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(RESEARCH ARTICLE)

EFFECTS OF *CAPSICUM ANNUUM* AND *MURRAYA KOENIGII* EXTRACTS ON THE CORROSION OF ALUMINIUM IN ACIDIC AND ALKALINE MEDIA

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ABSTRACT

The corrosion behavior of aluminium in acidic and alkaline environments was investigated using weight loss and electrochemical techniques. The effect of ethanol extracts of *Capsicum annuum (*Tatasi) fruits and *Murraya koenigii* (Curry) leaves, on the corrosion behavior of the metal was also investigated. Weight loss study revealed that *C.annuum* in 0.1MHCl with 73.8% inhibition efficiency, has a moderate protection, concentration - dependent effect. In 0.5MKOH, with 69.8% inhibition efficiency, it is a promising relative performance, but absolute alkaline mass loss remains very high and practical suitability is not established . *M koenigii* in 0.1 M HCl with 70.0 %, indicates a moderate inhibition efficiency in acidic medium and should be supported by replicate electrochemical parameters. *M.koenigii* in 0.5M, with 32.2 %, is weak inhibition. The corrosion rate was also assessed and was found to decrease with increase in extracts concentration. Hence, corrosion rate is inversely proportional to the concentration of the extracts. Thus, *C.annuum* exhibited a better corrosion inhibiting effect than *M.koenigii.* Generally, Inhibition efficiency increased with increase in the concentration of the extracts. Polarization studies revealed that the plant extracts functioned by mixed inhibition mechanism in 0.1M HCl but anodic mechanism in 0.5M KOH.

Key words: Corrosion, *Capsicum annuum*, *Murraya Koenigii*, Aluminium.

1 INTRODUCTION

Metallic materials are still the most widely used group of materials, particularly in mechanical engineering and transportation industries. (Buchweishaija, 2009) noted that metals are commonly used in electronics, and increasingly also in the construction industry [1]. However, the usefulness of metals and alloys is constrained by one common problem known as corrosion. (Raja and Sethuraman, 2009) defined corrosion as disastrous damages to metals and alloy structures in diverse environments, which causes economic waste due to repair, replacement, product losses, safety and environmental pollution[2]. Due to these harmful effects, corrosion is an undesirable phenomenon that has to be prevented. It results to spontaneous destruction of metallic surfaces or alloys, by chemical or electrochemical reaction

with their environment [3]. Refined metals have the tendency of reverting back to their natural state (ore), by reacting with oxygen and water in their environment. In daily life, corrosion manifests itself in many forms, such as corroded automobiles, nails, pipes, pots, pans and shovels; rusting of iron and steel structures such as pipelines, machinery, buildings, bridges, etc, which often have catastrophic consequences, including environmental degradation, and even loss of lives. One of the most serious problems in modern societies, is that caused by corrosion, and it affects these sectors: oil and gas, chemical allied industries, utilities, transportation, electronic, medical, etc. Corrosion is a costly materials science problem.

2 MECHANISM OF ALUMINIUM CORROSION

Aluminum alloys are widely used in structures, where a high strength to weight ratio is important, such as, in the transportation industry [4] (Davis, 1987). The actual mechanism of the corrosion of aluminium and its alloys is extremely complex and embraces the fields of chemistry and electro-chemistry. Aluminium will corrode only in the presence of both water and oxygen, forming aluminium oxide. There are always two distinct chemical reactions in the corrosion process;

Anodic process;

$Al = Al^{3+} + 3e^-$ (1)

$Al^{3+} + 3H_2O = Al(OH)_3 + 3H^+$ (2)

While hydrogen evolution and oxygen reduction are the important reduction processes at the cathode, as shown in the equations below:

Cathodic process;

$2H^+ + 2e^- = H_2$ (in acidic medium) (3)

$O_2 + 2H_2O + 4e^- = 4OH^-$ (in neutral/ alkaline medium) (4)

3 NATURAL PRODUCTS AS CORROSION INHIBITORS

3.1 Phytochemical basis and adsorption mechanism .

The efficacy of plant extracts as corrosion inhibitors is attributed to the presence of heterocyclic constituents containing polar functional groups with heteroatoms and multiple bonds that can donate lone pairs of electrons to the vacant orbitals of the metal surface to form protective films [5].

