



Probing the corrosion Inhibition Efficiency of Corn Cob Extract on Aluminium in 1.0 M H₂SO₄ descaling solution

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ABSTRACT: As the efforts towards green mitigation of corrosion are being intensified, the current research is aimed at probing the inhibition efficacy of corn cob extract on aluminium in 1.0 M H₂SO₄. The adsorbed inhibitor was subjected to weight loss, AAS and gasometric techniques to ascertain the inhibition performance. SEM was utilized to determine the surface morphology of the adsorbent (metal) before and after application of the adsorbate (corn cob extract). Three adsorption isotherm models were utilized to explain the reaction mechanism. The result obtained X-rays increasing efficiencies at different concentrations (10% v/v-100% v/v) of the inhibitor for the various techniques used; weight loss: 68.79%, 71.50%, 73.85%, 79.92%, 85.48%, 86.04%, 86.80%, 89.61%, 89.81% and 92.22%; AAS: 3.52%, 15.66%, 18.22%, 20.05%, 33.10%, 54.98%, 62.76%, 64.60%, 81.01% and 99.94%; and gasometric: 16.74%, 18.01%, 32.12%, 52.51%, 65.14%, 72.17%, 75.16%, 85.74% and 90.12%. SEM result shows that the surface morphology of the adsorbent was smoother in the presence of the inhibitor compared to the surface without it. The Langmuir and Temkin adsorption isotherm models revealed the reaction mechanism and chemisorption interaction of the inhibitor molecules.

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The extensive industrial uses of Aluminium (Al) as aerospace and automobile industries coupled with its easy process and relatively low cost with high corrosion resistance is an advantage over other metals, Avwiri and Igho (2003). However, several literatures have revealed that Al is susceptible to corrosion attack in acid medium such as H₂SO₄. Corrosion has posed enormous challenges to the industries and it is difficult to eliminate the menace completely, Eddy *et al.*, (2009). Corrosion inhibitors are widely used in industries to prevent or reduce corrosion rate of metals in alkaline or acidic media, Osarolube *et al.*, (2004). In industries acidic environment is usually created during industrial processes such as acid-pickling, cleaning of refinery equipment, oil well acidizing, and

descaling, Fontana (2005). When inhibitors are introduced into such environments, its action is usually associated with changes in the surface properties of the metal due to adsorption or formation of insoluble compounds with the metal cations. Such compounds decrease the area of active metal surface and thus increase the corrosion energy barrier, Kuznetsov (2004). When corrosion energy is increased the degradation process becomes hindered. The use of naturally occurring plant extracts as inhibitors is particularly interesting because they are cost effective, non-toxic, and environmentally friendly thus decreases the threats posed to the environment and promotes green chemistry, Avwiri and Igho (2003); Kuznetsov (2004). Corn cobs contain approximately

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39.1% cellulose, 42.1% hemicelluloses, 9.1% lignin, 1.7% protein, and 1.2% ash. Going by this X-rayed chemical composition, this material shows a great potential as a renewable source of corrosion inhibitor for a variety of metals. Corn cob is a simple wasteproduct from agricultural farms usually utilized in feeding livestock, such as goats and cows. However, researchers have not reported any such practical evidence of the inhibition performance of this material in literature. Hence, the objective of this work is to report on the probing of the corrosion inhibition efficiency of corn cob extract in 1.0 M H₂SO₄ descaling solution.

MATERIALS AND METHODS

Sample collection and preparation of sample extracts: Fresh samples of corn cob were collected from a plantation farmland in Opu-oko in Khana L.G.A., Rivers State of Nigeria. The corn cobs were sun dried then grounded into powder, and 100g of the corn cob powder were soaked in 1200 cm³ of ethanol. It was stirred and allowed to stand for 7 days. Within this period, the volume of ethanol was checked constantly and more ethanol was added if the ethanol level drops. The resultant mixture was filtered after the period of one week. This served as the corn cob extract solution.

Preparation of metal coupons: The Al coupons of 0.2 cm thickness used for the study were cut into 2cm by 3cm coupon size for weight loss analysis. The coupons were polished and brushed with an iron brush and a hole was made at the centre of the top edge of each coupon in such a way that the coupon will freely be suspended in the solution. The coupons were soaked in ethanol solution for 5 minutes for degreasing and rinsed with distilled water and acetone and finally were kept in desiccators for proper drying. This was necessary to prevent contamination before corrosion studies.

Preparation of 1.0 M H₂SO₄: 1 M stock solution of sulphuric acid was prepared by diluting 54.3 ml of the raw acid with distilled water in a 1000 ml volumetric flask and made up to the mark on the flask, with this the different concentrations of the test solutions are prepared according to Table 1. The prepared test solutions were allowed to stand for 24 h before use as a corrodent.

