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# CORROSION INHIBITION OF AISI 1007 STEEL IN HYDROCHLORIC ACID USING *CUCUMIS SATIVUS* (CUCUMBER) EXTRACTS AS GREEN INHIBITOR

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**Abstract:** The inhibiting effect of cucumber peel and seed extracts on corrosion of AISI 1007 steel in 2M solution of Hydrogen Chloride (HCl) at ambient temperature was studied using gravimetric and electrochemical measurements (TAFEL polarization). It was observed that corrosion rates reduced with increase in the extracts' concentration, and inhibition efficiency (IE%) increased with the concentration. The study revealed that the cucumber extracts possessed good inhibiting efficiency. Though, the cucumber peel extract's efficiency was greater than that of the seed (oil) extract during gravimetric measurement. The highest inhibition efficiency (IE) of 86.63% was achieved using the cucumber peel extract as inhibitor with 1.0 g/l concentration, while cucumber seed (oil) extract recorded 39.23%. The electrochemical measurements (TAFEL polarization) results revealed that the corrosion current density decreased with the increased in the concentration of the cucumber peel extract. The decreased in corrosion was due to increased blocking of the metal surface by adsorption of the leaf extract. Therefore, the extracts could be used as a green inhibitor to the corrosion of AISI 1007 steel in the hydrochloric acid medium as a replacement for toxic inhibitors.
**Keywords:** Tafel Polarization, Gravimetric, Current Density, Metal Surface Adsorption, Inhibiting Efficiency

## INTRODUCTION

For safety, environmental and economic purposes, corrosion has been identified as a major problem to be confronted (Umoren, *et al*., 2016; Prithiba & Rajalakshmi, 2016; Sharma, *et al*., 2009; Gupta & Jain, 2014; Thompson *et al*., 2007; Gunavathy, 2013; Satris, 2011). Most organic compounds used as corrosion inhibitors are found to be biodegradable, expensive and toxic (Gunavathy, 2013; El Ibrahim *et al*., 2017; Adeyemi & Olubomehin, 2017; Sharkma, *et al*., 2011). These organic compounds are not only expensive but also harmful to the environment. As a result of these, the development of cost effective and non-toxic corrosion inhibitors came into existence. According to Omotosho *et al*., 2011), "green inhibitors are known to be cheaply available, easily applicable and disposable without contaminating the environment". The concern of the toxicity and biodegradability of corrosion inhibitors discharged into the environment is increasing. Environmental problems should be of primary concern due to the importance of protecting marine life and the preservation of the ecosystem (El Ibrahim *et al*., 2017; Neha *et al*., 2013).

Plant products and some other sources of organic compounds are rich sources of environmentally acceptable corrosion inhibitors. Plant products are the main sources of environmentally friendly green inhibitors such as phthalocyanines (Satris, 2011). The yield of these natural products as well as the corrosion inhibition abilities of the plant extracts vary widely depending on the part of the plant and its location (Okafor, *et al*., 2008). Extract of different parts of plant like root, seeds, leaves, stem, flower and fruits can be used as inhibitor to reduce the corrosion rate of various ferrous and non-ferrous Salhi, et al., 2017; Neha et al., 2013; Gunasekaran & Chauhan, 2004; Uwah *et al*., 2013; Dharmaraj *et al*., 2017; Allam *et al*., 2017).

The basic components of the extracts are sugars, steroids, aloin, gallic acid, ellagic acid, tannic acid, flavanoids, etc. The presence of tannins, cellulose, and polycyclic compounds has been reported to enhance a film formation over the metal surface, thus decreasing corrosion (Mohamed *et al*., 2015; Chris *et al*., 2016; Arockia *et al*., 2018; Abd El-Aziz, *et al*., 2016). However, the constituent that provides inhibitive action, the mechanism of inhibition and the best condition for inhibition are still unclear.

Cucumber peels are rough and difficult to chew and digest as a result of the ignorance of the benefits the peel has to offer (Anne, 2018). Then this peels are been disposed indiscriminately which leads to environmental pollution. In addition, plant products are organic in nature, and contain certain photochemical including tannins, flavonoids, saponins, organic and amino acids, alkaloids, and pigments which could be extracted by simple less expensive procedures. Extracts from different parts of plant have been widely reported as effective and good metal corrosion inhibitors in various corrosive environments (Ji *et al*., 2012; Umoren *et al*., 2013).

