Lafia Journal of Scientific & Industrial Research (LJSIR), Vol. 2(1), 2024
e-ISSN:... p-ISSN: 3026 – 9288 pages: 1 – 4
https://lafiascijournals.org.ng/index.php/ljsir/index ⇒ Published by the Faculty of Science
Federal University of Lafia, Nasarawa State, Nigeria

Synsepalum dulcificum Extract as Green Corrosion Inhibitor for Acid Corrosion of Mild Steel in HCl Solution

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Abstract

Anticorrosive potential of *Synsepalum dulcificum* leaf extract on the corrosion of mild steel in HCl solution was investigated using chemical technique. The extract inhibited the deterioration of mild steel in HCl solution and the inhibition efficiency increased with increasing concentration of the extract at 30°C. The results obtained showed that inhibition was as a result of the adsorption of the inhibitor molecule onto mild steel surface and the adsorption obeyed Flory-Huggins adsorption isotherm.

Keywords: Mild steel, chemical technique, anticorrosive potential, adsorption, *Synsepalum dulcificum*, Flory-Huggins

Article History
Submitted
November 27, 2023
Revised
January 05, 2024
First Published Online
February 15, 2024

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doi.org/10.62050/ljsir2024.v2n1.273

Introduction

Mild steel is extensively used in industrial engineering to undertake the tasks of transportation of water, petroleum products, and chemicals [1]. Nevertheless, it is liable to corrosion, most especially in circumstances of acid pickling for the purpose of removing scales or rusts, and as a result providing clean surface for pre-passivity treatment [1, 2].

Among a host of corrosion mitigation schemes, anticorrosive materials have been considered as the most promising measure to retard the metal dissolution process due to the advantages of high efficiency and strong practicability [2-7]. However, increasing awareness on environmentally friendly practices for sustainable development has led to a tremendous increase in demand for non-toxic anticorrosive materials to replace the toxic ones. Thus, lately, several plant extracts [4, 5, 8, 10–21] have been investigated for the degradation of metals in acid media. This is because plants contain naturally synthesized chemical compounds that are readily available, harmless to the environment, cost effective, biodegradable, and renewable source of materials [12-14, 18].

Extensive literature search revealed that there is no reported work on the effects of *Synsepalum dulcificum* leaf extract on mild steel corrosion in HCl solution. Therefore, we deemed it fit to study and report on both the mitigation of mild steel corrosion by *S. dulcificum* leaf extract and its effects on the kinetics of corrosion process of mild steel in 1.0M HCl solution using weight loss technique.

Materials and Methods

Materials preparation

The mild steel coupons used for the corrosion studies were prepared from a rectangular mild steel plate of thickness 0.1 cm. These coupons mechanically press-cut (4 x 2 x 0.1 cm) were used without further polishing so as to ensure a reproducible surface. However, the specimens were degreased in absolute ethanol, dried using acetone and stored in desiccators prior their use [8].

Stock solution of *Synsepalum dulcificum* leaf extract was prepared by refluxing 10 g of the dried powdered leaves of *S. dulcificum* plant for about 1 h in 200 ml 1.0M HCl solution. The refluxed solution was allowed to stand for 8 h before filtering. The filtrate was stored and later diluted with the appropriate amount of 1.0M HCl solution to obtain inhibitor test solution of 100-500 ppm concentrations [8].

Weight loss determination

Previously weighed mild steel coupons were submerged in 250 mL open beakers containing
100 ml 1.0M HCl solution (blank) and then with addition of various concentrations of the *Synsepalum dulcificum* leaf extract (100 – 500 ppm) to the 1.0M HCl solution at 30°C [9].

The weight loss variation monitored after every 4 h immersion time per coupon progressively for a total 28 h immersion period. After 4 h, the coupons were taken out, immersed in distilled water, thereafter scrubbed with a bristle-brush under running water, dried and reweighed. The experimental readings were recorded to the nearest 0.0001 g using a Mettler digital analytical balance (sensitivity ± 1 mg). Duplicate experiments were set up for each concentration of inhibitor and the average weight losses of the duplicate experiments were taken as the weight loss of mild steel coupon [8]. The mean weight losses, percentage and inhibition efficiency values for duplicate specimens are presented in Table 1.