Determination of the phytochemical constituents in corn cob extract: The phytochemical screening of the corn cob extract was done to identify the main groups of active chemical constituents such as tannin, alkaloid, saponin, phenolics, oxalate, phytate and cyanide present in the extract.

Preparation of tannin standard stock solution in (100ppm): 0.1 g (100 mg) of tannic acid salt was dissolved in 1000 ml volumetric flask and made up to the mark with distilled H₂O as the stock solution (0.1 g of tannic acid in 1000 ml (1 litre) = 100 ppm) Then the Tannin working standard (10ppm) was prepared by the aid of a pipette, 10 ml from the stock (100 ppm) was added into 100 ml volumetric flask and made up to the mark. From the 10 ppm solution, serial dilutions of 0.5 ppm, 1.0 ppm, 1.5 ppm, 2.0 ppm and 2.5 ppm were prepared and poured into a 50 ml volumetric flask by pipetting 2.5 ml, 5.0 ml, 7.5 ml, 10.0 ml and 12.0 ml respectively into 50 ml volumetric flask and made up to the mark. A typical procedure for extraction of tannin is as follows: 0.2 g of finely grounded sample was weighed and 10 ml of 70% acetone was added and placed in an ice bath for 10mins. The solution was oscillated with oscillator for 15mins and allowed to cool for 30mins and the mixture was filtered into a conical flask. Pipette, 0.5 ml of the extract or filtrate was poured into 50ml volumetric flask. 0.5 ml of distilled H₂O was added to the sample and 1 ml of distilled water was added into another flask as blank. 0.5 ml folin–dennis reagent was added to sample and standard. Then 2.5 ml of 20% sodium carbonate solution was added to the sample and standard and mixed properly and made up to the mark with distilled H₂O. It was allowed to stand for 40mins for a bluish–green colour to develop. And the absorbance was read at 725nm using FTIR spectrophotometer.

Determination of alkaloid: 1 g of the sample was weighed and 40 ml of 10% acetic acid was added in ethanol. It was shaken and allowed to stand for 4 h at room temperature and then filtered. The filtrate was concentrated to 1/4 of its original concentration by evaporation then dropwise addition of NH₄OH to precipitate the alkaloid was made. The precipitated alkaloid was then placed in a weighed filter paper and washed with some amount of diluted ammonia

Table 1. Different concentrations of corn cob from varying percentage extract in test solution

Vol. of 1M H ₂ SO ₄ (ml)	Vol. of Corn Cob Extracts (ml)	Percentage Extract (%v/v)
100	-	-
90	10	10
80	20	20
70	30	30
60	40	40
50	50	50
40	60	60
30	70	70
20	80	80
10	90	90
-	100	100

solution. The filter paper was then dried in the oven and the percentage of alkaloid was determined according to Eq. 1 as follows.

$$\text{Alkaloid (\%)} = \frac{W_2 - W_1}{W_0} \times 100 \quad 1$$

Where: W_0 =Weight of sample, W_1 =Weight of empty filter paper, W_2 =Weight after oven-drying.

Determination of saponin: 1 g of the sample was Weighed and recorded as (w_0), 30 ml of n-hexane was added to remove traces of fat present and 30 ml of methanol was then added to extract. The extract was filtered and 30 ml of methanol was added to the residue. It was filtered again and 30 ml of methanol was added for the 3rd time to the residue. This residue was then filtered into another clean conical flask. The filtrate was heated to concentrate to 1/3 of the original concentration and 100 ml of cold acetone was added. It was placed in the refrigerator for 50 mins; thereafter filtered using a weighed filter paper of weight (W_1), the filter paper containing the saponin residue was dried, reweighed and recorded as (W_2), Berdimurodov *et al.*, (2021). Thereafter, the percentage of saponin was calculated in a similar way according to Equation 1.

Determination of total phenolics (gallic acid calibration standards): 0.5 g of garlic acid was dissolved in 10 ml ethanol and then diluted into 100 ml with water (giving 5 g/L). Then 1, 2, 5 and 10 ml were diluted with water to 100 ml to create standards with 50, 100, 250 and 500 mg/L concentration respectively which was stored up to 2 weeks at 4°C. *Note:* standards will retain 98% of their potency for 2 weeks if kept closed under refrigeration (4°C) but this potency is retained for only 5 days at room temperature. Commercial garlic acid is usually adequately pure but can be recrystallized from water if desired. Then 0.2 mg of sample was weighed into a conical flask. 10 ml of 50% methanol of the sample was extracted and then added to the conical flask containing the 0.2 mg of the sample and it was heated in water bath at 80°C for 30 mins and allowed to cool. The contents were transferred to centrifuge tubes and whiz for 5 mins at top speed. 0.2 ml of the sample, 2.8 ml distilled water, 0.25 ml Folin-Ciocalteu reagent, and 1 ml sodium carbonate were pipetted and allowed to sit for 15 mins it was read in a spectrophotometer at 760 nm, Tan *et al.*, (2021).