Low carbon steels, such as AISI 1007, are most widely used both in construction and structural applications, pressure vessels, marine and offshore equipment, and military applications, because they are cheap, strong, stiff, and possess good mechanical properties (Charmers, 1988; Chakravarthy & Mohana, 2014). The steel grade, elements and parameters are also important in how it is being used (Kennedy, 2017). Steels are also used as structural materials where they are exposed to outdoor conditions especially in acidic media (Fekry & Mohamed, 2010). One of the common problems being experienced by the materials in this environment is corrosion (Abdul Amir, *et al*., 20 10; Chinwko *et al*., 2014).

Corrosion inhibition of *Cucumis sativus* peel extract (*CSP*) on carbon steel in 1M HCl solution was investigated by potentiodynamic polarization, and electrochemical impedance spectroscopy (EIS) techniques. The inhibition efficiency from potentiodynamic polarization and impedance measurements was agreement where the maximum inhibition was around 82%. The inhibition efficiency decreased as the temperature increased. The results obtained showed that *CSP* extract inhibited the corrosion process by a physical adsorption mechanism that followed the Langmuir adsorption isotherm models. The adsorption thermodynamic parameters that were calculated include, free energy of adsorption (*ΔG°ads*), activation energy (*Ea*), enthalpy of adsorption (*ΔH°ads*), and entropy of adsorption (*ΔS°ads*) revealed that the adsorption process are spontaneous and endothermic. All the results show that the *CSP* extract can act as an inhibitor against the corrosion of carbon steel in the HCl medium (Al-Senani, 2016).

In an attempt to extend the investigation to other Cucumber extracts, which most of them (peel in particular) are regarded as waste product, especially in Nigeria, the present research reports on the suitability assessment of cucumber peel and seed oil as green inhibitor for AISI 1007 steel corrosion in HCl using gravimetric and Electrochemical Measurement (TAFEL Polarization).

## MATERIALS AND METHODS

### — Materials

Sample of the metal sheet used for this study was obtained in a local steel market in Surulere Area of Ilorin, Nigeria. The elemental composition (wt.%) of AISI 1007 steel sample include: C = 0.033; Si = 0.034;Mn= 0.220; Cr=0.038; Al=0.011; Cu=0.021, Ni=0.007; P = 0.015;S = 0.008; and Fe = 99.50. This was obtained using Spectromaxx LMF06 Spectrometer (Serial Number: 15007384). The results show that the carbon steel falls under AISI 1007 steel from AISI-SAE standard of carbon steel.

### — Steel Samples (Coupon) Preparation

To produce the specimens (coupons) for gravimetric measurements, the steel sheet was cut into 2.2 cm x 1.7 cm x 0.15 cm using guillotine machine. The coupons were drilled at the top center with drill bit (1.0mm diameter) for ease hanging, identification and easy withdrawal of the specimens from medium of exposure. The specimens were abraded with 220, 320, 400, 600, 800, 1000 grade of emery papers for removal of debris on the metal surfaces and to obtain uniformity on the surfaces of the coupons, then degreased with acetone, washed with double distilled water and dried in air in accordance with the ASTM guidelines for specimen preparation (ASTM, 2017) and immediately stored in desiccators.

### — Electrolytic Solution

The corrosive solution of Hydrochloric Acid (HCl, sp. gr. 1.18) was prepared in the Corrosion Laboratory, Department of Materials and Metallurgical Engineering, University of Ilorin, Ilorin, Nigeria to obtain 2 Molarity of HCl.

### — Preparation of Inhibitors

#### » Cucumber peel

The cucumber peel (Plate 1a) was recovered from fruit vendor waste bin and was thoroughly washed and cut into smaller size. The peel was air dried at room temperature and pulverized into desired microns as shown in Plate 1b.

(a) Cucumber peel

(b) Pulverized cucumber peel

Plate 1: Cucumber Peel Extract (a) Cucumber peel (b) Pulverized cucumber peel

#### » Cucumber seed extract

Cucumber plants (*cucumis* sativis) were obtained from a commercial fruit vendor in Ilorin (Nigeria), thoroughly washed and cut for proper view of the plants' seeds. The seeds were carefully removed and air dried at room temperature and subsequently pulverized. The pulverized seed was degreased in ethanol, and left open for about 48 hours at room temperature for evaporation of the ethanol for the production of oil. The production of the oil was carried out in a laboratory at the Department of Chemistry, University of Ilorin, Ilorin, Nigeria. Sample of the oil extracted from cucumber seed is shown in Plate 2.

