materials often deteriorate due to corrosion and ultimately strive to produce hydrated oxide known as rust.

Corrosion of ferrous metals is a continuous and recurring problem that is often difficult to eliminate completely. Prevention or correction methods to some degree tend to be more practical and achievable than complete elimination of the natural phenomenon.

Going by [3], corrosion processes in these ferrous materials develop fast after disruption of the protective barrier and are accompanied by a number of reactions that change the composition and properties of both the metal surface and the local environment thereby leading to formation of oxides, diffusion of metal cations into the coating matrix.

Corrosion is the gradual wearing and destruction of material, especially ferrous metals, by chemical or electrochemical reaction with the environment.

The adverse effects of this reactions are enormous and include reduction in the strenght, stiffiness, ductility, brittleness, toughness, malleability and hardness (i.e. mechanical properties) of the material and in some cases lead to failure and total collapse of struchture which may cause loss of life and inadvertently loss of capital among others, [4]

Traditionally, reduction of corrosion has been managed by various methods including cathodic protection, process control, reduction of the metal impurity content, and application of surface treatment or coating techniques, as well as incorporation of suitable alloys during the production processes. However, the use of corrosion inhibitors has proved to be the easiest and cheapest method for corrosion protection and prevention in acidic media such as HCL or H_2SO_4, [5]

According to [6], these inhibitors slow down the corrosion rate by either adsorption or chemisorption processes and thus prevent monetary losses due to metallic corrosion on industrial vessels, equipment, or surfaces. Organic, inorganic or a mixture of both inhibitors inhibit corrosion by either adsorption or by chemisorptions on the metal surface or reacting in the metal ions and forming a barriers-type precipitate on the surface which prevents corrosive elements from penetrating into the material.

Research reports mentioned in [5] have it that synthetic (inorganic inhibitors) inhibitors that are widely used for corrosion inhibition are toxic and costly and thus geared the recent focus on organic inhibitors most especially those that are sustainable, affordable and environmental friendly.

According to [6], many research works have been conducted by researchers on the use of organic inhibitors on prevention of corrosion of mild steel in different media. With the global awareness on the protection of the environment, most of these researches apply most environmental friendly organic substance to mitigate the rate of corrosion on the ferrous metal in different aqueous solutions as media.

However, going by [7], most of the experiments on use of organic inhibitors duel on acidic medium as corrosion environment. This is due to the fact that HCL or other acid solutions are extensively used for different purposes in various types of industries to clean steels, remove dirt on metal surface, for pickling operation to remove scales on steel surface and for improvement of heat transfer efficiency of equipment. Since corrosion due to acidic attaches in these units represent a significant portion of production cost and lead to loss production and inefficent operations if not mitigated, it becomes imperative to exhibit the corrosion since the usage of the acid solutions on those operations cannot be ignored or changed for economic reasons.

Bitter leaf, botanically called Vernoniaamygdalina is a non-toxic plant grown in many parts of Nigeria and other countries. In Nigeria, bitter leaf is mainly used locally as vegetable for soup because of its medicinal efficacy. In Nigeria bitter laves from one part of the country shows some slight differences in leaves and taste of the liquid extract and thus the possibility of variations in the constituents responsible for corrosion inhibition and others. Bitter leaf is a shrub or small tree that can reach 23 feet in height when fully grown. The herb is an indigenous African plant which grows in most part of sub-Saharan African, [5].

Going by [8] and [9], bitter leaf is a perennial shrub that belongs to the family asteraceae. The plant is known to contain chemical substance such as Saponnin and Tannin which are associated with corrosion inhibition in aqueous and acidic environments.

Honey on the other hand is a dark golden color, viscous and sweet liquid produced in the honey sacs of various bees from the nectar of flowers. It is used as source of sugar and medicine by various communities and most importantly used as a preservative, [5]

According to [10], honey is a natural liquid that result from bees activities on nectar of flowers or parts of plants. It contains a range of nutritiously important complementary elements such as saccharides, organic acids, amino acids, polyphenols, mineral matter, colors, aromatic substances, trace amounts of fat, and some valuable but unstable compounds such as enzymes, substances of hormonal character, some vitamins and a few minor compounds. Honey as part of traditional medicine being effective in gastrointestinal disorders, in healing of wounds and burns, and as an antimicrobial agent.