Capsicum annuum fruit contains capsaicin (8 - methyl - N - vanilla - 6 - noneamide), dihydrocapsaicin, flavonoids, tannins and ascorbic acid. Capsaicin possesses amide nitrogen, phenolic - OH, methoxy and carbonyl oxygen groups which provide multiple adsorption centres on aluminium via physisorption and chemisorption following Langmuir and Temkin isotherms [6].

Moussaoui et al. (2025) confirmed that O and N - containing Phytochemicals from agro - waste strongly adsorb on aluminium alloy in HCl via donor- acceptor interactions [7].

Murraya koenigii leaves are rich in carbazole alkaloids (murrayanine, mahanimbine, koenigine, koenimbine), flavonoids, phenolics and essential oils [8].

The carbazole nucleus contains a pyrrolic nitrogen and aromatic pie electrons capable of forming coordinate bonds with aluminium ions on the metal - solution interface.

3.2 Environmental and toxilogical superiority .

These plants are green, biodegradable, non - toxic and renewable, aligning with green chemistry principles for sustainable corrosion control [9].

3.3 Availability and economic viability in Nigeria .

Both plants are abundantly cultivated in Nigeria and available in local markets in Owerri at low cost compared to imported synthetic inhibitors.

Capsicum annuum is a common spice with post - harvest waste, while *murraya koenigii* is grown domestically as curry leaf, making large - scale extraction economically feasible for small industries.

This justifies their selection over exotic plants requiring importation.

Objectives of study

- To determine the corrosion rate of aluminium in 0.1MHCl and 0.5M KOH in the absence and presence of *capsicum annuum* and *murraya koenigii* extracts.
- To estimate the corrosion inhibition efficiency of the extracts in each aggressive medium.
- To assess the effect of extract concentration on inhibition efficiency
- To determine the overall suitability of the extracts for corrosion protection of aluminium immersed in acid

4 MATERIALS AND METHODS

4.1 MATERIALS PREPARATION

4.1.1 METAL SPECIMEN

A commercially pure aluminium specimen was used for this study. Each sheet, which was 0.1cm in thickness, was mechanically pressed-cut into coupons of 1cm×1cm× 0.1cm. These coupons were used without further polishing but were degreased in absolute ethanol, dried in acetone, weighed and stored in moisture free desiccators prior to use.

4.1.2 REAGENTS

All reagents were BDH analytical grade and used as source without further purification. Distilled water was used for all solution preparation. 0.1 M HCl and 0.5 M KOH solutions were used as corrodents.

4.1.3 EXTRACTION PROCEDURE

Fresh fruits of c*apscuum annuum* and leaves of m*urraya koenigii* were obtained at Ekeonunwa market, Owerri. Their aqueous extracts used as inhibitors were obtained by sun drying the fresh plants to a constant weight. The dried plants were ground into powder using an electric blender. 10 g of the ground plants were added into 400 ml of ethanol contained in a 500 ml round bottom flask. The resulting solution was heated under reflux for 3h; the filtrate obtained was measured and stored in air tight container and kept away from the sun. The residue obtained was dried and weighed. Thereafter, it was used in the determination of the amount of dissolved plant material in the ethanol. The stock solution was diluted with the corrodents to get different concentrations of the extract; 200 mg/L, 400 mg/L, 600 mg /L, 800 mg/L and 1000 mg/L.

4.1.4 GRAVIMETRIC MEASUREMENTS

Gravimetric experiments were conducted on test coupons of dimension 1cm × 1cm × 0.1cm, under total immersion conditions in 250ml of test solutions at room temperature. All tests were made in aerated and unstirred test solutions. With 0.1 M HCl as corrodent, test coupons were retrieved at 72 h intervals progressively for 216 h, scrubbed with bristle brush, washed, dried and reweighed. With 0.5 M KOH, test coupons were retrieved at 6h interval.

These coupons were subsequently scrubbed with bristle brush, washed, dried and reweighed. The weight loss was taken as the difference between the initial and final weights of the coupons. Measurements were undertaken using a FAJA weighing balance of range 0.001 to 200 g.