Plate 2: Oil extracted from cucumber seed

### — Gravimetric measurements

The gravimetric measurements method of corrosion tests were carried out using ASTM standard guidelines (ASTM, 2017; ASTM NACE 2012). The pre-treated specimens from the desiccators were weighed with an electronic weighing balance (HX 302T with 0.01 g accuracy) to determine the initial weight of the specimens ($M_1$) and completely immersed in different containers, each containing 750 ml of

2M Hydrochloric Acid with or without cucumber extract (peel or seed oil) as shown in Plate 3. The concentrations of the cucumber extracts (peel and seed oil) used varied from 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 g/l. The test specimens were exposed to the medium between 24 hours and 672 hours.

Plate 3: Gravimetric measurements Set-up

Sequel to removal of the specimens from the medium of exposure, the corrosion products formed on the surfaces and edges of the specimens were removed using chemical method of cleaning. This procedure involved the cleaning of the specimens in the prepared solution and air dried in accordance with the ASTM standard guidelines (ASTM, 2017; ASTM NACE 2012 ASTM 2014). The solution containing 200 g of Sodium hydroxide (NaOH), 20 g of granulated zinc and reagent water which makes it 1000 ml solution as recommended by ASTM (2017). The dried specimen was then reweighed using electronic weighing balance (HX 302T with 0.01g accuracy) to determine the difference in weight (weight loss). The cleaned specimens are shown in Plate 4. This procedure was repeated for all specimens exposed to the medium of exposure between 24 hours and 672 hours.

Plate 4: Cleaned specimen after corrosion test

From the weight loss, the Corrosion rate and inhibiting efficiency (IE %) of the plant extracts were calculated using Equation 1 and 2 respectively.

$$\text{Corrosion rate } (gcm^{-2}h^{-1}) = \frac{\Delta W}{AT} \quad \text{(Adewuyi \& Talabi, 2017) (1)}$$

where: W = Weight loss (g); A = Surface area of the AISI 1007 steel coupon ($cm^2$);

T = Time of exposure (hours)

The percentage inhibiting efficiency:

$$(IE\ \%) = \frac{CR_{Blank} - CR_{inh}}{CR_{Blank}} X100 \quad \text{(Adewuyi \& Talabi, 2017) (2)}$$

where: $CR_{Black}$ = Corrosion rate in the absence of inhibitor;

$CR_{inh}$ = Corrosion in the presence of inhibitor

— Electrochemical Measurement (TAFEL Polarization Technique)

A flexible cable was connected to the specimen with the use aluminum foil which held it together, and it was placed on a cup mould. Hardener was added to a polyester resin and mixed thoroughly in another cup mould, and then an accelerator was added to it in which they were all mixed together. The prepared solution was poured in the mould where the specimens were placed. It was then left for about 15-20 minutes to solidify. The coupon was further polished for surface exposure into the aggressive environments.

A single compartment electrochemical cell designed for varieties of flat samples for electrochemical test at room temperature was used to perform the electrochemical measurements. It consists of a three electrode systems; working electrode (AISI 1007 Steel), saturated calomel electrode as the reference electrode and graphite rod as the auxiliary/counter electrode. Potentiostat (VersaSTAT) was used as electrochemical work station. For connection of the specimen to the working cable, it has to be connected through a cable. Electrochem softwares were used for data analysis. This test was carried out at the Corrosion Laboratory of the Federal University of Technology, Akure. Plate 5 and 6 respectively shows the electrochemical measurement (TAFEL polarization) set up and some samples of the coupons after the test.

Plate 5: Electrochemical Measurement (TAFEL Polarization set-up)

Plate 6: Coupons after TAFEL Polarization test

## RESULTS AND DISCUSSION

### — Phytochemical Properties of Cucumber Extracts

The results of phytochemical constituents of cucumber peel and cucumber seed are presented in Table 1 and 2 respectively. The phytochemical properties of cucumber extracts (peel and seed) were determined to check for the presence of inhibitive functional groups.

