

American Chemical Science Journal
4(6): 847-854, 2014

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Corrosion Inhibition of Mild Steel in 0.1M H₂SO₄ Solution by *Anacardium occidentale* Gum

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Authors' contributions

This work was carried out in collaboration between all authors. Author DEA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GI and EO managed the analyses of the study. Author AA managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

Received 13th February 2014
Accepted 22nd April 2014
Published 9th July 2014

ABSTRACT

The corrosion inhibition of mild steel is of technological importance due to the increase of industrial requirements. This study reports the corrosion inhibition of mild steel in acidic solution of 0.1 M H₂SO₄ using *Anacardium occidentale* gum, also known as Cashew gum by way of gravimetric measurements. It was shown that the presence of cashew gum inhibited the corrosion of mild steel in the test solution and the inhibition efficiency increased with increase in concentration of the gum, hence it's depended on the concentration of the plant extract as well as on the time of exposure of the mild steel samples in H₂SO₄ solutions containing the extract. The experimental data complied with the Langmuir adsorption isotherm. The results obtained authenticate that cashew gum is a good corrosion inhibitor and the adsorption mechanism is physisorption.

Keywords: *Corrosion inhibition; mild steel; adsorption mechanism; Anacardium occidentale; Langmuir isotherm.*

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1. INTRODUCTION

Corrosion is the disintegration of a material or its properties by reaction when interacting with its surrounding environment. The use of inhibitors is one of the best options of protecting metals against corrosion. Several inhibitors in use today are either synthesized from cheap raw materials or chosen from compounds having hetero atoms in their aromatic or long chain carbon system [1-3].

There is increasing concern about the toxicity of corrosion inhibitors in industries today.

The toxic effect not only affect living organisms but also poison the earth. The safety and environmental issue of corrosion inhibitors arisen in industries has always been a global concern. Chromates for example are used in the pretreatments of aluminum alloys and they are found to be both toxic and carcinogenic [4]. Hence many alternative corrosion inhibitors are developed ranging from rare earth elements to organic compounds [5]. Green corrosion inhibitors are biodegradable and do not contain heavy metals or toxic compound [6]. The successful use of natural substances to inhibit the corrosion of metals in acidic and alkaline environments has been reported by some research groups [7-9]. *Anarcadium occidentale*, the cashew, is an evergreen tree in the *Anacardiaceae* (cashew or sumac family) that originated in Central and South America and is now cultivated commercially in semi-arid tropical areas in Africa, e.g. Nigeria for the production of cashew nuts. The gum exuded from the plant has been known to have various medicinal and nutritional values. The gum is also used in pharmaceutical and medical fields as well as additives in other industries involving cosmetics, adhesive paints and inks [9].

Umoren et al. [8] reported the potential of gum Arabic as a corrosion inhibitor for aluminium in alkaline medium. The inhibition of aluminium corrosion was attributed to the presence of arabinogalactan, oligosaccharides, polysaccharides and glucoprotiens since these compounds contain oxygen and nitrogen atoms which are the centers of adsorption. This reputation as well as the presence of heteroatoms, for example O, N and S, has been found to increase basicity and electron density in polymers and plant extracts, thus intensifying their corrosion potential. O, N, and S are the active centers for the process of adsorption on the metal surface. The inhibition efficiency should follow the sequence $O < N < S < P$.

2. MATERIALS AND METHODS

2.1 Collection of Gum

Crude gum of *Anarcadium occidentale* was obtained as dried exudates from their parent trees grown in Samara, Zaria in Sabon Gari LGA of Kaduna State. Tapping of the gum was done using the method according to Umoren, 2006. The gum droplets collected were dried and hardened on exposure to the atmosphere.

2.2 Purification of Gum

The crude sample of the gum consisted of mixture of large and small modules and other impurities. These were hand sorted to remove fragments of bark and other visible impurities and then were spread out in the sun to dry for one to two weeks. The crude gum was dissolved in cold distilled water and the solution was strained through muslin, centrifuged to obtain a small quantity of dense gel. The straw colored supernatant liquor obtained was

separated and acidified to pH of 2 with dilute hydrochloric acid. Ethyl alcohol was added until it was 80%. The gum precipitated out was removed by centrifugation at rate of 2000 revolution per minutes, washed with alcohol, ether and dried in a desiccator.

2.3 Steel Coupons

Materials used for the study were mild steel sheets of composition (wt%, as determined by quantimetric method), Mn (0.6), Pb (0.36), C (0.16), Si (0.03) and Fe (98.85). The sheets were cut into coupons, in dimensions of 5 x 4 x 0.11 cm. Each coupon was degreased by washing with ethanol and dipped in acetone and allowed to dry in air before they were preserved in desiccator. All reagents used for the study were analytical grade and double distilled water was used for their preparation.

