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Green approach to stainless steel protection: lycopene as a sustainable corrosion inhibitor in HCl acidic media

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Abstract: Over the years, numerous failures that leads to massive losses in industries have been traced to the effect of corrosion on industrial materials such as. metals. This effect is as a result of acid- attack on metals during industrial processes. In order to protect the environment and reduce cost, the use of green inhibitors as substitutes and partial replacement of chemical inhibitors have become a method of choice. However, inhibitors are supposed to be environment friendly, therefore necessitating the need for this research. In this study, the effect of lycopene on stainless steel 304 when immersed in 2 M and 3 M HCl acid media at varying lycopene inhibitor concentrations was analyzed using gravimetric method. In addition, Fourier transform infrared spectra (FTIR), and Scanning Electron Microscopy (SEM) analysis were employed to inspect the stainless-steel surface in the blank and inhibited medium. From the results generated, from the weight loss (WL), the optimum value of the inhibition efficiency (IE%) of Lycopene inhibitor was recorded for 2 M and 3 M HCl acid respectively as 88.71% and 86.02% at room temperature. Stainless steel 304 surface examination confirmed from the SEM micrograph the presence of a protective adsorbed film on the stainless-steel surface after immersion in both acidic media.

1. Introduction

Over time, it has been discovered that corrosion has applications in the fields of science and technology. Corrosion can be defined as the deterioration or degradation of materials, mostly metals, as a result of their reaction with the environment (Popoola *et al.*, 2014). Corrosion can thus be said to be a problem because it is constant, continuous and difficult to eliminate completely. It can be caused

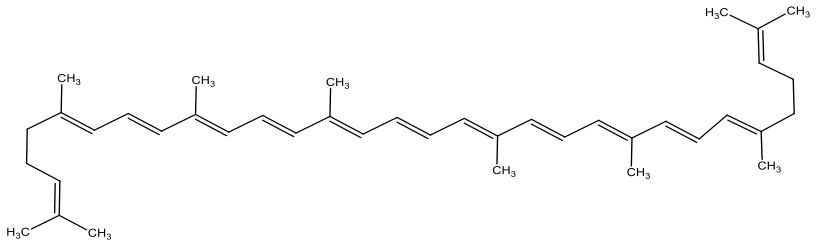
by the natural abilities of metals due to their unstable nature to return to their stable state. For example, iron (Fe) in the presence of moist air is converted to the stable state of iron oxide. Literally speaking, Corrosion can be defined as the process of returning metals to their natural or stable state (Petrovic, 2021). And this process involves the oxidation of metal ores to a thermodynamically stable state. When metals corrode, they lose their structural integrity and aesthetic appeal or attractiveness, this has thus called for replacement of the rusted or corroded metal, thereby causing a great effect on the economy (Ejikeme *et al.*, 2012; Arrousse *et al.*, 2021).

Metals are widely used in human activities because they are known to have excellent mechanical and electrical properties. Examples include mild steels, stainless steels, etcetera, which are mostly used in the oil, food, energy, chemical, and construction industries due to their different applications. These metals become weaker as a result of corrosion, which reduces their desired properties and state. Therefore, in order to preserve the desired state of these metals in general, their preventive maintenance is a priority (Miralrio & Espinoza Vázquez, 2020). One of the most well-known and practical corrosion prevention techniques in the industrial field is the use of corrosion inhibitors. Inhibitors can therefore be defined as substances or mixtures that, when added in low concentration to an aggressive environment inhibit, prevent or minimize corrosion (Obot *et al.*, 2009; Zarrouk *et al.*, 2011; Beniken *et al.*, 2022; Akpan *et al.*, 2014)

The choice of an inhibitor to prevent the corrosion of metals depends on the ability of the inhibitor to be made from cheap raw material. It also depends on the ability of the inhibitor to be environmentally friendly. Most inhibitors especially the organic ones have been reported to be toxic. The use of toxic inhibitors in industries as an approach to solving corrosion inhibition is at an alarming rate and has been recorded harmful to both plants and animal life (Barouni *et al.*, 2014; Pal *et al.*, 2020). Understanding that the toxicity of these inhibitors is very harmful and taking measures to ensure that they are prohibited is necessary. This is to ensure their safe use and prevent potential harm to workers in the industries, consumers, and ecosystems at large (Asmara *et al.*, 2024; Savitri *et al.*, 2024).