Table 1: Phytochemical analysis of cucumber peel extract

| Parameters (mg/100g) | Cucumber Peel | Parameter (mg/100g) | Cucumber Peel |
|---|---|---|---|
| Alkaloids | 0.89 (+) | Saponins | 0.06 (+) |
| Flavonoids | 2.72 (+) | Terpinodols | 0.07 (+) |
| Tannins | 0.15 (+) | Phenols | 0.20 (+) |
| Cardiac glycoside | 0.08 (+) | Phoxatanninu | 0.14 (+) |
| Steroids | 1.32 (+) | | |

Table 2: Phytochemical analysis of cucumber seed

| Parameters (mg/100g) | Cucumber Seed oil | Parameter (mg/100g) | Cucumber Seed oil |
|---|---|---|---|
| Alkaloids | 1.32 (+) | Saponins | 0.09 (+) |
| Flavonoids | 2.86 (+) | Terpinodols | 0.13 (+) |
| Tannins | 1.16 (+) | Phenols | 0.28 (+) |
| Cardiac glycoside | 0.09 (+) | Phoxatanninu | 0.18 (+) |
| Steroids | 1.38 (+) | | |

In the results (Tables 1 and 2), it is shown that out of all constituents present in the extracts, the flavonoid has the higher proportion, followed by the Steroids. It can be suggested that flavonoid which has the highest constituents might be the most active ingredient in inhibiting the efficiency corrosion (Umoren, *et al.*, 2016; Odewumi *et al.*, 2015; Al-Otaibi *et al.*, 2014).

— Gravimetric Measurement

» Cucumber Peel Extract

The weight loss results, the variation of corrosion rate and inhibition efficiency in AISI 1007 steel at different concentrations of cucumber peel extract in 2M HCl at different time of immersion are represented in the Figures 1 to 3.

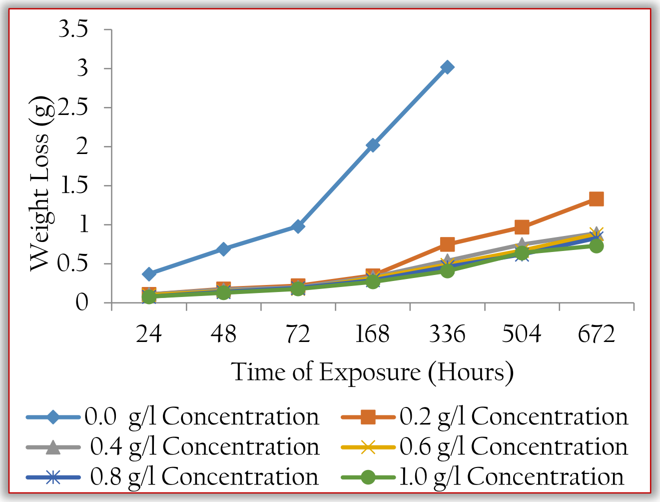


Figure 1: Variation of weight loss with time for the corrosion of AISI 1007 Steel in 2M HCl with and without inhibitor (peel extract)

Figure 1 clearly shows increased in the specimens' weight loss with increased in time of exposure. The figure also revealed reduction in the weight loss of the specimens in the presence of inhibitors; but decreased with increased in the concentration of the inhibitors (peel). The reduction in weight loss may be as a result of adsorption of the inhibitor on the metal surface (Karthikaiselvi & Subhashini, 2014; Lai *et al.*, 2017; Andreani *et al.*, 2016). This indicates good inhibiting potential of cucumber extracts at all concentrations. After 672 hours of exposure, 0.2, 0.4, 0.6, 0.8 and 1.0 g/l concentration of peel recorded weight loss of 1.33, 0.88, 0.88, 0.83, and 0.73 g respectively. This is an indication of significant inhibitory properties of passive film formed on the surface and edges of the steel specimens. The passivity could be traced to synergistic concentrations of phytochemical constituents of the extract, which is in line with the observation of Loto *et al.* (2017) that the weight loss of mild steel in $H_2SO_4$ decreased with increase in concentration of inhibitor (*Benzamide*).

Figure 2 shows the variation of corrosion rates within the time of exposure. The results indicate that the corrosion rate of the specimens with plant extract (peel) decreased with concentration of the extract within the period of exposure. This is in line with the findings of Guinavathy *et al.* (2013), Chinweuba (2014) and Ahmed *et al.*(2014) that corrosion rate of mild steel decreased with increase in inhibitors' concentration.