2.4 Corrosion Study

The purified cashew gum was used to prepare stock solutions, by dissolving a known mass in grams of the gum in 0.1 M solution of H₂SO₄ in order to obtain 0.2, 0.4, 0.6, 0.8 and 1.0g of the gum in 250 ml of 0.1M H₂SO₄ respectively.

A previously weighed metal (mild steel) coupon was completely immersed in 250ml of the test solution in an open beaker. The beaker was inserted into a water bath maintained at 303°K. At every 12 hours, the corrosion product was removed by washing each coupon (withdrawn from the test solution) in a solution containing 50% NaOH and 100gl⁻¹ of zinc dust. The washed coupon was rinsed in acetone and dried in air before reweighing. The difference inweight for a period of 168 hours was taken as the total weight loss.

3. RESULT AND DISCUSSION

3.1 Gravimetric Technique and Corrosion Rates

From the average weight loss (mean of triplicate analyses) results, the inhibition efficiency (IE%) of the inhibitor, the degree of surface coverage (θ) and the corrosion rate of mild steel (CR) were calculated using equation 1, 2, and 3 respectively [9].

$$IE\% = \left(1 - \frac{W_1}{W_2}\right) \times 100 \quad (1)$$

$$\theta = 1 - \frac{W_1}{W_2} \quad (2)$$

$$CR = \frac{\Delta W}{A t} \quad (3)$$

Where W1 and W2 are the weight losses (g) for mild steel in the presence and absence of the inhibitor, θ is the degree of surface coverage of the inhibitor, ΔW= W₂- W₁, A is the area of the mild steel coupon (in cm²), t is the period of immersion (in hours) and W is the weight loss of mild steel after time, t.

The results are presented in Table 1.

Table 1. Corrosion rate (CR) of mild steel, inhibition efficiencies (IE) and degree of surface coverage (θ) for different concentrations of cashew gum in 0.1M H₂SO₄.

Systems	CR (gh ⁻¹ cm ⁻²) × 10 ⁻³	IE (%)	θ
Blank (0.1M H ₂ SO ₄)	4.55	-	-
0.2g/250cm ³ of Cashew gum	1.45	80.478	0.8048
0.4g/250cm ³ of Cashew gum	1.33	83.260	0.8326
0.6g/250cm ³ of Cashew gum	1.24	84.439	0.8444
0.8g/250cm ³ of Cashew gum	1.08	85.946	0.8595
1.0g/250cm ³ of Cashew gum	0.96	88.746	0.8875

3.2 Corrosion Inhibition Potentials

Fig. 1 shows that the extent of weight loss depends on the concentration of cashew gum present in 250ml of 0.1M H₂SO₄ solution prepared, while Fig. 2 shows the percentage increase in the gum inhibition potential as the concentration of the gum was increased.

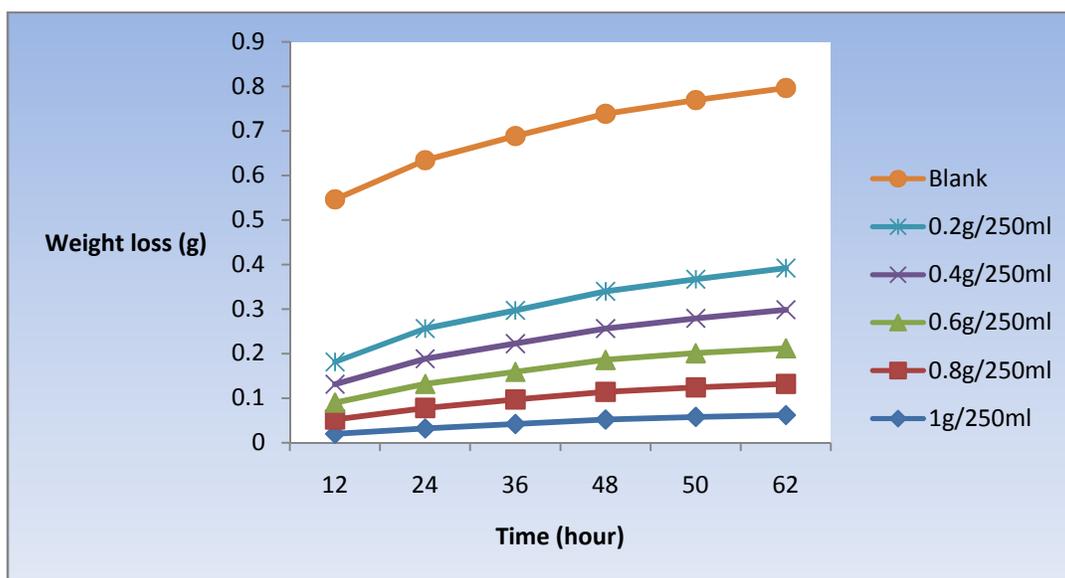


Fig 1. Variation of weight loss with time for corrosion of mild steel in 0.1M H₂SO₄ containing various concentrations of cashew gum