Interview conducted by [5] showed that honey, similar to bitter has different tastes and possible different constituents base on location grown or found in Nigeria and thus call for more research in that direction.

Both bitter leaf extract and honey had been used separately for corrosion inhibition of mild steel in HCL medium by [5] in Bauchi town, Nigeria, the efficiencies of inhibitions were 60% and 48.5% at 120 hours in 8ml concentrations of the inhibitors respectively. The use of 50:50 ratios of blended bitter leaf extract and honey materials is an attempt to investigate the possibility of improving their efficiencies which constitutes the main objective of the work.

II. MATERIALS AND METHODS

2.1 Materials

The materials, equipment and hand tools used to carry out the work include:

Bitter leaves, Honey, Mild steel (0.16%C), Dilute hydrochloric acid (HCL), Ethanol, Emery paper, Glass breaker, Setra electronic digital weighing balance model BL-410S, Measuring cylinder, hand grinding machine, hack saw and hand files.

2.2 Methods

2.2.1 Preparation of bitter leaf extract

After the collection of needed quantity of bitter leaves from the trees, they were kept in the sun for five days to dry and later pounded to reduce the particle size using mortar and pestle. This is to achieve the particle size suitable for Soxhlet extraction process. The honey was bought from the market. Plates 1, 2 and 3 show the honey, fresh bitter leaves and the pounded bitter leaves respectively.

Plate 1: Honey used for the study

Plate 2: Fresh bitter leaves kept in the sun to dry**.**

Plate 3: Pounded bitter leaves ready for Soxhlet extraction.

2.3 Extraction of the aqueous extract of the bitter leaf

The required pounded bitter leaf was extracted using Soxhlet extraction method for six hours using methanol as solvent. The experimental set up is shown in plate 4 while detail extraction processes are found in [5].

Plate 4: Experimental set up for Soxhlet extraction of Bitter leaf liquid

Plate 5: 50:50 blended bitter leaf extract and honey arranged for experiments

2.4 Production of mild steel coupons

A rectangular mild steel of carbon content (0.16%C) was sourced from the town. It was grinded using hand grinding machine to remove the debris and previous protection coatings on the surface and polished with emery paper. Twenty six (26) pieces were later cut into dimension of 44.55mm x 20mm x 1.5mm each using hack saw. Extra effort was intensified to ensure that each weight of the coupon comes out to be 10.51 grams. Plate6 shows a sample of the mild steel coupons.

Plate 6: Samples of some of the mild steel coupons before inhibition.

Experiments

100ml of 0.5M HCl was poured into five 250ml beakers. This volume was kept constant for all beakers. Different volumes of 0ml, 2ml, 4ml, 6ml and 8ml mixtures of the inhibitor (bitter leaf extract and honey blended in the ratio of 50:50) were poured into the diluted acid in the beakers respectively. Each of the mild steel plate coupons were put in the content of the beakers. The first coupon was removed from the corrodant (HCL) after 24hours. This was followed by the second, third, fourth and fifth at intervals of 48, 72, 96 and 120 hours immersion time respectively. Each coupon removed from the corrodant was immediately brushed, cleaned and rinsed in 34.4% ethanol to remove the corrosion product on the surface. Their weights were measured after it had dried and tabulated as shown in table 1. The weight loss (difference between the initial weight, w_o and final weight, w_1) were calculated and tabulated as shown in table 2.

Plate 7: Sample of some the coupons after Inhibition

Experimental Calculations

(i). Corrosion Rate

The corrosion penetration rate (CPR) in millimeters per year (mm/year) was calculated from weight loss of the coupons at room temperature (33^{o}C) at various concentrations and immersion time using equation in [13].

Thus, CPR = $\frac{87.6W}{\rho AT}$ ……(i)

Where,

W= weight loss in grams (g) after exposure in corrosive medium

ρ = density of the material in grams per centimeter cube. (g/cm^3).