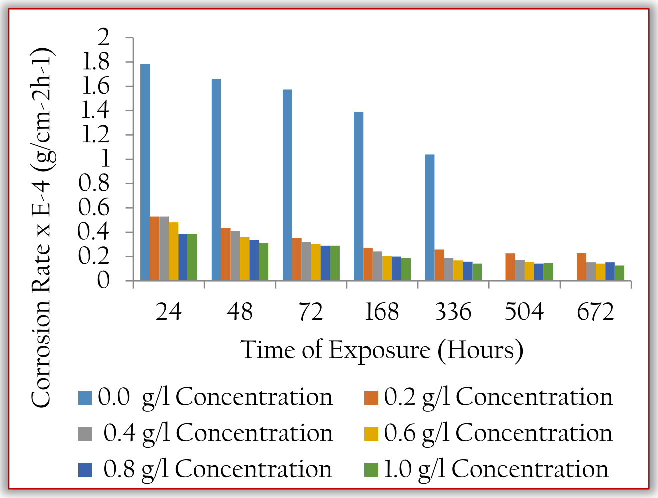


Figure 2: The variation of Corrosion rate in cucumber peel extracts

After 672 hours of exposure in 2M HCl, the calculated corrosion rates were 2.288 x $10^{-4}$, 1.531 x $10^{-4}$, 1.514 x $10^{-4}$, 1.428 x $10^{-4}$ and 1.256 x $10^{-4}$ g/cm$^{-2}$h$^{-1}$ with concentration of the cucumber peel extract of 0.2, 0.4, 0.6, 0.8 and 1.0 g/l respectively. As a result of this, it could be deduced that there was an increase in adsorption of the constituents of the extract on the surface of the AISI 1007 steel (specimen) that led to the loss of corrosion rate (Okoronkwo, 2015; Nnanna & Owate, 2014).

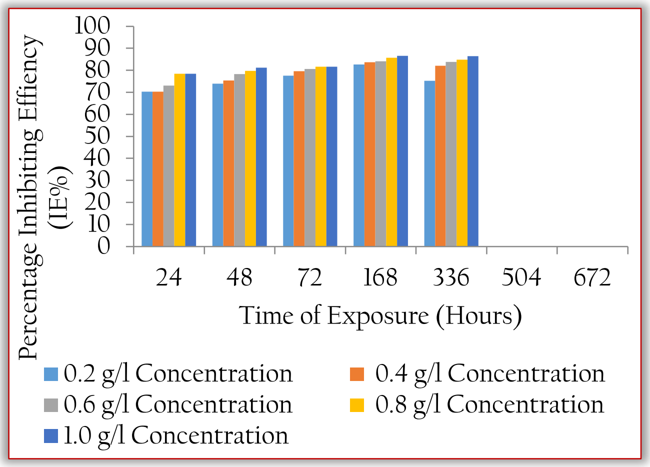


Figure 3: The value of Percentage Inhibition Efficiency for concentration of cucumber peel extracts

The steadiness of the inhibitive behaviour of the extract was evaluated by trend of the inhibition efficiency as a function of time. Figure 3 shows the values of percentage inhibition efficiency (I.E%) for each concentration of cucumber peel extract. The results show that the calculated IE% range between 70.28 and 86.63% with the presence of cucumber peel as an inhibitor in HCl medium during the time of exposure. The highest IE (86.63%) was achieved using 1.0 g/l cucumber peel after 168 hours of immersion. Although a close value of 86.42% was also achieved after 336 hours of immersion with 1.0 g/l peel. The least IE value (70.28%) was attained with 0.2 and 0.4 g/l after 24 hours of immersion in the media. It indicates that the Inhibition Efficiency (I.E%) increased with increase in inhibitor's concentration. For instance, after 336 hours of exposure in in 2M HCl, the calculated IE% using 0.2, 0.4, 0.6, 0.8 and 1.0 g/l inhibitor (peel) were 75.16, 82.11, 83.77, 84.76 and 86.42% respectively. Also, after 24 hours, the IE% were 70.28, 70.28, 72.98, 78.38 and 78.38% with 0.2, 0.4, 0.6, 0.8 and 1.0 g/l inhibitor (peel). This is might be a result of formation of a protective film which results to transition of metal interface from an active dissolution state to a passive state.

The IE% of the specimens immersed for periods beyond 336 hours could not be determined since the specimens in the medium of exposure without inhibitor could not survive beyond the period due to the aggressiveness of the environment as shown in Plate 7.

Plate 7: AISI 1007 steel that could not withstand beyond 336 hours

» Cucumber Seed oil Extract

The results for the weight loss, the variation of corrosion rate and Inhibition efficiency in AISI 1007 steel at different concentrations of Cucumber Seed oil extract in 2M HCl at different time of immersion are graphically presented in Figure 4, 5 and 6 respectively.