Lycopene is one pigment which belongs to a large family of plant pigments known as carotenoids. It is the most important antioxidant among dietary carotenoids and these carotenoids produce colors ranging from the yellow color of squash, to the orange color of pumpkins, to the red color of tomatoes (Long *et al.*, 2024; Jiang*et al.*, 2015). They are also found in some plant food aromas (Rodríguez-Bustamante & Sánchez, 2007). Unlike other carotenoids, the biological activity that occurs in lycopene is as a result of the presence of double bond in its structure and also it lacks terminal ionic ring (Naveen Kumar *et al.*, 2017). The chemical formula for lycopene, a carotenoid is $C_{40}H_{56}$. It has 11 conjugated and 2 unconjugated double bonds present which allows for extensive isomerization of the structure. It exists in trans and cis form (**Structure 1**). Lycopene is an unsaturated acyclic tetraterpenic hydrocarbon with the chemical name 2,6,10,14,19,23,27,31-octamethyl-2,6,8,10,12,14,16,18,20,22,24,26,30-dotriacontatridecaene and common names Ψ,Ψ-carotene, all-*trans*-lycopene, and (all-E)-lycopene (Olempska-Beer, 2006). The 11 congugated double bonds present in the lycopene structure gives it its interesting biological ad physiological activities (Sgherri *et al.*, n.d.; Linnewiel *et al.*, 2009).

Several scientific studies have been made on the corrosion inhibiting effect of some plant extracts they include; water hyacinth plant (*Eichhornia crassipes*) extract which includes extracts from the leaves and roots.



Molecular weight of lycopene =536.9
Chemical Abstract Service (CAS) number= 502-65-8.

Structure 1: General structure of lycopene

In the studies the effect of temperature and concentration of the extract on the inhibition performance of the extracts on mild steel was considered and the results gotten showed that both the leaf and root extracts functioned as effective corrosion inhibitors, with the leaf extracts exerting a greater effect (Ulaeto *et al.,* 2012). Another plant that has been used to inhibit corrosion in both mild steel and zinc is neem plant (*Azadirachta indica*). In the studies using mild steel, extracts of the leaves, roots and seeds of the plant were used differently for the studies and the results gotten showed that they were good inhibitors. The inhibition efficiency was shown to increase in the order SD > RT > LV (Okafor *et al.,* 2010). Using zinc, *Azadirachta indica* was also reported to be a good inhibitor in the corrosion of zinc metal at different concentrations and temperature (Sharma *et al.,* 2009). Sycamore figure plant (*Ficus Sycomorus*) which can also be called figure-mulberry because the leaves resemble those of the mulberry was reported also to be a good inhibitor of corrosion in mild steel and Aluminum (Ogwo *et al.,* 2017). Watermelon (Citrullus lanatus) rind was also used and reported to be a good inhibitor in the corrosion of mild steel (Odewunmi *et al.,* 2015a) and African breadfruit (Treculia Africana) leaves was studied at different temperatures which are from 30^0c -60^0c. The leave was used to inhibit corrosion of aluminium and the results presented in the report showed that it was a good inhibitor. The Inhibition efficiency was reported to have increased with increase in Treculia Africana leaves concentration, but decreased with increase in temperature. (Ejikeme *et al.,* 2012; Ogwo *et al.,* 2017).

Corrosion inhibition of stainless steel 304 in HCl as acid medium was reported by Fouda, (2019) (Fouda *et al.,* 2019). Clindamycin antibiotic a drug was used as the inhibitor at different temperatures and concentrations. The weight loss measurements of the steels were taken at various time intervals. He then reported that the percentage Inhibition Efficiency, IE value, of Clindamycin drug increases with increasing drug concentration and this is due to increase of the surface coverage and also the adsorption of drug molecule on the surface of SS304. The IE also decreases due to rising in temperature as a result of increase of desorption of the drug molecules from SS304 surface. The increase in the inhibitor concentration was accompanied by a decrease in weight loss WL and an increase in the %IE. Also, Loto and Loto. *(*2015) in their report used 2-Amino-5-ethyl-1,3,4-

thiadiazole (TTD) to inhibit corrosion of 304 austenitic stainless steel in dilute Sulphuric acid using potentiodynamic polarization test, mass loss technique and potential measurements. In their work, it was observed that the organic derivative used was very effective in the inhibition with an inhibition efficiency of 70.22% from mass loss analysis and 74.2% from polarization tests. TTD from previous researches has been reported as a good inhibiting agent not only for stainless steels but for other metallic alloys like for copper in 3% NaCl solution, copper in 0.5% HCl using gravimetric and electrochemical method and also for brass in natural seawater was evaluated by potentiodynamic polarisation and electrochemical impedance spectroscopic techniques. Loto and Loto (2015) in their work also reported some significant numbers of researches that have been done using organic compounds as inhibitors for some metallic alloys in corrosive acid media with satisfactory results (Loto & Loto, 2015).