Density of mild steel = 7. 86g/ cm^3.

A = surface area in square centimeters (cm^2) of the coupon. A = 8.91cm^2

T = time of exposure in hours

,(ii). Weight loss

The weight loss after exposure in corrosive medium is simply, $w_o - w_1$ ……(ii)
Where,
w_o = initial weight of workpiece before corrosion
w_1 = final weight of workpiece after corrosion
(iii). Inhibition Efficiency (IE)
The efficiency (IE) of the inhibitor (mixture of bitter leaf extract and honey) was calculated from weight loss measured at different inhibitor concentrations. The inhibitor efficiency (IE) was calculated using equation from [13]

$$IE = \frac{CR_{UN} - CR_{IN}}{CR_{UN}} \times 100 \quad .....(iii)$$

Where,
CR_{UN} = corrosion rate of uninhibited solution
CR_{IN} = corrosion rate of inhibited solution

The results of all the calculations and the supporting information are found in tables 1, 2. 3 and 4 respectively and also figures 5, 6 and 7 respectively at the results and discussion section of the paper.

III. Results and Discussion

3.1 Results

Table 1: Weights (g) of coupons before and after immersion in 50:50 blended inhibitors for indicated hours and concentrations

Inhibitor Concentration (ml)	Initial weight (g)	After 24 hours	After 48 hours	After 72 hours	After 96 hours	After 120 hours
0	10.51	10.255	10.198	10.054	9.978	9.873
2	10.51	10.359	10.312	10.305	10.300	10.281
4	10.51	10.384	10.379	10.333	10.326	10.296
6	10.51	10.425	10.427	10.402	10.389	10.385
8	10.51	10.445	10.443	10.428	10.419	10.405

Table 2: Weight (g) loss in indicated hours and concentrations

Concentration (ml)	After 24 hours	After 48 hours	After 72 hours	After 96 hours	After 120 hours
0	0.255	0.312	0.456	0.532	0.637
2	0.151	0.198	0.205	0.210	0.229
4	0.126	0.131	0.177	0.184	0.214
6	0.085	0.083	0.108	0.121	0.125
8	0.065	0.067	0.082	0.091	0.105

Table 3: Corrosion rate in indicated hours and concentrations

Concentration (ml)	After 24 hours	After 48 hours	After 72 hours	After 96 hours	After 120 hours
0	0.0133	0.00813	0.00792	0.00693	0.00664
2	0.00787	0.00516	0.00356	0.00274	0.00239
4	0.00657	0.00341	0.00308	0.00240	0.00223
6	0.00443	0.00216	0.00188	0.00158	0.00130
8	0.00339	0.00175	0.00142	0.00119	0.00110

Table 4: Inhibition efficiency (%) in indicated hours and concentrations

Concentration (ml)	After 24 hours	After 48 hours	After 72 hours	After 96 hours	After 120 hours
0	0	0	0	0	0
2	40.8	36.5	55.1	60.5	64.0
4	50.6	58.1	61.1	65.4	66.4
6	66.7	73.4	76.3	77.2	80.4
8	74.5	78.5	82.1	82.8	83.4