Results and Discussion

Weight loss studies

As presented in Table 1, the amount of material loss (mg) decreased significantly when the extract concentration is increased from 100-500 ppm in 1.0 M HCl solution for 4 h immersion period at 30^{o}C. For instance, addition of 500 ppm extract greatly reduced the weight loss of mild steel in 1.0 M HCl solution, with about 89% decrease in weight loss when compared with that of control. These results indicated that the extract inhibits the acid corrosion of mild steel in 1.0 M HCl solution at the specified conditions.

The values of percentage inhibition efficiency (%IE) were determined for 4 h immersion period and 30^{o}C using the equation (1)

$$\%IE = [(Wu - Wi)/Wu]x\ 100 \quad (1)$$

where Wu and Wi are the uninhibited and inhibited weight losses, respectively.

Assuming a direct relationship between percentage inhibition efficiency (%IE) and degree of surface coverage (Θ) for different inhibitor concentrations, the degree of surface coverage (Θ) was calculated using the relationship (2):

$$\theta = \%IE \quad (2)$$

Table 1: Weight loss (mg), percentage inhibition efficiency and surface coverage of *Synsepalum dulcificum* leaf extraction mild steel corrosion at 30^{o}C for 4 h immersion period

Concentration (ppm)	Weight loss (mg)	Percentage inhibition efficiency (%IE)	Surface coverage (Θ)
0	62.5	-	-
100	40.6	35.04	0.35
200	38.1	39.04	0.39
300	19.4	68.96	0.69
400	16.9	72.96	0.73
500	6.9	88.96	0.89

The inhibition efficiency increases with increasing concentration of the extract, and reaches a maximum value of 88.96% with 500 ppm extract. This implies that the organic compounds in the extract are adsorbed onto mild steel surface, resulting in the blocking of the reaction sites, and protects the mild steel surface from attacks by the aggressive ion from the acid solution [22].

Synsepalum dulcificum leaf extract is rich in several phytochemicals such as quercetin, kaemferol, saponins, tannins, alkaloids, steroids, flavonoids, terpenoids, and glycosides [21, 23, 24]. Some of these compounds contain heteroatoms and pie centers in their molecular structures that are considered as active centers for adsorption on metal surfaces. For example, quercetin and kaemferol are heterocyclic organic compounds containing oxygen heteroatom as depicted in Fig. 1.

The inhibitive effect of *Synsepalum dulcificum* leaf extract is attributed to the presence of these organic compounds containing π-electrons centers and oxygen nitrogen have been reported as corrosion inhibitors [23].

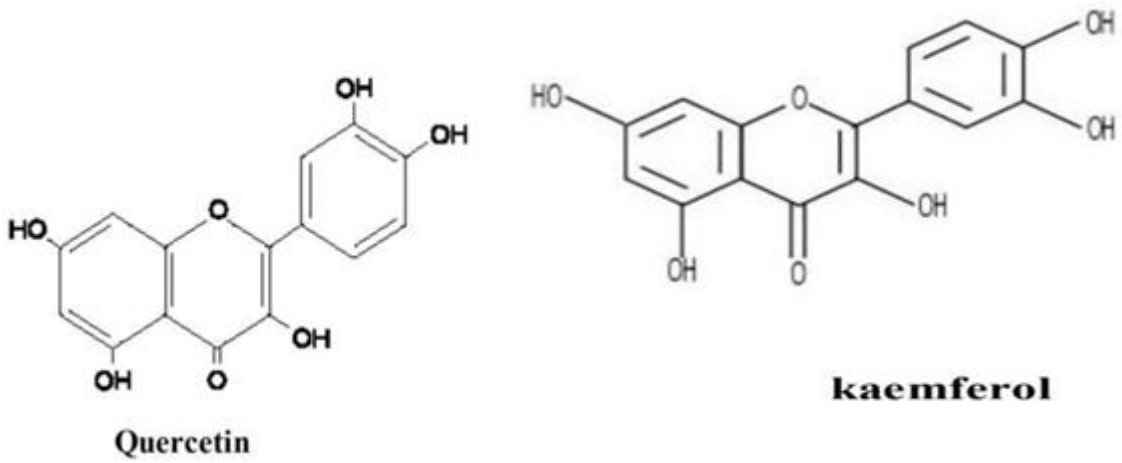

Figure 1: Molecular structures of quercetin and kaemferol in *Synsepalum dulcificum* plant