The above literature analysis highlights the importance of identifying effective corrosion inhibitors for metal steel in order to increase safety, reduce maintenance costs and restricts the use of imported chemical inhibitors when it is adopted, especially, in the industries, for flow systems or chemical plants experiencing severe acidic conditions. For the purpose of marketing and discovering new inhibitors, the proposed inhibitor should be closely examined by low cost, availability and near-to-zero environmental impact. Following these directives, this work proposes the application of the novel lycopene in order of inhibit corrosion generally of metals when placed in a corrosive environment.

2. Materials and method

2.1. Materials

Corrosion studies were performed on austenitic stainless steel of chemical compositions; 0.12 Carbon, 0.01 Sulphur, 8.34 Nickel, 0.18 Molybdenum, 1.36 Manganese, 20.12 Chromium, Bal Iron,0.03 Phosphorus, 0.54 Silicon. Before the studies was carried out, the metal steels were cut into a measurement of 3cm× 1cm ×0.25 cm dimensions for the weight loss studies. Each coupon was polished smoothly using emery papers 220, 600 and 800 in order to obtain a smooth / uniform surface area. They were further degreased with acetone, rinsed with deionized water to remove debris and then dried in warm air (Anadebe *et al.*, 2020).

2.2. Method

2.2.1. Preparation of 2M and 3M HCl solution

To prepare 2M amd 3M solutions of HCl, 171.82ml and 257.73ml of HCl l (37 wt%, specific gravity of 1.19) were respectively measured and poured into two different 1L volumetric flask. The flask was topped up to the 1L line of the volumetric with distilled water. These solutions were kept for weight loss studies (Anadebe *et al.*, 2020).

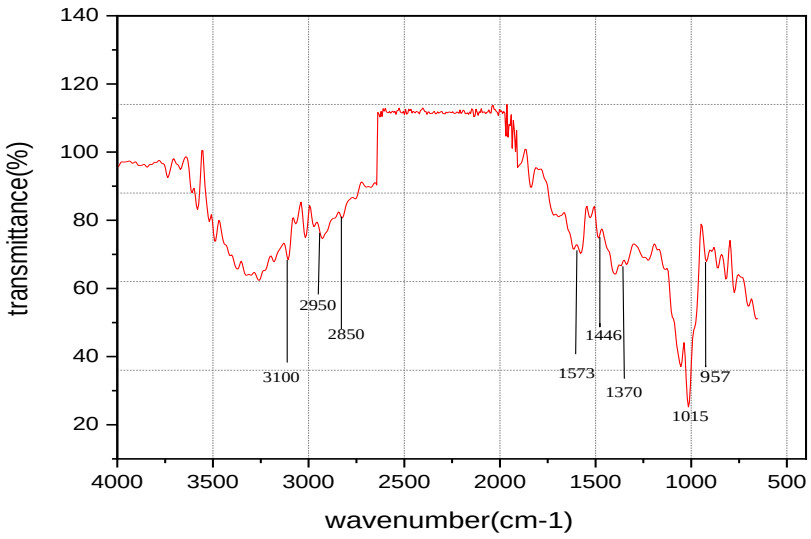
2.2.2 Extraction of lycopene inhibitor

Extraction of lycopene was done using recrystallization method. The recyclization method that was used was done by Saeid et al, (2016) with slight modifications. 50g of carrot peel was suspended in a

65ml methanol and stirred for 1h at room temperature (30 ± 2°C). The suspension was later filtered using a Whatman No. 4 filter paper and the residue gotten was washed with 45ml carbon tetrachloride and 30ml methanol for 15minutes. The solution was then filtered again using the whatman No. 4 filter paper and transferred into a separatory funnel for separation. Before allowing the solution to stand, 1 volume of water was added into the solution and shake well. Two layers were formed, the lower being lycopene layer containing carbon tetrachloride was formed. This was collected in a beaker and the carbon tetrachloride phase was evaporated. The residue was redissolved in 2ml of benzene and 1ml of boiling methanol. Crude lycopene crystals were formed and kept at room temperature with ice bath. The crystals were washed again 10 times with benzene and boiling methanol. The solution was then kept for further analysis.(Saeid *et al.*, 2016).

2.2.2.1. Characterization of lycopene inhibitor

The molecular structure of lycopene extract was characterized using the Fourier Transform Infrared (FTIR) spectroscopy technique. The spectral Peaks obtained in the spectra (**Figure 1**) of lycopene showed prominent bands of C-H symmetrical stretch of sp^2 hybridized alkenes (3100cm^{-1}), and C-H asymmetrical stretch alkane at wave number (2950) cm^{-1}, C-H stretch of alkane at (2850) cm^{-1}, other bands which include (1573) cm^{-1} C=C stretch of the polyene chain of alkene, C-H bends stretch of alkene at (957) cm^{-1}. In plane wagging (1010-1200) cm^{-1}, Out of plane wagging (850- 1000) cm^{-1} and (1370) cm^{-1} stretch of CH_3 (methyl) and CH_2 (methylene) bending vibrations (Raduly *et al.*, 2011; Vidhya & Arunadevi, 2015).