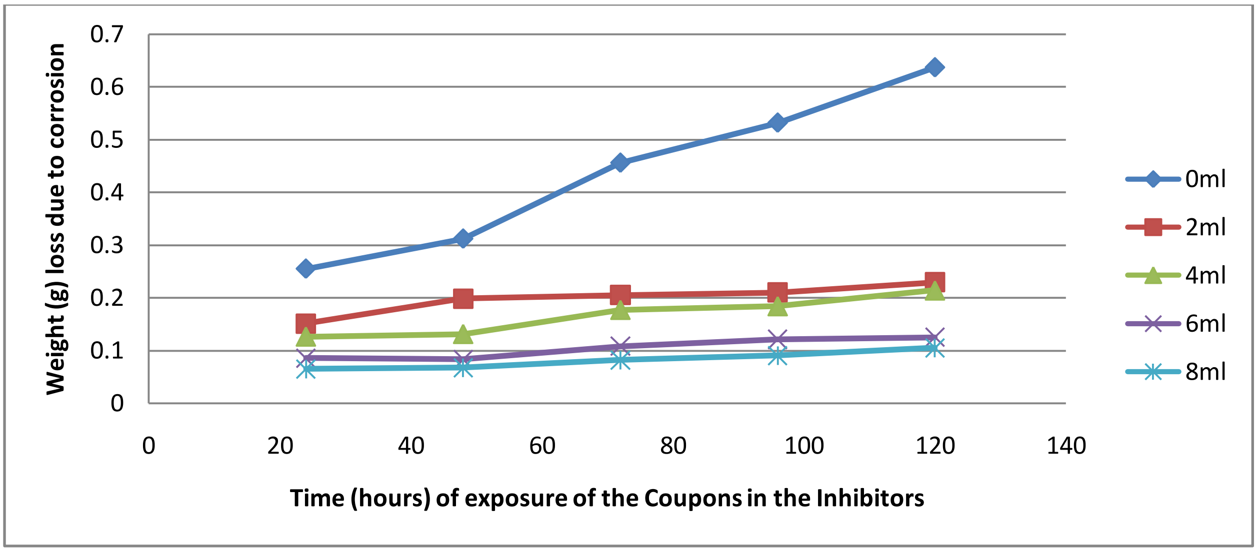

Figure 1: Graph of weight loss (g) against time (hours) of coupons exposure in the inhibitors

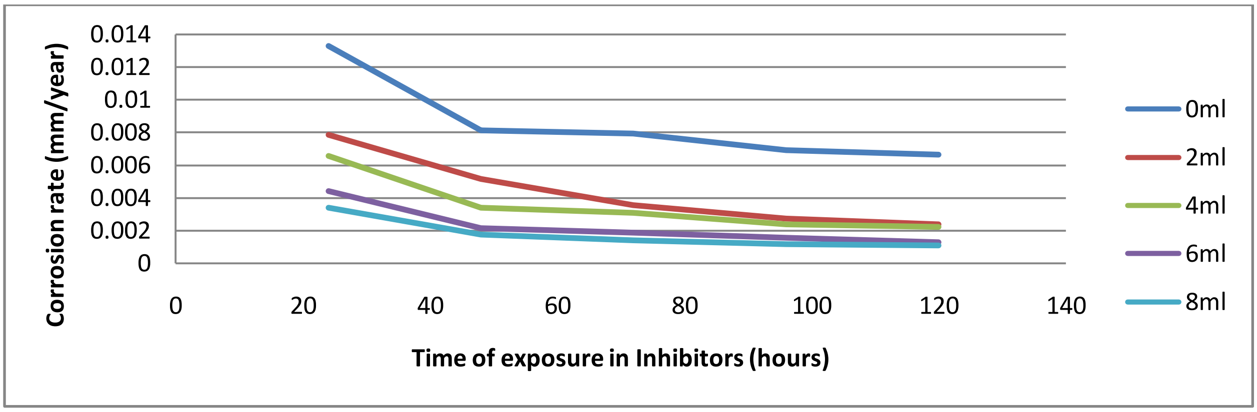

Figure 2: Graph of corrosion rate (mm/year) against time (hours) of coupons exposure in the inhibitors