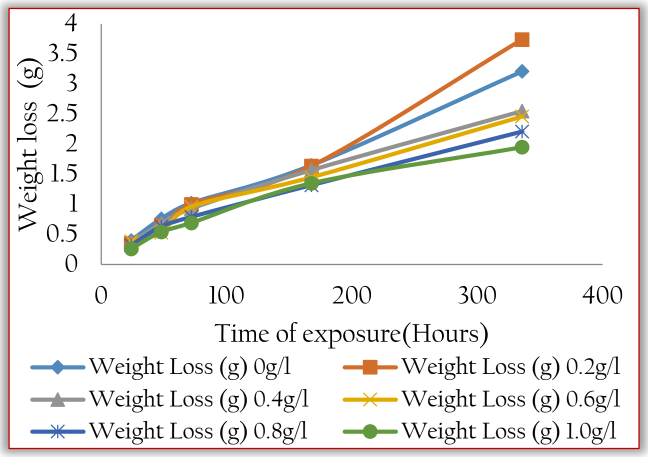


Figure 4: Variation of weight loss with time for the corrosion of AISI 1007 Steel in 2M HCl

The variation of weight loss against time of exposure for corrosion of AISI 1007 Steel in 2M HCl containing various concentration of cucumber seed oil is shown in Figure 4. It is found from Figure 4 that the weight loss of the AISI 1007 steel specimens also increased with time of exposure; but decreased as the concentration of inhibitor increased. It could be deduced that the rate of corrosion of AISI 1007 steel increased within the period of exposure, and decreased as the concentration of the extract increased. The reduction in weight loss might be as a result of adsorption of the inhibitor on the metal surface. The weight loss of steel decreases as the concentration of the inhibitor increases (Salami, *et al*., 2012). With the 0.2 g/l of cucumber oil (inhibitor), weight loss of 3.74 g after 336 hours of exposure was recorded, while at the same time 0.4 g/l cucumber oil recorded 2.55 g, 0.6 g/l cucumber oil recorded 2.46g, 0.8g/l cucumber oil recorded 2.21 g and 1.0 g/l cucumber oil recorded 1.95 g weight loss as shown in Figure 4. The reduction in the specimens' weight loss revealed stable coverage of the passive layers formed by the inhibitor on the steel surfaces, which prevent further attack of the medium on the steel surface. This is in line with the findings of Aji *et al.*(2016) that at higher concentration of inhibitors, weight loss becomes almost constant. The specimens could also not withstand the corrosion beyond 336 hours due to the aggressiveness of the environment as revealed in Figure 5 and shown in Plate 7.

Figure 5 shows the variation of corrosion rate within the time of exposure. It is shown that the samples' corrosion rates in the medium of exposure with cucumber extract are lower than that of specimens (samples) in the same medium without inhibitor throughout the periods of this study. Continous formation of protective passive film on the surfaces of the steel samples serves as a strong barrier for the acid to penetrate onto the steel surfaces. This inhibited the corrosion of the steel ion the study medium of exposure (HCl). More so, the calculated corrosion rates of AISI 1007 Steel in HCl with or without the plant extract generally decreased with time of exposure.