4.1.5 ELECTROCHEMICAL STUDIES

Electrochemical experiments were conducted in a Model K0047 corrosion cell using a VERSASTAT 400 complete DC voltameter and corrosion system with V3 studio software. The data was obtained in a three - electrode mode, with a graphite rod and saturated calomel electrodes as counter and reference electrodes respectively. The material used for constructing the working electrode was aluminium that had dimensions 1cm × 1cm× 0.1 cm. Measurements were performed in aerated and unstirred solutions at the end of 1h of immersion at 303K. Potentiodynamic polarization studies were carried out in a potential range ± 250 mV versus corrosion potential, at a scan rate of 0.333 mV/S. The aluminium was encapsulated in epoxy resin in such a way that only one surface was left uncovered. The exposed area ($1cm^2$) was mechanically abraded with emery papers of variable grades. The samples were then washed thoroughly with distilled water, followed by A.R. acetone, dried before insertion in the cell. Each test was run in duplicate to verify the reproducibility of the system. Temperature control was achieved using a thermostatted water bath. 200 mg/L and 1000 mg/L of the extracts were investigated.

5 RESULTS

As a consequence of the reactions mentioned earlier in equations 1, 2 and 3 including the high solubility of the corrosion products, the metal loses weight in the solution. The results for the gravimetric measurements are shown in Tables 1 - 8, while that from electrochemical measurements is presented in Table 9.

Corresponding plots are presented in Figures 1-4 and Figures 5-8 respectively.

Table 1: Weight loss and inhibition efficiency values for aluminium corrosion in 0.1 M HCl without and with ethanol extract of *capsicum annuum* after 72h.

Extract conc (mg/L)	Initial weight (g)	Final weight (g)	Average weight loss (g)	Inhibition Efficiency (IE %)	Corrosion rate (mm/y)
Blank A	2.3882	2.3802	0.0080		3.6409
B	2.2946	2.2866			
200 A	2.3010	2.2966	0.0044	45.0	1.9827
B	2.3818	2.3774			
400 A	2.3412	2.3370	0.0042	47.5	1.8926
B	2.2526	2.2484			
600 A	2.4712	2.4672	0.0040	50.0	1.8025
B	2.2986	2.2946			
800 A	1.9632	1.9598	0.0034	57.5	1.5321
B	1.9976	1.9942			
1000 A	2.2259	2.2238	0.0021	73.8	0.9430
B	2.3113	2.3092			

Table 2: Weight loss and inhibition efficiency values for aluminium corrosion in 0.1 M HCl without and with ethanol extract of *capsicum annuum* after 144h.

Extract conc (mg/L)	Initial weight (g)	Final weight (g)	Average weight loss (g)	Inhibition Efficiency (IE %)	Corrosion rate (mm/y)
Blank A	2.3802	2.3692	0.0110		4.9568
B	2.2866	2.2756			
200 A	2.2966	2.2895	0.0071	35.5	3.1994
B	2.3774	2.3703			
400 A	2.3370	2.3311	0.0059	46.4	2.6586
B	2.2484	2.2428			
600 A	2.4672	2.4616	0.0056	49.1	2.5235
B	2.2946	2.2890			
800 A	1.9942	1.9889	0.0053	51.8	2.3883
B	1.9598	1.9545			
1000 A	2.2238	2.2187	0.0051	53.6	2.981
B	2.3092	2.3041			

Table 3: **Weight loss and inhibition efficiency values for aluminium corrosion in 0.1 M HCl without and with ethanol extract of *capsicum annuum* after 216h**

Extract conc (mg/L)	Initial weight(g)	Final weight (g)	Average weight loss (g)	Inhibition Efficiency (IE%)	Corrosion rate (mm/y)
Blank A	2.3692	2.3561	0.0131		5.9031
B	2.2756	2.2625			
200 A	2.2895	2.2805	0.0090	31.3	4.1006
B	2.3703	2.3613			
400 A	2.3311	2.3237	0.0074	43.5	3.3346
B	2.2428	2.2354			
600 A	2.4616	2.4546	0.0070	46.6	3.1542
B	2.2890	2.2820			
800 A	1.9545	1.9480	0.0065	50.4	2.9290
B	1.9889	1.9824			
1000 A	2.2187	2.2125	0.0062	52.7	2.7938
B	2.3041	2.2979			

Table 4: Weight loss and inhibition efficiency values for aluminium corrosion in 0.1 M HCl without and with ethanol extract of *murraya koenigii* after 72h.