Figureure 1: FTIR of lycopene extract

2.2.2.2. Preparation of test solution

Preparation of the test solutions used was adopted from Odewunmi et al. (2015). The solution used for preparation is 2M HCl. It was prepared with A-R grade 37% HCl (Sigma–Aldrich). The stock solution of the lycopene was prepared by weighing 5 g of lycopene extract and added in 1 L of 2M

HCl. Test solutions at different concentrations of 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9g/L of the extract were prepared from the stock solution by dilution with the corrodents 2M and 3M HCl respectively (Odewunmi *et al.*, 2015a, 2015b).

2.2.3. Weight loss studies

The weight loss studies involve two stages which are the pretreatment (before immersion) and post treatment (after immersion) stage. The experiment was carried out at room temperatures. Test coupons in triplicates were suspended freely in glass reaction vessels containing 200 ml of test solution (2M HCl) without and with varying inhibitor concentrations. At the appropriate time, the stainless steel samples were taken out, immersed in acetone, scrubbed with a bristle brush under running water, and dried in warm air before reweighing. The weight loss was calculated in grams as the difference between the initial weight and the weight after the removal of the corrosion product (Odewunmi *et al.*, 2015a). The experimental readings were recorded. The weight loss (WL), corrosion rate (CR), inhibition efficiency (IE), and degree of surface coverage (Θ) were calculated using the equations below:

$$WL - w2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1)$$

$$CR = \frac{87.6\,(w1-w2)}{\delta AT} = \frac{WL}{\delta AT} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

$$\%\,IE = \frac{CR-CR(i)}{CR} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

$$\theta = \frac{CR-CR(i)}{CR} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.4)$$

Where CR is the corrosion rate, w1 and w2 are the weights before and after immersion respectively, A is the surface area of the stainless steel in cm^2, t is the immersion time in hours, δ is the density of the metal, CR (i) is corrosion rate in the presence of the inhibitor and WL is the loss in weight of the stainless-steel coupon (Ngobiri & Obi, 2020).

2.2.4. Surface morphological studies.

The surface morphology of the stainless steel was examined using the JSM-5800 LV scanning electron microscope (SEM) and FT-IR spectroscopy. The stainless-steel coupon was placed in the desiccator, later removed and then completely immersed into 2.00 M and 3.00 M HCl with and without 2.0 g/L of lycopene extract (inhibitor) in a glass vessel at 25^0C. They were retrieved after 24 h of exposure in the test solution or corrodent, rinsed with distilled water, dried in warm air and stored in a desiccator before submission for SEM surface examination. Before the placement of the stainless steel which is prior to its exposure to the test solution and corrodent, the stainless-steel specimen was cleaned and polished. The surfaces of the stainless steel samples were examined with a Joel JSM-6610 LV scanning electron microscope (Odewunmi *et al.*, 2015a, 2015b). The Fourier transform infrared (FTIR) was also used to analyze the nature of the film formed on the metal surface after immersion in the corrodent.

3. Results and discussions

3.1Weight loss measurement

Gravimetric data (corrosion rate, efficiency and surface coverage) of austenitic stainless steel 304 in 2M and 3M HCl with and without lycopene as inhibitor are collected in **Table 1a** and **Table 1b,** respectively. Results show that the corrosion rate increase with the concentration of HCl due to the high activity of H^+ ion (Emran, 2015; Loto *et al.*, 2015; Elouafi *et al.*, 2011).

Table 1a: Gravimetric analysis result of austenitic stainless steel 304 in 2M HCl with lycopene as inhibitor