Determination of oxalate: 1.0 g of sample was weighed and recorded (W_1) 75 ml of 1.5M H_2SO_4 was then added to the sample inside the 100 ml conical flask, Stirred for 1 hour using a magnetic stirrer. It was filtered using Whatman filter paper. 25 ml of the

extract was pipetted into another conical flask and 25 ml of the extract when hot was titrated against 0.1N $KMNO_4$ solution to a faint pink coloured point and the titre value was determined according to Eq. 2 as follows.

$$\text{Oxalate} = (\text{titre value} \times 0.9004) \text{ mg/g} \quad 2$$

Determination of phytate: 1.0 g of the powdered sample was weighed into a conical flask and 50 ml of 2% HCl was added and allowed to stand for 3 h. It was filtered through a whatman filter paper and 25 ml of the extract/filtrate was pipette into a conical flask 0.5 ml of 0.3% ammonium thiocyanate solution was added and 53.5 ml of distilled H_2O was also added and then titrated against 0.005 ml standard ferric chloride ($FeCl_3$) solution, the titre value was recorded when a reddish brown appears and persists for 5 mins as indication of phytate presence.

Determination of cyanide: In the extraction method, 5 g of sample was grinded into paste; the paste was then dissolved in 50 ml distilled water in a conical flask. The cyanide extraction was allowed to stay overnight. The extract filtered and the filtrate was used for the analysis.

Preparation of alkaline picrate solution: 1 g of alkaline picrate and 5 g of sodium carbonate were weighed and little quantity of warm distilled water was added. The mixture was transferred into 200 ml volumetric flask and made up to the mark with distilled water. Then 0.25 g of KCN salt was weighed and dissolved in 100 ml volumetric flask as stock cyanide standard solution (1000 ppm). The Working Standard was prepared as follows; 10 ml of the stock of cyanide was pipette into another 100 ml flask and made up to mark (100 ppm). From 100 ppm 0.5 ml, 1.0 ml, 1.5 ml, 2.0 ml, 2.5 ml was pipetted into a 50 ml flask also a blank of standard solution was prepared. 1 ppm, 2 ppm, 3 ppm, 4 ppm, 5 ppm and 0 ppm (blank). 4 ml alkaline picrate solution was added and was prepared and make up to the mark with distilled water. A reddish brown color was developed; it was incubated in a water bath at 60°C for 5 mins and was read spectrophotometrically at 490 nm.

FTIR (fourier transform infrared spectroscopy) analysis: The structural organization of the corn cob extract was investigated to identify the functional group present. The functional groups of the corn cob extract was determined using (FTIR – Perkins Elmer Spectrum BX II) model.

Weight loss analysis: The aluminium coupons dried in the desiccators were carefully weighed and their

respective weights in grams were recorded as the initial weight. Each of the aluminium coupons was placed in different beakers containing the different concentration of the test solution (10% v/v, 20% v/v, 30% v/v, 40% v/v, 50% v/v, 60% v/v, 70% v/v, 80% v/v, 90% v/v, 100% v/v and control). A rubber thread was used to suspend the coupons in the test solutions. The various test solutions containing the coupons were maintained at room temperature. The coupons were retrieved from the test solutions at every 30 minutes interval progressively for 4 hours. At each interval the retrieved coupons were brushed with an iron brush under running tap water and then dipped in ethanol, distilled water, and acetone. After which they were allowed to dry before the final weight was taken. The weight loss was calculated in grams as the difference between the initial weight (w_i) prior to immersion and the final weight (W_f) after removal of the corrosion product from the surface of the coupons by iron brushing. The Weight Loss is determined using Eq. 3 as follows.

$$\text{Weight loss } (\Delta W) = W_i - W_f \quad 3$$

Where: W_i = Initial weight; W_f = Final weight

The percentage inhibition efficiency (IE %) is calculated according to Eq. 4;

$$IE (\%) = \frac{\Delta W_c - \Delta W_i}{\Delta W_c} \times 100 \quad 4$$

Where ΔW_c and ΔW_i are weight loss of metal coupons without and with inhibitor, respectively.

Atomic absorption spectroscopy (AAS) analysis: The concentration of Al in each test solution was determined using atomic absorption spectroscopy (GBC XPLORAA, model). Each of the labeled coupons were dipped in their respective test solutions for a period of 4 h, after which the amount of Al deposited in each of the test solutions was analyzed according to Eq. 5 for percentage inhibition efficiency IE (%) from the AAS data as follows.

$$IE (\%) = \frac{C_o - C_{inh}}{C_o} \times 100 \quad 5$$

Where C_o and C_{inh} are concentrations of iron without and with inhibitor, respectively.