Extract conc (mg/L)	Initial weight (g)	Final weight (g)	Average weight loss (g)	Inhibition Efficiency (IE%)	Corrosion rate (mm/y)
Blank A	2.1830	2.1750	0.0080		3.6049
B	2.5400	2.5320			
200 A	2.4431	2.4371	0.0060	25.0	2.7037
B	2.1593	2.1533			
400 A	2.2285	2.2189	0.0048	40.0	2.1630
B	2.3121	2.3073			
600 A	2.7111	2.7072	0.0039	51.3	1.7574
B	1.9472	1.9433			
800 A	2.3815	2.3787	0.0038	65.0	1.7574
B	2.3331	2.3303			
1000 A	2.4664	2.4640	0.0024	70.0	1.0815
B	2.0113	2.0089			

Table 5: Weight loss and inhibition efficiency values for aluminium corrosion in 0.1 M HCl without and with ethanol extract of *murraya koenigii* after 144h.

Extract conc (mg/L)	Initial weight (g)	Final weight (g)	Average weight loss (g)	Inhibition Efficiency (IE%)	Corrosion rate (mm/y)
Blank A	2.1750	2.1640	0.0110		4.9568
B	2.5320	2.5260			
200 A	2.4371	2.4286	0.0085	22.7	3.8302
B	2.1533	2.1448			
400 A	2.3073	2.3005	0.0068	38.2	3.0642

	B	2.2189	2.2121			
600	A	2.7072	2.7013	0.0059	46.4	2.6586
	B	1.9433	1.9374			
800	A	2.3787	2.3747	0.0040	63.6	1.8025
	B	2.3303	2.3263			
1000	A	2.4640	2.4605	0.0035	68.2	1.5772
	B	2.0089	2.0054			

Table 6 Weight loss and inhibition efficiency values for aluminium corrosion in 0.1 M HCl without and with ethanol extract of *murraya koenigii* after 216h

Extract conc (mg/L)	**Initial weight (g)**	**Final weight (g)**	**Average weight loss (g)**	**Inhibition Efficiency (IE%)**	**Corrosion rate (mm/y)**
Blank A	2.1640	2.1509	0.0131		5.9031
B	2.5260	2.5129			
200 A	2.4286	2.4181	0.0105	19.9	4.7315
B	2.1448				
400 A	2.3005	2.2915	0.0090	31.3	4.0556
B	2.2121	2.2031			
600 A	2.7013	2.6935	0.0078	40.5	3.5148
B	1.9374	1.9296			
800 A	2.3747	2.3695	0.0052	60.3	2.3432
B	2.3263	2.3211			
1000 A	2.4605	2.4560	0.0045	65.7	2.0278
B	2.0054	2.0009			

Table 7: Weight loss and inhibition efficiency values for aluminium corrosion in 0.5 M KOH without and with ethanol extract of *capsicum annuum* after 6h.

Extract conc (mg/L)	Initial weight (g)	Final weight (g)	Average weight loss (g,)	Inhibition Efficiency (IE %)	Corrosion rate (mm/y)
Blank A	2.4105	0.8591	1.5514		8389.0519
B	2.0703	0.5189			
200 A	2.1331	0.6551	1.4780	04.7	7992.1481
B	2.4045	0.9265			
400 A	2.7155	1.4066	1.3089	15.6	7077.7556
B	1.9993	0.6904			
600 A	2.2874	1.6350	0.6524	58.0	3527.7926
B	2.3284	1.6760			
800 A	1.9253	1.3995	0.5258	66.1	2843.2148
B	2.6845	2.1555			
1000 A	2.6845	2.1587	0.5358	69.8	2843.2148
B	2.0267	1.5009			

Table 8: Weight loss and inhibition efficiency values for aluminium corrosion in 0.5 M KOH without and with ethanol extract of *murraya koenigii* after 6h.

Extract conc (mg/L)		Initial weight (g)	Final weight (g)	Average weight loss (g)	Inhibition Efficiency (IE %)	Corrosion rate (mm)
Blank	A	1.9934	0.4420	1.5514		8389.0519
	B	2.0388	0.4874			
200	A	2.3421	0.9037	1.4384	07.3	7778.0148
	B	2.2631	0.8247			
400	A	2.2613	1.3169	1.3244	14.6	7161.5704
	B	2.1169	0.7925			
600	A	2.4003	1.1539	1.2464	19.7	6739.2519
	B	2.1333	0.8769			
800	A	2.1363	0.9710	1.1653	24.9	6301.2519
	B	2.5111	1.3458			
1000	A	2.6423	1.5900	1.0523	32.2	5690.2148
	B	2.0717	1.0194			

Table 9: Kinetic parameters from Tafel polarization of aluminium in 0.1 M HCl and 0.5 M KOH in the absence and presence of *murraya koenigii* and *capsicum annuum* .