Time (days)	IC/g/L^{-1}	Weight loss (ΔW)/g	CR/mmyr^{-1}	IE/ %	Surface coverage/Θ
1	0	0.331	0.013		
	0.3	0.231	0.0091	30.2115	0.3021
	0.6	0.109	0.0043	67.0695	0.6707
	0.9	0.059	0.0023	82.1752	0.8218
2	0	0.494	0.0097		
	0.3	0.333	0.0066	32.5911	0.3259
	0.6	0.154	0.003	68.8259	0.6883
	0.9	0.082	0.0016	83.4028	0.834
3	0	0.655	0.0086		
	0.3	0.425	0.0056	35.1145	0.3511
	0.6	0.201	0.0026	69.313	0.6931
	0.9	0.105	0.0014	83.9695	0.8397
4	0	0.82	0.0081		
	0.3	0.52	0.0051	36.5857	0.3659
	0.6	0.237	0.0023	71.0976	0.711
	0.9	0.123	0.0012	85	0.85
5	0	1.022	0.0081		
	0.3	0.647	0.0051	37.6712	0.3767
	0.6	0.273	0.0022	73.2877	0.7329
	0.9	0.142	0.0011	86.1057	0.8611
6	0	1.149	0.0075		
	0.3	0.712	0.0047	38.0331	0.38 03
	0.6	0.299	0.002	73.9774	0.7398
	0.9	0.149	0.001	87.0322	0.8703
7	0.0	1.24	0.007		
	0.3	0.731	0.0041	41.0484	0.4104
	0.6	0.31	0.0017	75	0.75
	0.9	0.16	0.0009	88.7097	0.8871

Table 1b: gravimetric analysis result of austenitic stainless steel 304 in 3M HCl with lycopene as inhibitor

Time (days)	IC/g/L^{-1}	Weight loss(ΔW)/g	CR/mmyr^{-1}	IE/ %	Surface coverage/Θ
1	0	0.435	0.0188		
	0.3	0.31	0.0134	28.7234	0.2872
	0.6	0.15	0.0065	65.4255	0.6543
	0.9	0.08	0.0035	81.383	0.8138
2	0	0.715	0.0155		
	0.3	0.505	0.0109	29.6774	0.2968
	0.6	0.235	0.0051	67.0968	0.671
	0.9	0.124	0.0027	82.5806	0.8258
3	0	1.01	0.0146		
	0.3	0.694	0.01	31.5068	0.3151
	0.6	0.311	0.0045	69.1781	0.6918
	0.9	0.17	0.0025	82.8767	0.8288
5	0	1.211	0.0131		
	0.3	0.79	0.0085	35.1145	0.3511
	0.6	0.352	0.0038	70.9923	0.7099
	0.9	0.193	0.0021	83.9694	0.8397
	0	1.345	0.0116		
	0.3	0.842	0.0073	37.0690	0.3707
	0.6	0.376	0.0033	71.5517	0.7155
	0.9	0.202	0.0017	85.3448	0.8534
6	0	1.449	0.0104		
	0.3	0.882	0.0064	38.4615	0.38 46
	0.6	0.389	0.0028	73.0769	0.7308
	0.9	0.212	0.0015	85.5769	0.8558
7	0	1.508	0.0093		
	3	0.898	0.0055	40.8602	0.4086
	0.6	0.392	0.0024	74.1935	0.7419
	0.9	0.216	0.0013	86.0215	0.8602

3.2. Corrosion rate and inhibition efficiency.

3.2.1 Effect of lycopene concentration

The dissolution of metal steel in acidic media has been shown in the form of an electrochemical reaction for many years. These reactions are shown in the loss in mass of the metal steel (Tsoeunyane *et al.*, 2019). The performance of lycopene as a corrosion inhibitor was investigated by monitoring the loss in weight of the stainless steel as the dissolution process took place. There is a positive impact of the concentration the lycopene inhibitor on the corrosion rate of the metal steel (Figure 1). The

inhibition efficiencies were calculated from the corrosion rates as shown in tables 1a and 1b using the formulas (2.2) and (2.3) while the surface coverage was calculated using the formula (2.4). in brief, 5g of lycopene in 2M HCl was used as stock solution. The weight loss of SS was determined in the presence and absence of the inhibitor lycopene. As the concentration of the inhibitor is increased, more of it is seen to be adsorbed on the surface of the metal, this there by leads to a reduction in the dissolution of the metal in the corrosive media (Bhardwaj *et al.*, 2021).

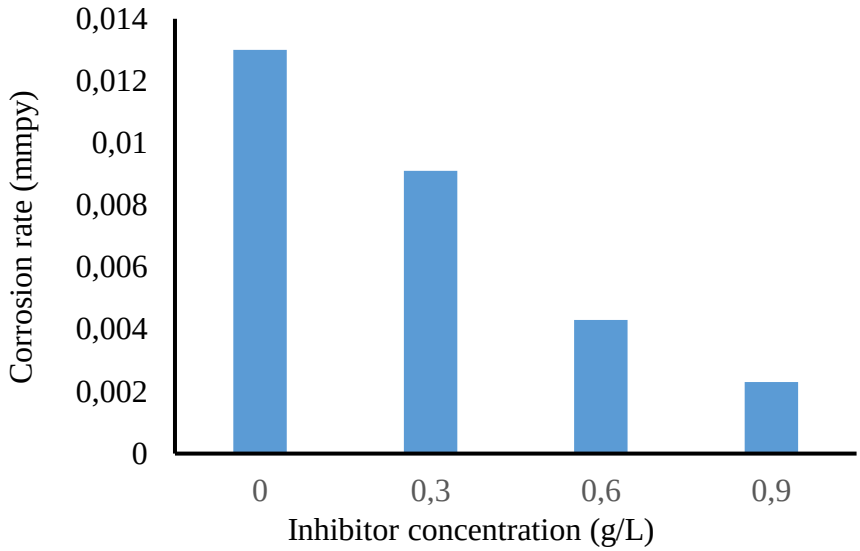


Figure. 1: A bar chart showing the relationship between corrosion rates of SS304 in HCl acid with lycopene.