Gasometric experiment: Gasometric experiment is used to determine the amount of hydrogen gas evolved when the metal reacts with the acid. 100ml of the 10% test solution was measured into the reacting vessel of the gasometer. Thereafter, the metal coupon was

introduced into it and then closed properly. The amount of hydrogen gas evolved was recorded after every interval of one minute for a period of 30 mins. The process was repeated for the different test solutions and the percentage inhibition efficiency IE (%) from the gasometric technique data Eq. 6 was calculated as follows.

$$IE (\%) = \frac{V_c - V_{inh}}{V_c} \times 100 \quad 6$$

Where V_c and V_{inh} are volume of gas evolved without and with inhibitor, respectively.

The rate constant (K) is calculated according to Eq. 7 from the weight loss data obtained.

$$K = \frac{2.303 \log W_i}{\text{Time}(t) W_f} \quad 7$$

Where W_i = initial weight, W_f = final weight and Time (t) in mins.

Whereas the surface coverage (θ) is calculated according to Eq. 8 from the weight loss data as follows.

$$\theta = \frac{\Delta W_c - \Delta W_i}{\Delta W_c} \quad 8$$

Where ΔW_c and ΔW_i are weight loss of metal coupons without and with inhibitor, respectively.

The corrosion rate (CR) of Al was calculated according to Eq. 9 as follows.

$$CR = \frac{534 W}{\rho AT} \quad 9$$

Where T is the operational time (h), W is the weight loss of Al, ρ is the density of Al and A is the exposed area to the electrolyte.

Scanning electron microscopy (SEM) analysis: Before and after immersion into the test solutions, images of the Al samples were taken using the scanning electron microscope. The SEM analysis was conducted on a JEOL JSM 6060 microscope with 20 kV to obtain the surface morphology of the pitting corrosion attack on the samples after immersion tests.

RESULTS AND DISCUSSION

Phytochemicals of corn cob: The percentage composition of the different phytochemicals contained in corn cob have been analyzed and presented on Table 2. This shows that the major components of corn cob include phytate (8.08%), followed by alkaloids

(6.01%), flavonoid (2.64%) and others in low percentage composition as shown. It is clear that phytate has the highest percentage composition(8.08%) in corn cob material.

Table 2. Percentage composition of phytochemicals in corn cob

Phytochemicals	Molecular mass of phytochemicals (g/mol)	% Composition
Alkaloids	162	6.01
Flavonoid	293	2.64
Saponin	1233.3	1.15
Phenol	94.11	0.488
Tannin	1701.2	0.268
HCN	27.03	1.95
Phytate	660.029	8.08
Oxalate	128.10	0.62

FTIR(Fourier transform infrared spectroscopy) of corn cob: To identify the functional groups in corn cob extract FTIR was carried out. Fig. 1 shows the FTIR characteristic spectrum of corn cob extract. A stretch at 3438 nm falls within the range of N-H (stretching of amines). A stretch at 2925.63 nm shows the presence of a C-H stretch this suggests the presence of a phytate that has a cyclohexane ring. A stretch at 1642.43nm shows the presence of carboxylic acid C=O. A stretch at 1045 nmsuggests the presence of an alkylamine. A stretch at 2355 nm shows the presence of C=C conjugated acid. The observed functional groups are in line with the phytochemicals already screened in corn cob. The phytochemicals have large molecular mass, contain hetero atoms and pi electrons. The presence of these functional groups indicates the corrosion inhibition potential of the corn cob extract.

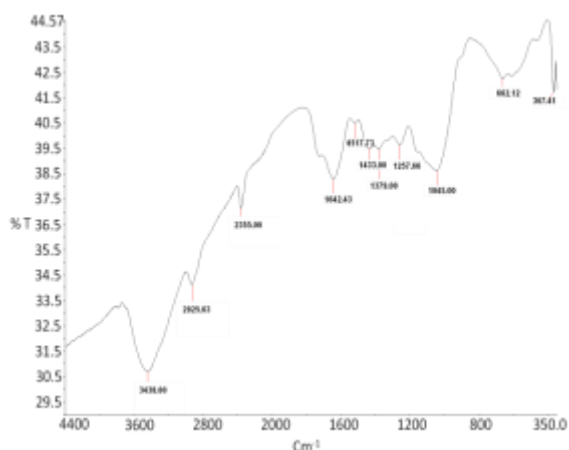


Fig. 1. FTIR analysis of corn cob extract

Weight loss analysis: Fig. 2 presents the analysis of weight loss in grams (g) against time of exposure; this indicates that weight loss increases with increase

in exposure time and decrease in inhibitor concentration. This might be as a result of less active site that are available to bind the metal surface thus exposing the metal to attack by the acid which in-turn leads to further dissolution of the metal in the acidic medium. Also, the weight loss increase with exposure time might be as a result of the inability of the inhibitor to bind to the metal surface for a longer duration in the face of aggressive environment during exposure. At equilibrium the interaction between the adsorbate on the adsorbent and that in the bulk solution makes it difficult for more of the adsorbate to adsorb on the adsorbent, hence reducing inhibition efficiency, thus, exposing the area of metal not properly covered by the adsorbate to further corrosion attack, Niu et al., (1996); Asselin et al., (2007); and Chukwuike et al., (2019).