System	Ecorr	Icorr	Inhibition Efficiency(IE %)	Corrosion rate (mm/y)
Blank : 0.1 M HCl	-470.38	269		2.9294
MK : 1000mg	-472.6	87.9	67	0.9572
CA : 1000mg	-483.1	44.9	83.3	0.4890
Blank: 0.5M KOH	-582.4	118		1.2850
MK : 1000mg	-488	63.3	46.4	0.6893
CA :1000mg	-481	39.9	66.2	0.4345

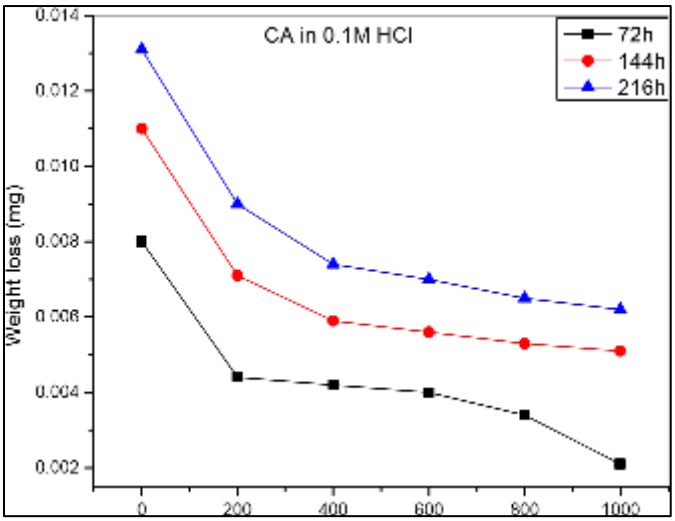


Figure 1: Variation of weight loss with concentration for aluminum corrosion in 0.1 M HCl in the presence of ethanol extract of *capsicum annuum* for different exposure times.

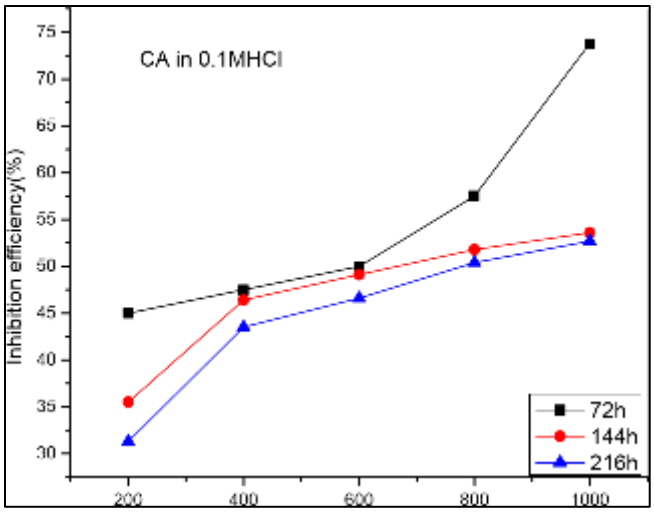


Figure 2: Variation of inhibition efficiency with concentration for aluminium corrosion in 0.1 M HCl in the presence of ethanol extract of *capsicum annuum* at 30°C.

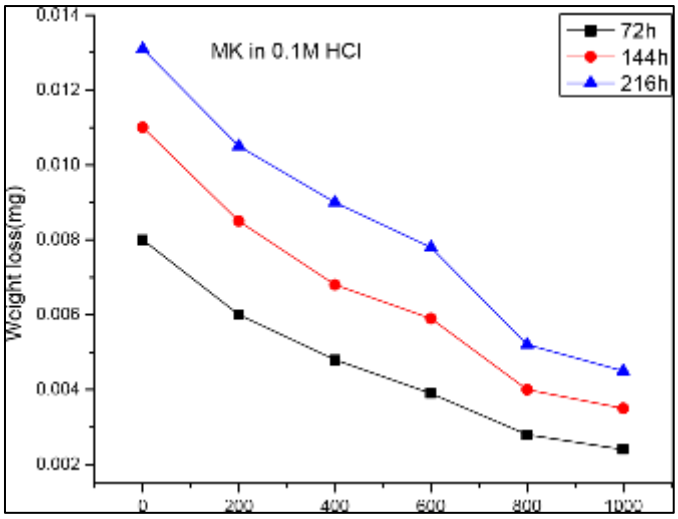


Figure 3: Variation of weight loss with concentration for aluminium corrosion in 0.1 M HCl in the presence of ethanol extract of *murraya koenigii* for different exposure times.