3.2.2. Effect of immersion time

In corrosion inhibition studies, time is a standout factor when characterizing the corrosion inhibitor. In order to determine the stability of the inhibition film and the rate of inhibitor adsorption, immersion time studies were conducted. The immersion periods were varied from one to seven days. (24-168 hrs.). The result as shown in Figure 2 indicated that the immersion time has effect on the inhibition efficiency of lycopene on SS. The maximum corrosion inhibition efficiency was attained at the early period of immersion because at the early stage of immersion, the presence of maximum numbers of available active inhibitor molecules on the surface of the metal steel quickly adsorbs the inhibitor on to the stainless-steel surface, thereby inhibiting the metal steel from corroding. The corrosion rate (CR) increased rapidly also as the immersion time increased. The longer the period of immersion of stainless steel the higher the corrosion rate.

3.2.3. Effect of acid concentration

Weight loss/ gravimetric measurements were also used to study the effect of increasing the concentration of the corrosive agent on the corrosion of the stainless steel in the presence of the same amount of lycopene inhibitor. From the result in the table above, the inhibition efficiency was observed to decrease in the 3M HCl corrosive agent in the presence of the lycopene inhibitor compared to the 2M HCL corrosive agent in the same amount of lycopene inhibitor. The inhibition

efficiency in 0.3g/L of 2M and 3M HCl was found to be 41.05% and 40.86% respectively while in 0.9g/L of the same 2M and 3M HCl corrosive agent, the inhibition efficiency was found to be 88.71% and 86.02% respectively. At a higher concentration of acid, the lycopene inhibitor was desorbed from the stainless-steel surface. This therefore led to the increase in corrosion rate the metal steel. The available active inhibitor molecules on the surface of the stainless steel are lesser when placed in a higher concentration of corrosive environment.

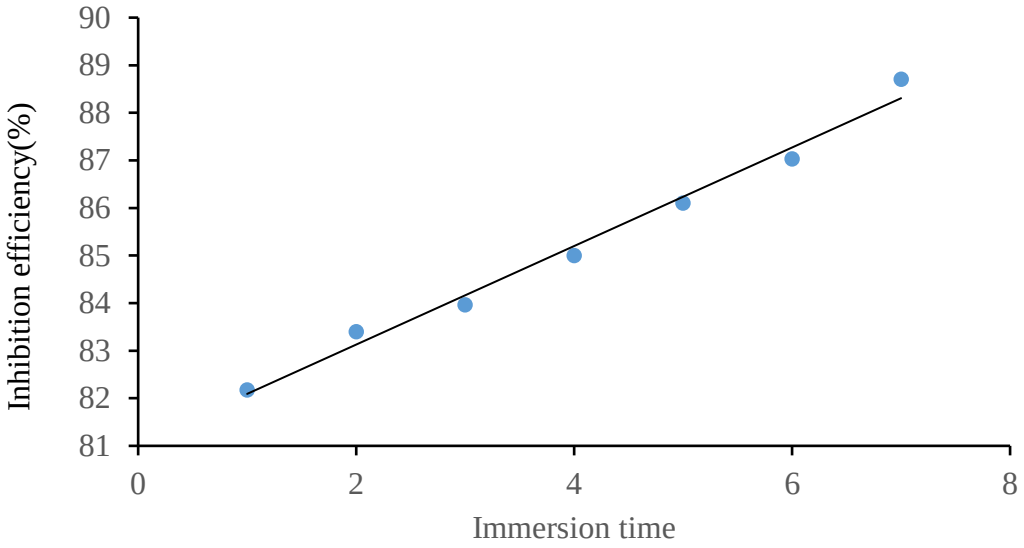


Figure. 2: Inhibition Efficiency of SS304 in 2.00 M HCl at varying immersion time with 0.9g'L lycopene inhibitor