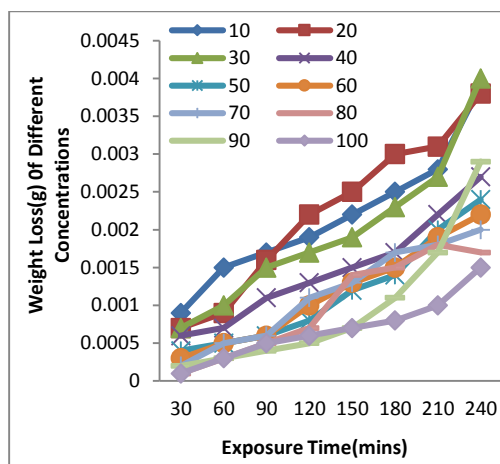


Fig. 2. Weight loss (g) against exposure time of aluminium in 1.0 M H₂SO₄ containing different concentrations of corn cob extract.

The effects of the discussed parameters on the inhibition efficiency during exposure time of Al in 1.0 M H₂SO₄ containing different concentrations of corn cob extract was investigated and presented in Fig. 3. This shows that inhibition efficiency decreases with increase in exposure time. An observation that could be attributed to the adsorbate being unable to adsorb on the adsorbent for a long period of time which in-turn exposes part of the metal surface not properly covered for attack by the acid.

This could be as a result of water molecule penetration from the bulk electrolyte to displace the loosely bound inhibitor film leading to delamination of the previously covered area by the compound. However, there was a clear stability within the duration of 60 to 240 mins as indicated by the straight line exhibited by the curve in Figure 3 which shows a good corrosion protection performance of the inhibitor at different concentrations tested within this time. It equally shows that at a higher concentration the inhibitor ability to

stabilize the metal surface improved drastically as evidence of better protection.

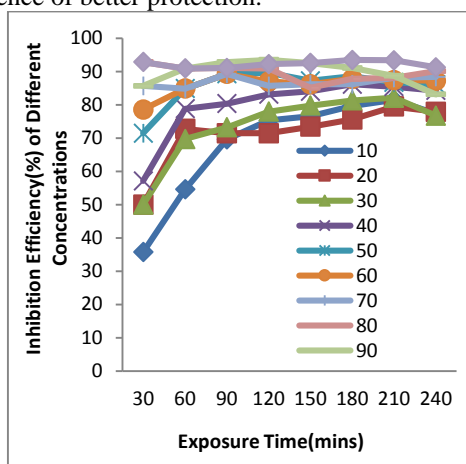


Fig. 3. Inhibition efficiency against exposure time of aluminium in 1.0 M H₂SO₄ containing different concentrations of corn cob extract.

Inhibition efficiency analysis from the different techniques used Weightloss: The weight loss analysis of the inhibition efficiency with different concentrations of corn cob extract in 1.0 M H₂SO₄ was carried out and presented in Fig. 4. This shows that the inhibition efficiency increases with increase in concentration of the adsorbate inhibitor which could correlate to a reduction in the anodic and cathodic reactions resulting from metal surface blockage by the film coverage. This equally indicates that more molecules of corn cob extract adsorb on the metal as its concentration in H₂SO₄ solution increases by the loading of more quantities of the material into the corrosive medium at higher concentration. These phenomena will continue up to the optimum concentration of the extract before reversal could take place as observed in the weight loss analysis. The reason for this is the improved coverage due to the arrival of more molecules of the extract on the metal surface from the bulk solution via diffusion into the double layer. While desorption could dominate at the later stage of the immersion as already discussed, resulting from electrolyte penetration.

AAS Analysis: Similar trend is observed in AAS analysis (Figure 5). Fig. 5 shows that the inhibition efficiency increases with increase in concentration of the adsorbate which implies the slowdown in the electrochemical reactions. This equally helps to confirm the results from the weight loss analysis previously discussed.

Gasometric: Fig. 6 shows that the inhibition efficiency increases with increase in concentration of the adsorbate as final confirmation of the two previous

analyses (weight loss and AAS), making the data strongly reliable. Due to reduction reaction that takes place at the anodic region, hydrogen gas evolution was witness heavily, however by the application of the corn cob green inhibitor the gas pressure was drastically reduced as an evidence of increase in corrosion inhibition efficiency.