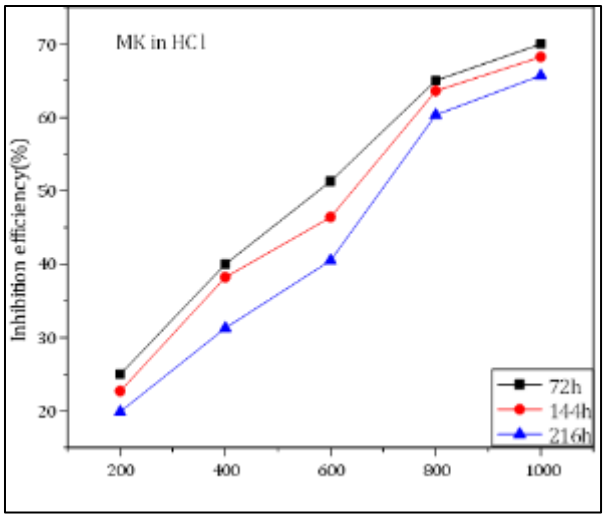


Figure 4: Variation of inhibition efficiency with concentration for aluminium corrosion in 0.1 M HCl in the presence of ethanol extract of *murraya koenigii* 30°C.

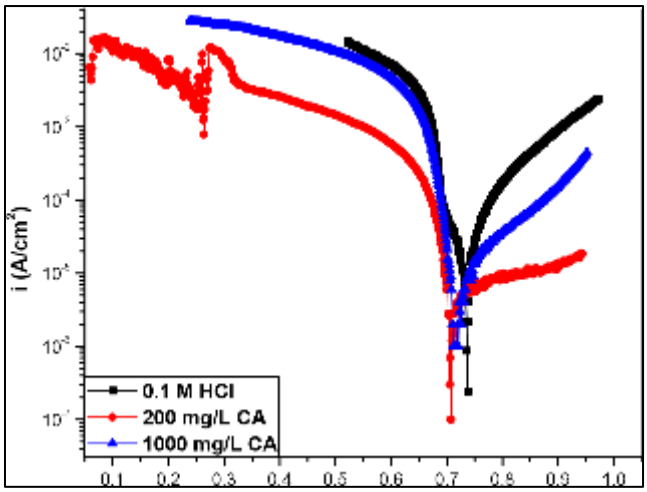


Figure 5: Potentiodynamic polarization curves for Al in 0.1 M HCl in the presence and absence of 200 mg/L and 1000 mg/L concentration of *capsicum annuum* extracts.

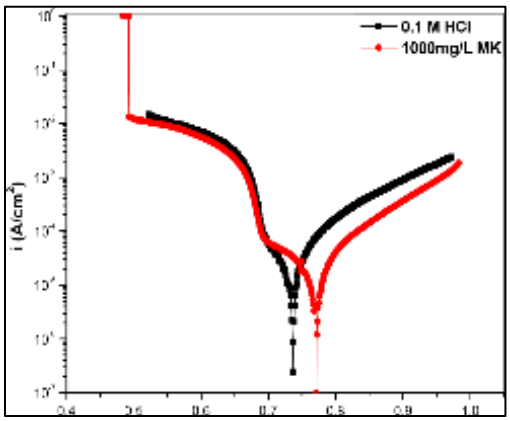


Figure 6: Potentiodynamic polarization curves for Al in 0.1 M HCl in the presence and absence of 1000 mg/L concentration of murraya *koenigii extracts*.