3.3. Surface morphology

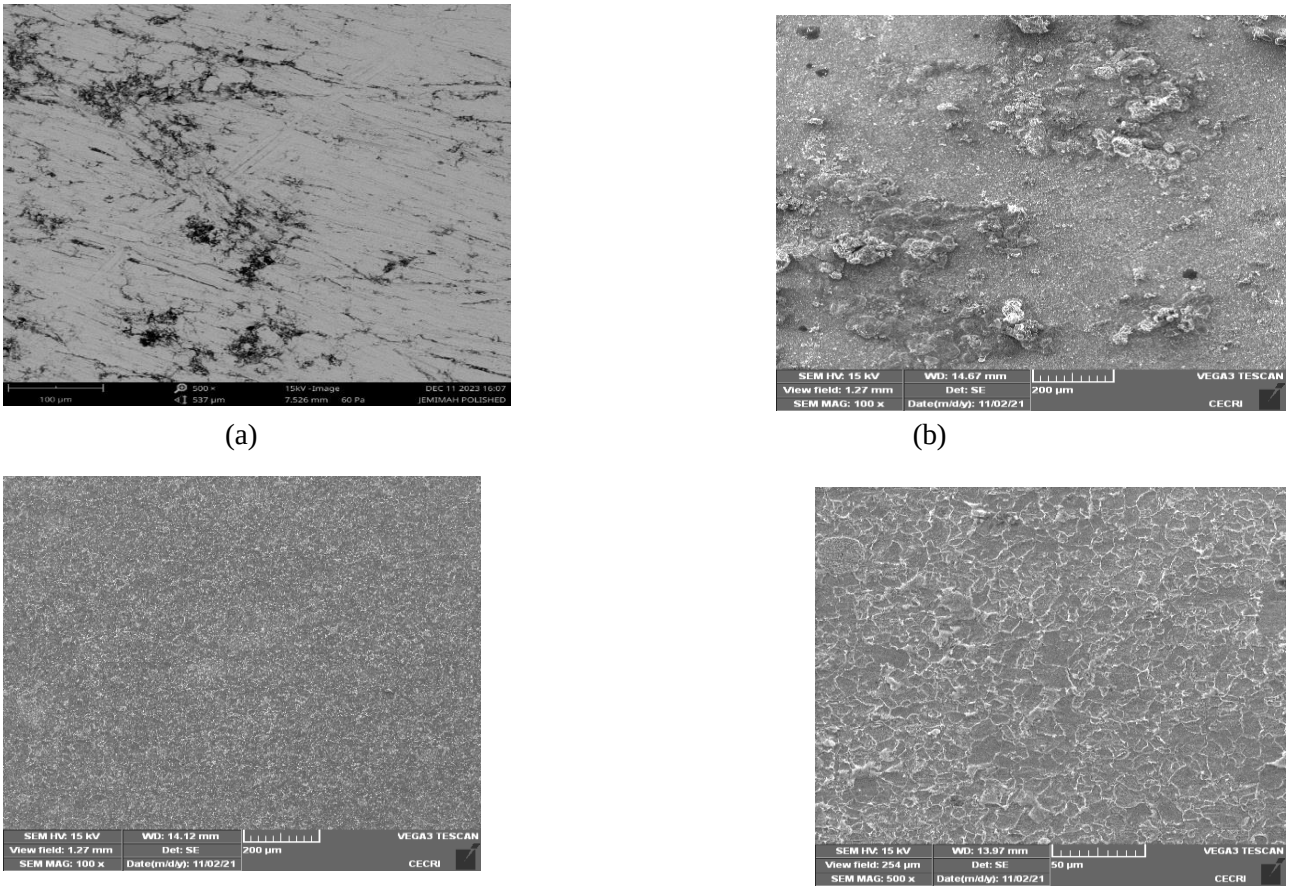
3.3.1. Surface electron morphology (SEM)

The surface morphology of the steel in acid was analyzed so as to understand the level at which the lycopene inhibitor protected the stainless steel surface. **Figures. 3a to d** shows the micrograph of polished SS304 before immersion in acid, in 3M HCl blank, in 2M HCl with 0.9g/L lycopene, and in 3M HCl with 0.9g/L lycopene respectively. In figure 7b, the micrograph of SS304 was seen to exhibit dark, coarse holes with rough surface that contains tiny pores on it. On the other hand, figure 7c and d differs from that of the stainless steel in the control medium because of the presence of the inhibitor in the both media. It was observed that the stainless steel in the medium containing the inhibitor appears evidently smooth than that of the blank. The corrosion topography was visible enough due to the harsh nature of chloride in the acid. The level of iron oxide formed on the steel that was in the medium containing the inhibitor was suppressed due to the physical formation of a dense film on the surface layer of the steel.