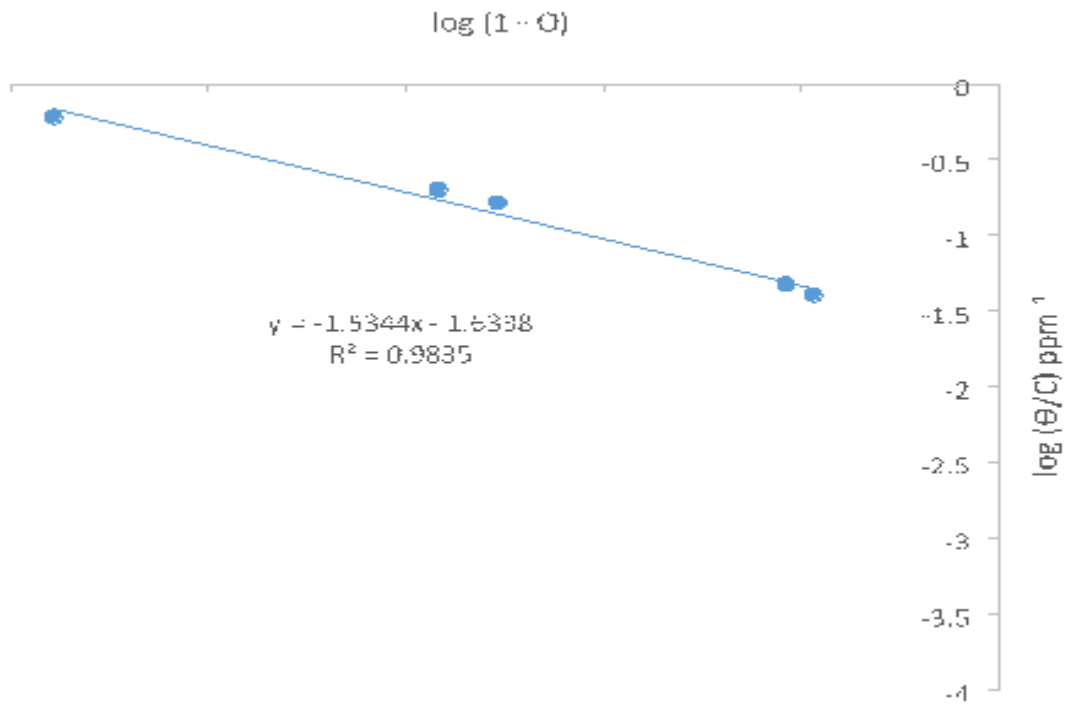

Figure 2: Flory-Huggins adsorption model on mild steel surface of *Synsepalum dulcificum* leaf extract in 1.0 M HCl solution for 4 h immersion period at 30°C

Figure 2 confirms that the inhibition is as a result of the adsorption of the active organic compounds onto metal surface. This is because a straight line graph is produced when log (Θ/C) is plotted as a function of log (1 - Θ) and the linear correlation coefficient of the fitted data is close to unity.

This indicates that the adsorption of the inhibitor molecules conforms with Flory-Huggins adsorption isotherm [25] expressed as equation (3):

$$Log\left(\frac{\theta}{C}\right) = nlog\,(1-\theta) + logK \qquad (3)$$

where Θ is degree of surface coverage, C is concentration, n is number of adsorbates occupying adsorption sites, and K is Flory-Huggins equilibrium constant.

Conclusion

The current study reveals that *Synsepalum dulcificum* leaf extract was very effective in inhibiting the acid corrosion of mild steel in 1.0M HCl solution, with up to 89% inhibition efficiency at optimum concentration and the inhibitory action of the extract is attributed to the presence of heterocyclic organic compounds containing heteroatoms in the extract. The adsorption of the inhibitor molecules was consistent with Flory-Huggins adsorption model. *Synsepalum dulcificum* leaf extract can be added to HCl solution as non-toxic corrosion inhibitor.

Conflict of interest: Authors have declared that there is no conflict of interest reported in this work.

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Citing this Article

Kazeem, W. O. and Abiola, O. K. (2024). *Synsepalum dulcificum* extract as green corrosion inhibitor for acid corrosion of mild steel in HCl solution-part 1. *Lafia Journal of Scientific and Industrial Research*, *2*(1), 1 – 4. https://doi.org/10.62050/ljsir2024.v2n1.273