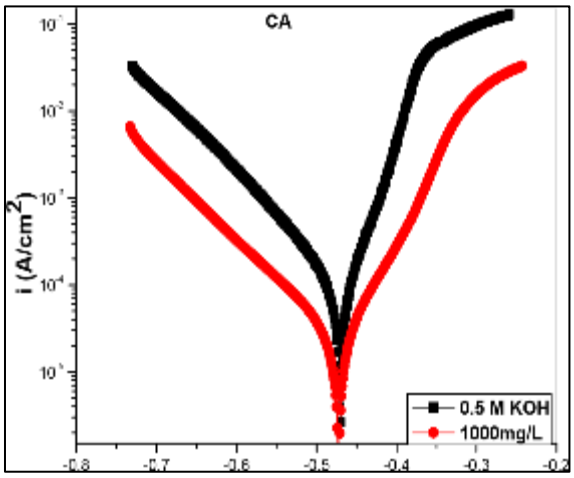


Figure 7: Potentiodynamic polarization curves for Al in 0.5 M KOH in the presence and absence of 1000 mg/L concentration of *capsicum annuum* extracts.

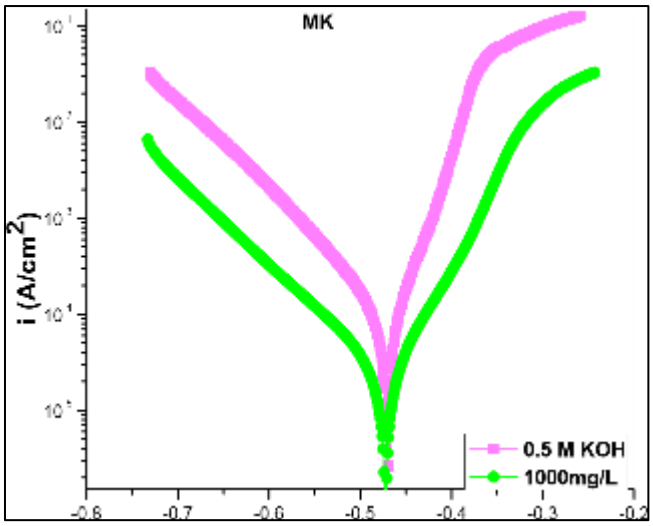


Figure 8: Potentiodynamic polarization curves for Al in 0.5 M KOH in the presence and absence of 1000 mg/L concentration of *murraya koenigii* extracts.

6 DISCUSSION

6.1 Corrosion inhibition by *Capsicum annuum* (CA) extract

Figure 1 shows plots of weight loss versus concentration in 0.1 M HCl and in the presence of CA respectively for different concentrations for different periods. The plots indicate that CA actually retarded the corrosion of aluminium in 0.1 M HCl. Table 7 shows the data for the inhibition of aluminium corrosion by CA in 0.5 M KOH and it shows that weight loss decreased with increase in CA concentration. However, the weight loss in 0.5 M KOH is higher than in 0.1 M HCl.

6.2 Inhibition efficiency

The characterization of the free corrosion of aluminium in the presence of CA/Corrodent solution was carried out by an assessment of the inhibition efficiency (IE %) defined by:IE%= $(1-W_1/W_2) \times 100$

Where,

W_1 and W_2 are the corrosion rates in inhibited and uninhibited corrodent respectively. The calculated values are given in Tables 1-3 (for different immersiom times) and the plots in Figure 2. The plots show that IE% increased with increase in CA concentration. This suggests that at higher concentration, more extract was adsorbed on the metal surface leading to greater surface coverage. A maximum of 73.8% inhibition efficiency was obtained.

In 0.5 M KOH, inhibition efficiency also increased with increase in CA concentration which suggests that more extract was adsorbed on the metal surface at higher concentration, leading to greater surface coverage. A maximum of 69.8% inhibition efficiency was obtained.

6.3 Standard deviation

The standard deviation of each trial was calculated using;

$$\text{S.D.} = \sqrt{\sum_{(i=1)}^{n} \frac{\{I.E_i - |\ \overline{I.E}\}_2}{n-1}}$$

Where,

I.E.= individual inhibition efficiency value from each replicate trial,

$\overline{I.E}$.= mean inhibition efficiencyof all trials,

n =number of replicate measurements

6.4 Corrosion rate

The corrosion rate was also evaluated using;

$$CR = \frac{K \times W}{D \times A \times T}$$

Where,

CR=corrosion rate

K= a constant , a mathematical scaling factor used to convert the dimensions into standard engineering or scientific corrosion rate units,