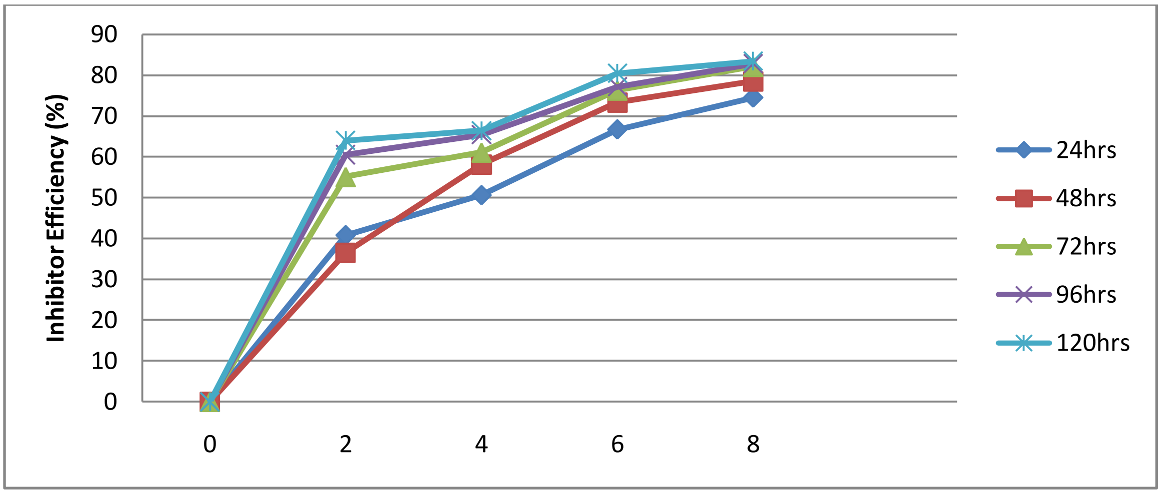

Figure 3: Graph of Inhibitor efficiency (%) against concentration of inhibitors

3.2 Discussion of results

Corrosion of ferrous metals in acid solutions can be inhibited by a wide range of methods and substances. This research work was centered on investigating the effectiveness of 50:50 ratio of blended bitter leaf extract and honey for corrosion inhibitor for hypoeutectoid steel in HCL solution. The results of the work are shown in tables 1, 2, 3 and 4 respectively and also in figures 1, 2 and 3 respectively.

Visual observation of the mild steel coupons in the corrosive mdium with and without inhibitor after indicated hours of exposure revealed changes in colour of the coupons from intial bright sliver surface to dull ones. Scales and cracks were also observed which indicated corrosion attack on the coupons by the corrosive medium. However, the Scales and cracks were more conspicuous on the coupons in the solution without inhibitor and reduce as the inhibitor concentration increases. This simply mean that as the concentration of the inhibitors are increased, the corrosion rates decreased and vice-versa. This fact is proved by the results in tables 1 and 2 which generally show that the more the concentration of inhibitor, the lesser the corrosion and of course the weight loss.

As shown in the tables, the weights of the coupons decreased with increase in the time of the exposure. The weight decrease was much more in the corrosive medium without inhibitor. Also, as the concentrations of the inhibitors increased, the rate at which the weights decrease became much slower. Figures 1 and 2 portrayed the trends of the decrease in weight loss with increase in the concentrations of the inhibitor and increase in the time of the exposure.

The results obtained on corrosion rate and inhibition efficiency are shown in table 3 and 4. Table 3 showed that the corrosion rate decreases with increase in the concentration of the inhibitor while table 4 showed increase in inhibition efficiency as the inhibitor concentration increases. The general trend of the corrosion rate decrease with increase in the inhibitor concentration and of course the inhibition efficiency is portrayed in figure 3.

The primary step in the action of inhibitors in acid solutions is generally adsorption onto the metal surface, which is usually oxide-free in acid solutions. The adsorbed inhibitor then acts to retard the penetration and absorption of the elements or substances responsible for the chemical corrosion processes. The production of the adsorbed chemicals as seen in this work is faster and more when the concentration of the inhibitor and time of the exposure are increased respectively.

According to [13], the adsorbed inhibitor shielded the corroded surface from further corrosion attack thereby depressing the rate of coorrosion.

Going by this work the adsorbed moleculs of the inhibitor on the metal surface contains tannin from bitter leave and oil film from honey which both acts as a physical barrier to restrict the diffusion of ions to and from the metal and prevent its atoms from participating in futher reactions and thus decrease the corrosion rate in the medium.