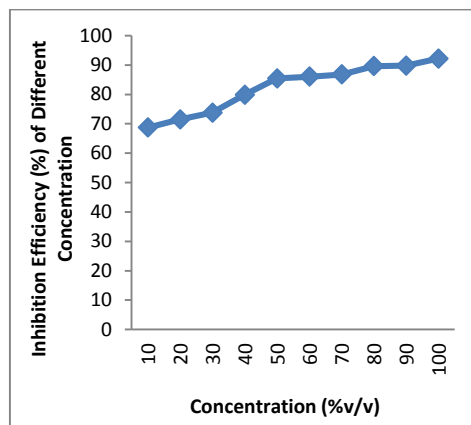


Fig. 4. Inhibition efficiency against different concentrations of corn cob extract in 1.0 M H₂SO₄ for weight loss analysis.

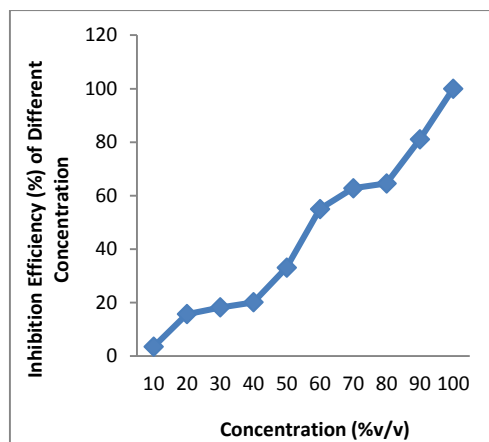


Fig. 5. Inhibition efficiency against different concentrations of corn cob extract in 1.0 M H₂SO₄ for AAS analysis.

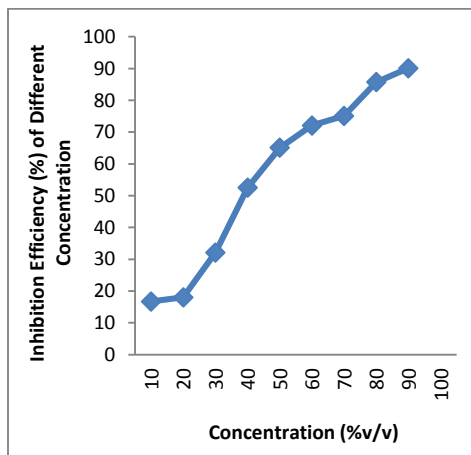


Fig. 6. Inhibition efficiency against different concentrations of corn cob extract in 1.0 M H₂SO₄ for gasometric analysis.

To investigate the direct effect of increased loading of the inhibitor material into the corrosive system, comparison study of the inhibition efficiency as a function of concentration was carried out. Fig. 7 presents the comparison of the inhibition efficiencies against different concentrations of corn cob extract in 1.0 M H₂SO₄ for all the methods used in this research; AAS, gasometric and weight loss analysis. This shows that the inhibition efficiency of the various techniques follows the order weight loss > gasometric > AAS. However, the trending pattern remains the same irrespective of the technique used. The minor differences in the patterns can be attributed to the likely experimental errors associated with the methods such as accuracy in weighing, improper brushing of coupons prior to weighing, improper handling of coupons among others. While gasometric technique the possible leakage of the hydrogen gas from the outlets under the experimental conditions could be the major factor affecting the accuracy of the results. However, combining the three techniques gives the results more credence and reliability.

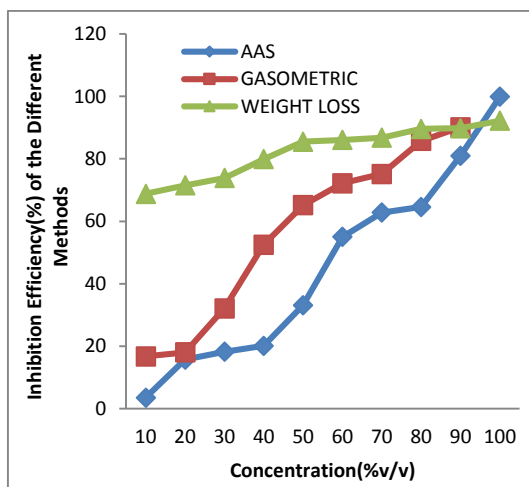


Fig. 7. Comparison of the inhibition efficiency against different concentrations of corn cob extract in 1.0 M H₂SO₄ for AAS, gasometric and weight loss analysis.

Scanning electron microscope (SEM) analysis: Fig. 8 presents the micrographs from SEM images of Al coupons before and after immersion into 1.0 M H₂SO₄ without and with corn cob corrosion inhibitor. This shows that the surface prior to immersion (Fig. 8a) was not affected by any corrosion reaction because it has not made any contact with the corrosive medium. However, the surface becomes heavily damaged by corrosion after immersion in the absence of corn cob extract (Fig. 8b), whereas in its presence the corrosion reaction decreased as evidenced by less corrosion pits

on Fig. 8c. The protected surface was rather smooth and undamaged, confirming the corrosion protection efficiency of the green approach via corn cob extract introduction into the corrosive medium.