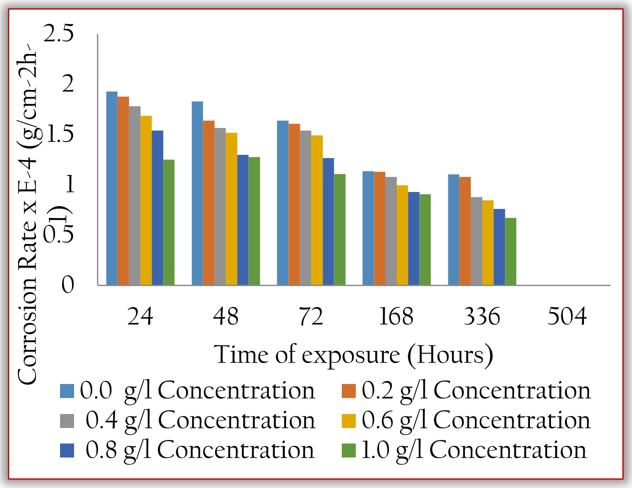


Figure 5: The variation of corrosion rate against the time of exposure

The corrosion rate values also decreased with the concentration of cucumber seed oil extract. For instance after 336 hours of immersion, the calculated corrosion rate values of AISI 1007 steel samples in 2M HCl were respectively 1.104, 1.0804, 0.8774, 0.8464, 0.7604, 0.6709 x $10^{-4}$ $g/cm^{-2}h^{-1}$ in the medium with 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 g/l concentration of cucumber seed oil extract. This implies that decreased in corrosion rate of the samples with the concentration of cucumber seed oil extract in the medium of exposure is an indication that there was increased in adsorption of the constituents of the extract on the surface of the AISI 1007 steel that led to the loss of corrosion rate (Okoronkwo, *et al.*, 2015; Nnanna & Owate, 2014; Ghames *et al.*, 2017; Verma *et al.*, 2017; Arthur *et al.*, 2013). Inhibiting potential of the extracts might be as result of the presence of organic compounds, like steroids, amino acids, alkaloids, flavonoids, tannins, cardiac glycoside, phenols, saponins, terpinodols, and phoxatanninu, etc. This has been asserted in previous studies (Satris, 2011; Mohamed *et al.*, 2015; Chris & Emeka, 2016; Salami *et al.*, 2015; Okewale & Olaitan, 2017).

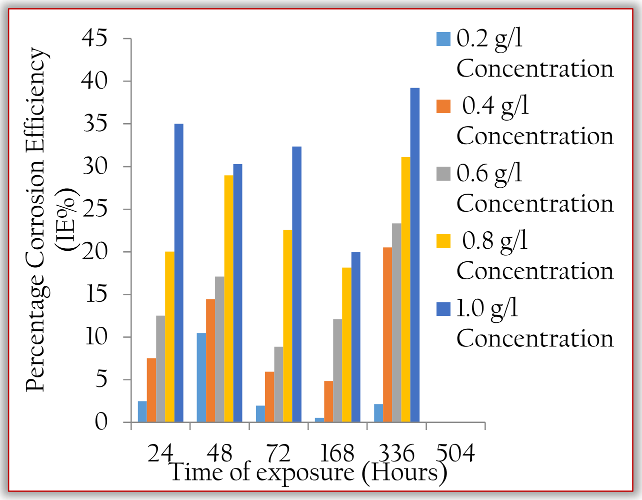


Figure 6: The value of Inhibition Efficiency for concentration of cucumber seed oil extracts

The steadiness of the inhibitive behaviour of the extract was evaluated by trend of the Inhibition Efficiency as a function of time. Figure 6 shows the values of Inhibition Efficiency (I.E%) for each concentration of cucumber seed oil extract. The Inhibition Efficiency (I.E%) achieved using cucumber seed oil range between 2.49 and 39.23%. The lowest IE% value (2.49%) was achieved after 24 hours of immersion in HCL with 0.2 g/l cucumber oil concentration, while the highest value (39.23%) was achieved after 336 hours of immersion with 1.0 g/l cucumber oil. The I.E% increased with inhibitor concentration and time of exposure. The result is in agreement with the findings of Ramya *et al.* (2016), Hui *et al.* (2012) and Popoola *at al.* (2012). This is an indication that the inhibitor acts through adsorption on iron surface and formation of a barrier layer between the metal and the corrosive media (Laamaria, *et al.*, 2012). According to Abbasov *et al.* (2013), the surface of the steel is effectively separated from the medium as adsorption and surface coverage increase with the increase in concentration which results to decrease in in corrosion rate as inhibitor concentration increases to attain higher inhibition efficiency. Omotosho *et al.* (2013) was also of the view that occurrence of physical absorption on the surface of the metal leads to increase in the IE%. The results therefore revealed that the extract (seed oil) could be used as potential corrosion inhibitor of AISI 1007 steel samples in 2M HCl in industries.

— Electrochemical Measurements (Tafel Polarization Technique) Cucumber Peel

Tafel extrapolation measures corrosion rate. For an electrochemical reaction under activation control, polarization curves exhibit linear behaviour in the Corrosion potential ($E_{corr}$) Vs log Corrosion current density ($I_{corr}$) plots called TAFEL behaviour. Polarization measurements were carried out starting from a cathodic potential of -200mV/s to an anodic potential of +250mV/s at a cam rate of 0.166. The linear Tafel segments of the cathodic curves and the calculated anodic Tafel lines were extrapolated to corrosion potential to obtain the corrosion current densities $I_{corr}$ (Amin *et al.*, 2009).