In the case of the inhibitor efficiency, it was observed that corrosive medium without inhibitor had zero corrosion efficiency while the highest corrosion efficiency of 83.4% was recorded from the inhibitor with highest concentration of 8ml and exposure time of 120 hours. This simply implies that the efficiency of inhibitors increase with increase in the concentration of the inhibitors. These trends of variations of the inhibitor corrosion rates and efficiencies with respect to concentrations and periods of interactions with corrosive environment are illustrated in figures 2 and 3 respectively.

Conclusions

The following conclusions are made sequel to the results obtained from the work:

(i). The 50:50 ratios of blended bitter Leaf extract and honey decreased the corrosion rate of mild steel in HCL medium with efficiency of 83.4% .

(ii) The corrosion rate decrease with increase in the concentration of the inhibitor and increase in the time of interaction in the corrosive medium.

(iii) The 50:50 ratios of blended bitter Leaf extract and honey gave improved efficiencies of 28.1% and 41.8% on bitter Leaf extract and on honey respectively used separately. This implies that blended organic inhibitors have potential of better inhibition efficiency than when used separately.

References

[1.] Kakani, S. L. and Amit Kakani (2004). Material science, new age international publisher, New Delhi, India

[2.] Idenyi, N.E., and Nzife, S.I. (2005). Study of industrial construction steels and corrosion environment. Jonarnal of corrosion science and Technology, NICA, Nigeria, vol. 1, pp 9.

[3.] Rani, B.E.A.; Basu, B.B.J. (2012). Green inhibitors for corrosion protection of metals and alloys: An overview. *International ournal of corrosion. Vol*. 2, Pp 1–15.

[4.] Sadiq, A. S., Ayoola, O. D. and Aliyu B. (2015). Investigation into the effectiveness of neem leaf extract as corrosion inhibitor for hypoeutectoid steel in Hcl solution. Journal of engineering and technology (JET). Vol. 10 No.1. www.bayerojet.com. pp 27 -34

[5.] Otogor P. U and Nnamani D.N (2019). Investigating the effect of Bauchi town bitter leaf extract and honey on corrosion of mild steel in corrosive environment, unpublished report, ATBU, Bauchi.

[6.] Singh, A., Ebenso, E.E and Quraishi, M.A. (2012). Corrosion inhibition of Carbon Steel in Hydrochloric Acid Solution by Some Plant Extract. International Journal of Corrosion, vol.2012, pp.1-20.

[7.] Ayoola O. D. (2012), investigation of neem leaf extract as corrosion inhibitor for mild steel in HCL solution, unpublished report, ATBU, Bauchi.

[8.] Loto, C. A. (2003). The effect of Vernoniaamygdalina (Bitter leaf) solution extract on the corrosion inhibition of mild steel in 0.5 M hydrochloric and tetraoxosulphate (VI) acids. *Corrosion Prevention & Control Journal*, Vol. 50, 43 – 49

[9.] Al-Sehaibani, H. (2000). "Evaluation of extracts of Henna leaves as environmentally friendly corrosion inhibitors for metals, *Material wissenschaft und Werkstofftechnik*, vol. 31, no. 12, pp 1060–1063

[10.] El-Etre, A. Y. (1998).Natural honey as corrosion inhibitor for metals and alloys. Journal of *Corrosion Science*, Vol. 40, PP 1845–1850.

[11.] Eddy, N.O.; Ebenso, E.E. Adsorption and inhibitive properties of ethanol extracts of Sapientum peels as a green corrosion inhibitor for mild steel in H_2SO_4. African Journal of Pure and Applied Chemistry. Vol. 2, Pp 46–54.

[12.] Okafor, P.C. and Ebenso, E.E. (2007), "Inhibitive action of Carica papaya extracts on the corrosion of mild steel in acidic media and their adsorption characteristics," *Pigment and Resin Technology*, vol. 36, no. 3, pp 134–140.

[13.] Fontana M. G. (1994) "*Corrosion Engineering*," 3rd Edition, Mc- Graw-Hill Book Company, Boston.

[14.] Kuznetsov. Y.I. (2004). Chemical Reviews, Russia Academy of Science and Turpion Ltd, vol.73 pp 75.