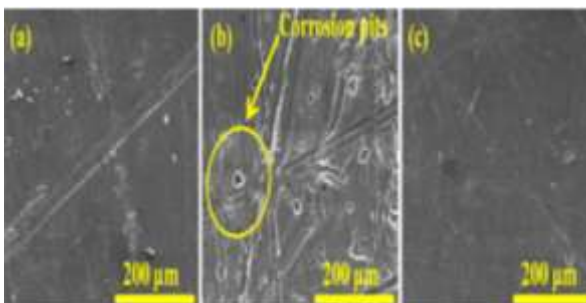


Fig. 8. SEM micrographs of aluminium coupon; (a) before and (b, c) after immersion into 1.0 M H₂SO₄ without and with corn cob corrosion inhibitor, respectively.

Surface coverage: Surface coverage against exposure time of Al in 1.0 M H₂SO₄ containing different concentrations of corn cob extract are examined and presented in Fig. 9. This shows that surface coverage decreases with exposure time and increases with concentration.

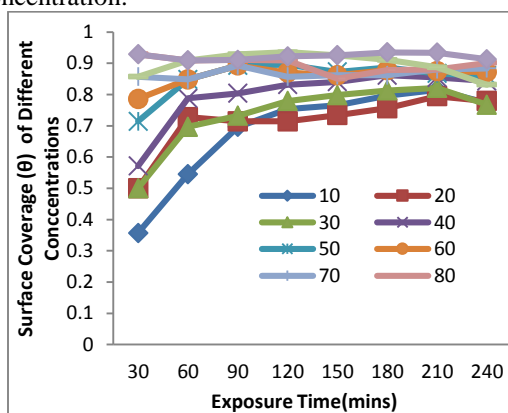


Fig. 9. Surface coverage against exposure time of aluminium in 1.0 M H₂SO₄ containing different concentrations of corn cob extract.

As concentration increases more of the adsorbate are readily available to cover the metal surface hence reducing the area for acidic attack on the metal whereas with increase in time duration, desorption of inhibitor molecules becomes more pronounced as previously displaced water molecules tends to penetrate back into the filmed surface via the pores thus affecting efficacy of the film coverage.

Corrosion rate: The rate at which the metal surface corrodes away when immersed in a corrosive electrolyte was equally of interest in this research and thus was monitored via corrosion rate measurement and subsequent calculations. From the data corrosion rate against exposure time of Al were plotted and presented in Fig. 10. This reveals that corrosion

rate decreases with increase in concentration of the adsorbateinhibitor even in the face of longer exposure duration. This might be as a result of the adsorbate that are readily available to adsorb on the metal surface when larger amount of the inhibitor is introduced into the corrosive medium thus reducing corrosion as evidenced by the surface stability observed from 60 to 240 mins time duration for this accelerated tests.

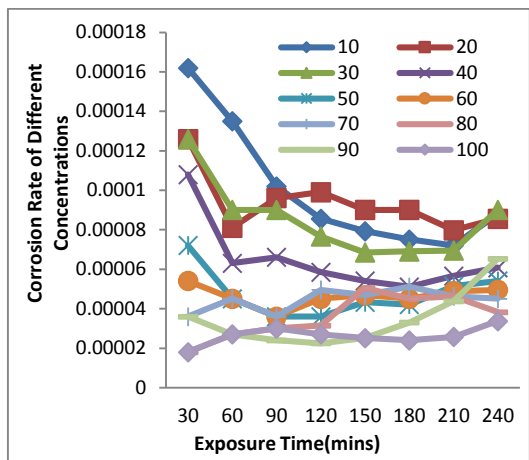


Fig. 10. Corrosion rate against exposure time of aluminium in 1.0 M H₂SO₄ containing different concentrations of corn cob extract.

Adsorption isotherm: Adsorption isotherm plots is a good method to access the mechanism and nature of interaction of the inhibitor molecules on the metal surface, thus different isotherm models such as Langmuir, Temkin and Freundlich were utilized in this work to probe the efficacy of the corn cob extract green inhibitor. Langmuir adsorption isotherm plot for corn cob extract inhibitor on Al is presented in Fig. 11. From the Langmuir Isotherm plot the observed R²-value is 0.9973, R² value > 0.70 indicates a monolayer adsorption, Geethamani *et al.*, (2019); Ragadhita and Nandiyo(2021).

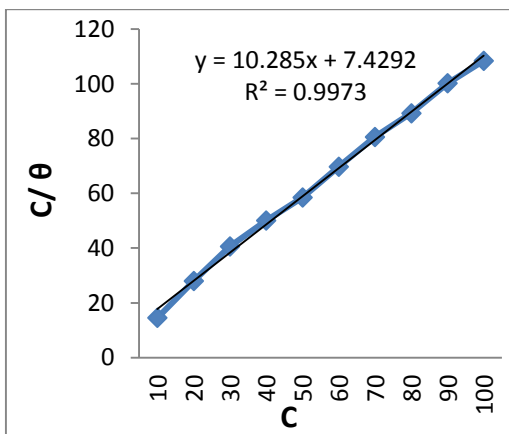


Fig.11. Langmuir adsorption isotherm plot for corn cob extract inhibitor on aluminium.