A=the exposed surface area of the metaltest coupon in cm^2

D= the specific mass per unit volume of the tested metal in g/cm^3

T=the precise duration the metal coupon stays exposed inside the corrosive test environment in hour

6.5 Potentiodynamic polarization results

To evaluate the effect of CA on the electrochemical behavior of aluminium, cathodic, as well as anodic polarization studies were carried out. The potentiodynamic curves for aluminium in 0.1 M HCl and 0.5 M KOH without and with CA extracts are presented in Figures 5 &7. These tell us the effect of the CA extract on anodic and cathodic half reactions. The values of the electrochemical parameters E_{corr} and I_{corr} obtained from the polarization curves are summarized in Table 9. It can be seen that the E_{corr} shifted slightly in the negative direction in the presence of CA extracts. In HCl, E_{corr} shifted slightly to the positive direction, showing greater barrier for cathodic hydrogen proton discharge. Despite this, CA is regarded as a mixed-type inhibitor because of the effect on the cathodic and anodic parts of the curves. The value of the corrosion current (i_{corr}) decreased on addition of CA extract (ie 1000mg/L). However, in 0.5 M KOH,E_{corr} is greater than + 85 mV to the positive side, thus C.annuum behaved as anodic inhibitor. Inhibition efficiency was calculated from the i_{corr} values in the absence and presence of extract using the equation below:

I.Ei % = (1-iinh / icorr)

Where; $I.E_i$ % = inhibition efficiency of the extract

$i_{corr.}$= current density in the absence of inhibitor

I_{inh} = current density in the presence of inhibitor

The inhibition efficiency increased with the addition of the extract.

Corrosion inhibition by Murraya koenigii (MK)

Figure 3 shows plots of weight loss versus concentration in 0.1 M HCl and the presence of different concentrations of MK respectively. The plots show that MK fairly retarded the corrosion of aluminium in HCl but rarely affected aluminium corrosion in KOH. Hence, MK does not actually afford corrosion inhibition of aluminium in KOH.

6.6 Inhibition efficiency

The characterization of the free corrosion of aluminium in the presence of MK/Corrodent solution was carried out by assessment of the IE% defined by:

$I\ \% = (1-W_1/W_2) \times 100$

Where,

W_1& W_2 are the corrosion rates in inhibited and uninhibited corrodent respectively. The calculated values are given in Tables 4 to6 and the plots in Figures3 and 4. The results show that IE% increased with increase in concentration of MK. A maximum of 70.0% inhibition efficiency was observed in 0.1 M HCl and 32.2% in 0.5 M KOH. MK can be recommended for inhibition of aluminium corrosion in 0.1 M HCl but not in 0.5 M KOH.

6.7 Potentiodynamic polarization results

The potentiodynamic polarization curves for MK are presented in Figures 7 & 8. These tell us the effect of the MK extract on the anodic and cathodic half reactions. To evaluate the effect of MK on the electrochemical behavior of aluminium, cathodic as well as anodic polarization studies were carried out. The values of the electrochemical parameters E_{corr} and i_{corr} are presented in Table 9. The results show that MK inhibited the anodic reaction; therefore, it is ananodic inhibitor. Comparing the polarization results of CA and MK, CA is a better inhibitor than MK which is in line with the gravimetric results.

7 CONCLUSION

Ethanol extracts of *C. annuum* and *M.koenigii* reduced the corrosion of aluminium in 0.1 MHCl, with inhibition efficiency increasing with extract concentration under the tested conditions.*C. annuum* also showed moderate inhibition in 0.5M corrosive medium, while *M. koenigii* gave weak protection in acidic medium extract concentration under the tested conditions. *C. annuum* also showed moderate inhibition in 0.5MKOH, whereas *M.Koenigii* gave weak protection in that alkaline medium.Polarization results indicate that the extracts influenced both anodic & cathodic processes in 0.1M HCl but only anodic process in 0.5M KOH. Further work involving replicated measurements, extract characterization, surface analysis, adsorption thermodynamics, temperature effects, and long term testing is required before practical application can be inferred.

STATEMENTS ON COMPLIANCE WITH ETHICAL APPROVAL

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The authors have no known competiting financial interests or personal relationships that could have appeared to influence the work reported in this paper. The plant materials were obtained from local markets in Owerri, Imo State, Nigeria and no commercial entity influenced the study, design extraction, or interpretation of corrosion data.

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