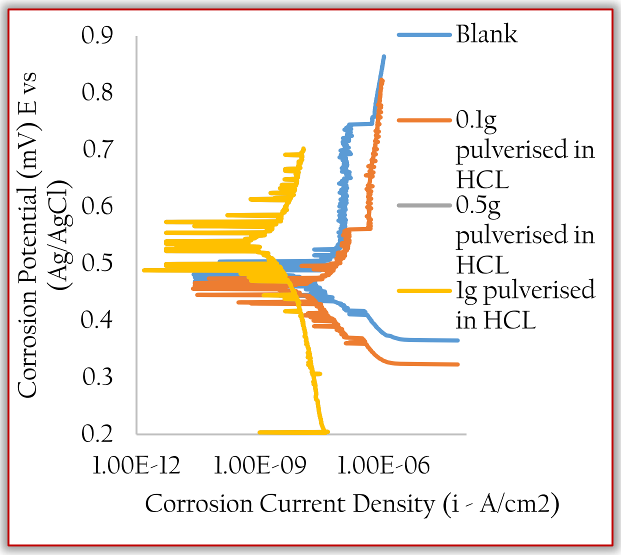


Figure 7: Corrosion Potential against Corrosion Current Density (Pulverised Peel)

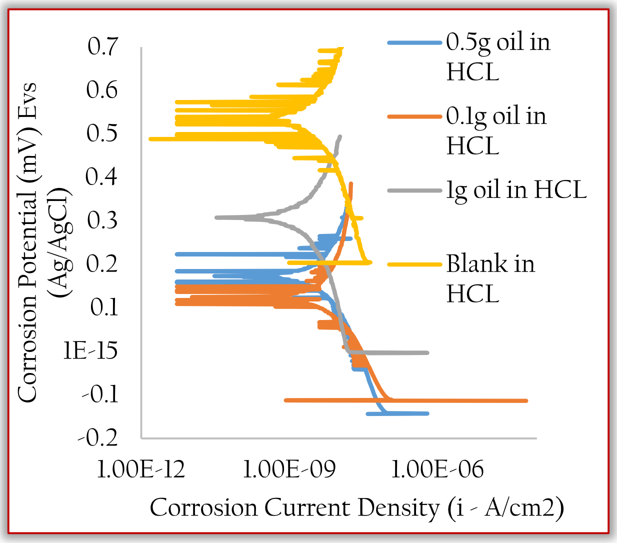


Figure 8: Corrosion Potential against Corrosion Current Density (Cucumber Seed Oil)

It is shown that as the concentration of cucumber peel increased the corrosion potential shifts toward a more noble direction (Figures 7 and 8). Furthermore, the corrosion current decreases markedly in the presence of cucumber peel extract, and the magnitude of such an effect increases with increasing cucumber peel extract concentration. These results showed the inhibitive action of the extract to corrosion of AISI 1007 steel in the 2M HCl. It could be seen that the inhibition efficiency increases with increasing extract concentration. This result reflects the effect of the extract on both anodic and cathodic reactions. Therefore, it could be concluded that cucumber peel extract and cucumber seed oil acts as a mixed inhibitor.

## CONCLUSIONS

Based on the on the study of inhibition of the corrosion of AISI 1007 steel in Hydrochloric Acid solution by the cucumber peel and seed oil extracts using gravimetric and electrochemical measurement (TAFEL Polarization Technique). The following conclusions were drawn:

- Gravimetric technique shows that the corrosion rate of AISI 1007 steel in HCl solution was found to decrease with increasing concentration of the cucumber peel and seed oil extract.
- Cucumber seed and oil exhibited good inhibiting tendency on corrosion of AISI 1007 in HCl up to period of 336 hours. The IE% achieved ranged between 70.28 and 86.63%%; 2.49 and 39.23% for cucumber peel extract and seed (oil) extract respectively
- The inhibition of the corrosion of AISI steel by acid extracts of cucumber was due to the phytochemical constituents in the plant extract.
- The inhibition efficiency of the cucumber peel and seed extracts in gravimetric technique was dependent on the concentration of the extract, and it increased with increasing concentration of the extract in the acidic medium.
- Maximum IE% of 86.63 % and 86.42 % was attained after 168 and 336 hours of exposure in the presence of 1.0 g/l cucumber peel extract concentration respectively. While 39.23% of IE% was obtained after 336 hours exposure with 1.0 g/l cucumber seed (oil) extract. Hence, the cucumber peel extract inhibition efficiency was greater than that of the cucumber seed oil extract (CSP > CSS).
- Tafel polarization technique results showed that the extract acted as a mixed type inhibitor via a simple adsorption of the phytochemicals present in the extract on the AISI steel surface in HCl solution.
- The cucumber extracts (peel and oil) could serve as effective inhibitor of corrosion of AISI steel in Hydrochloric Acid solution.

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ACTA TECHNICA CORVINIENSIS BULLETIN OF ENGINEERING
ISSN: 2067-3809