It was also observed that the slope value was greater than unity which has been explained by Shabanet al., (2015) and other authors, Dehghani *et al.*, (2019); Chukwuike *et al.*, (2021); Abeng *et al.*, (2021) and Khadom *et al.*, (2021), where they suggested that one or more of each inhibitor unit occupies more than one adsorption site; therefore, there are interactions between adsorbed species on the metal surface or the adsorption heat (enthalpy) changes with increasing surface coverage. Fig. 12 shows Temkin isotherm plot for corn cob extract inhibitor on Al. From the Temkin isotherm plot the R² value is 0.9291 Geethamani *et al.*, (2019), R² > 0.70 indicates uniform distribution of adsorbate to adsorbent surface. Also, from the Temkin isotherm plot the calculated B_T (heat of adsorption) value is 94KJ/mol and according to the group, B_T > 8KJ/mol suggests a chemical interaction between adsorbate molecules and the metal surface.

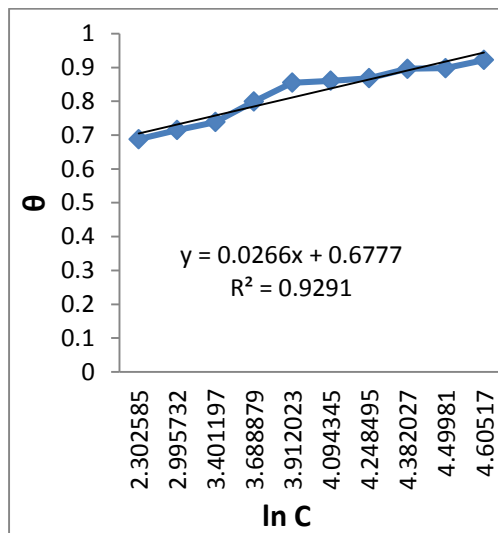


Fig. 12. Temkin isotherm plot for corn cob extract inhibitor on aluminium.

Fig. 13 shows the Freundlich isotherm plot for corn cob extract inhibitor on Al. Freundlich isotherm describes physical type of adsorption, multilayer adsorption with weak Van der waal forces as well as heterogenous sites of adsorption, Shaban *et al.*, (2015); N'guessan *et al.*, (2018) and Qiang *et al.*, (2021). From the Freundlich isotherm plot the R² value is 0.9159 and the observed n (slope) value is (0.0331); R² > 0.70 shows a multilayer adsorption while n < 1 value indicates that the adsorption process is with chemical interaction between adsorbate molecules and the metal Geethamani *et al.*, (2019). From the thermodynamics of the corrosion process, the calculated Gibb's free energy -15.991KJ/mol shows that the adsorption reaction is spontaneous. Therefore, the three isotherm methods conclude that corn cob extract inhibitor adsorbs on the Al surface via chemical and physical

adsorption with a multilayer of molecules lying horizontally for proper protection of Al metal, Qiang et al., (2017); Qiang et al., (2019); Guo et al., (2020); and Chukwuike and Barik (2021).

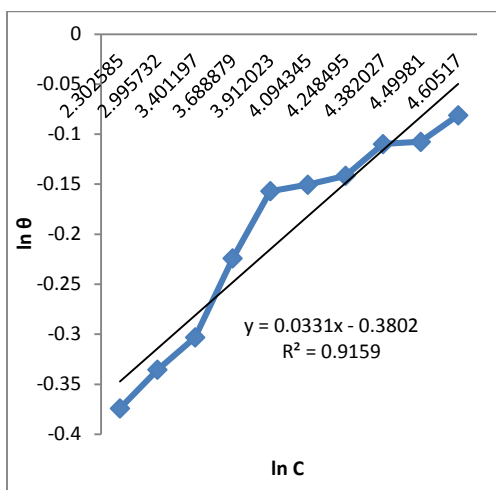


Fig.

13. Freundlich isotherm plot for corn cob extract inhibitor on aluminum.

Conclusion: The corrosion protection strength of corn cob extract on Al in 1.0 M H₂SO₄ solution has been successfully investigated. The molecules of the inhibitor extract got adsorbed on the Al surface via a combination of chemical and physical adsorption. The performance of the adsorbate from the different techniques employed revealed good inhibition efficiency. The Gibbs' free energy value indicates that the adsorption reaction is spontaneous. The Langmuir and Temkin isotherms best explain the reaction mechanism as chemisorptions with multilayer film.

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