3.3.2. Fourier Transformed Infrared adsorption (FTIR) spectrum.

Previous studies have shown that FTIR analysis is capable of providing evidence concerning the bonding and adsorption mechanisms of inhibitors on metal surfaces (Anadebe *et al.*, 2020). After

corrosion took place on the metal surface when immersed in acid in the presence of the inhibitor, the protective film that developed on the metal surface was subjected to analysis using the FTIR spectrometer. **figure 1** gives the spectra of solely the lycopene inhibitor while **figure. 4** shows the FTIR spectra of the film layer that was generated on the metal surface when the metal has been dipped into the acid for 5hrs in the presence of the lycopene inhibitor.



(a) (b)

(c) (d)

Figure. 3. SEM Micrographs: polished SS before immersion in acid medium (a), SS in 3.00 M HCl blank medium (b), SS in 0.9 g/L lycopene /2.00 M HCl (c), SS in 0.9 g/L lycopene /3 M HCl (d).

The later spectra exhibit the existence of C-H, O-H. C-O, C=O and C=C bonds in lycopene. From the analysis of the two spectra, it can be observed that nearly all the peaks detected in the pure inhibitor were also detected in the corrosion product. Furthermore, certain bands in the corrosion product spectrum displayed became weaker. The slight changes in the FTIR spectra of the corrosion product and the absence of certain bands indicates that a a potential interaction between the compounds, which is the corrosion product, and the metal surface took place. This interaction leads to the creation of a protective film layer (Alibakhshi *et al.*, 2019).

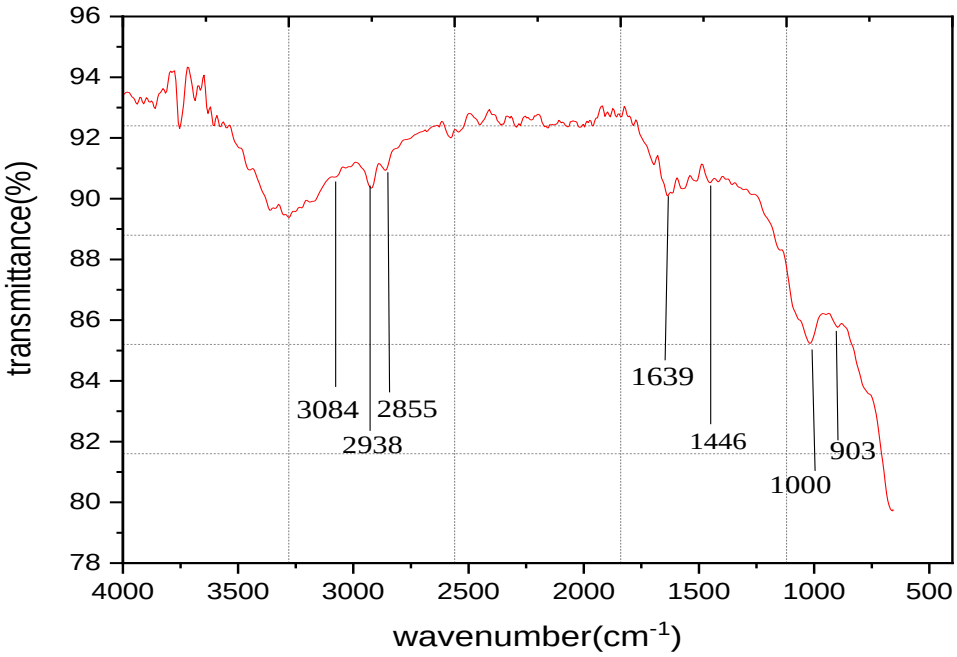


Figure 4. FTIR spectra for adsorbed molecules of lycopene on SS surface.

Conclusion

In this study, an environmentally friendly way of reducing corrosion in SS304 was initiated to generate measurable and testable data towards controlling corrosion. From the data generated, it was concluded that;

- The green inhibitor, Lycopene is a strong corrosion inhibitor in 2M and 3M HCl solution for the protection of stainless steel.
- The lycopene inhibitor produced its best percentage inhibition efficiency value of 88.71 and 86.05 in 2M and 3M HCl respectively at a concentration of 0.9 g/L of the inhibitor stainless steel.
- The inhibition effect of lycopene depends on its concentration. Therefore, this inhibitor should be applied at high concentrations.
- Increasing concentration of the corrodent had significant effect on the corrosion rate and inhibition efficiency of the studied system. Increasing the concentration was proportional to the corrosion rate and inversely related to the inhibition efficiency.
- The surface analysis of SS is in good agreement with the experimental findings. This indicates that there was a safe and well distributed film over the metal surface. In the 2M and 3M HCl solution containing inhibitor, a substantial reduction in surface roughness was seen when compared to the solution without the inhibitor.

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