Fig. 3, highlights the trend in the decrease of inhibition efficiency of the gum concentration with time in hours, while Fig. 4, shows that the corrosion rate of mild steel decreases with increase in concentration of cashew gum added to the media.

3.3 Adsorption Considerations and Adsorption Isotherms

In the situation where it is suspected that the inhibition of metal corrosion occurred as a result of the adsorption of molecules of plant extracts onto the metal surface, it is instructive to investigate the possible adsorption mode by testing the experimental data obtained with several adsorption isotherms such as Langmuir, Temkin, Flory-Huggins, Frumkin, Freundlich

and Brockris Swinkel adsorption isotherm [10]. Such an exercise will greatly elucidate one's understanding of the corrosion inhibition mechanism. The test indicated that Langmuir adsorption isotherm best described the adsorption characteristics of cashew gum on mild steel surface.

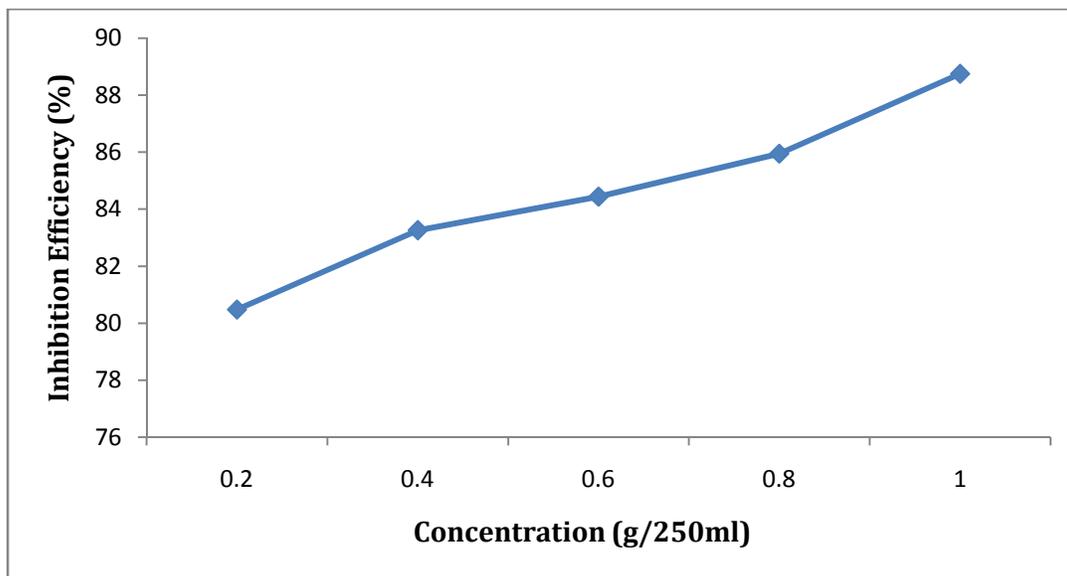


Fig. 2. Variation of inhibition efficiency of cashew gum with concentration for the corrosion of mild steel in 0.1M H₂SO₄

The Langmuir adsorption model relates the degree of surface coverage of the inhibitor (θ) to its concentration as follows [11].

$$\theta = KC \times \frac{1}{(1+KC)} \quad (4)$$

Where K designates the adsorption equilibrium constant and C is the concentration of the inhibitor in the bulk solution. From rearrangement of equation 4, equation 5 is obtained and given as

$$\frac{1}{K} + C = \frac{C}{\theta} \quad (5)$$

Using equation 5, plot of (C/ θ) versus C was linear indicating that the assumptions establishing the Langmuir adsorption isotherm are valid for the present study.

Fig. 5 shows that the Langmuir isotherm for the adsorption of cashew gum on mild steel surface and its R² was found to be close to unity, hence showing a strong adherence of the adsorption of the studied inhibitor to the Langmuir model.

The equilibrium constant of adsorption (obtained from Langmuir adsorption isotherm) is related to the equilibrium constant of adsorption according to equation 6 [11].

$$\Delta G_{ads}^0 = -2.303RT \log(55.5K_{ads}) \quad (6)$$

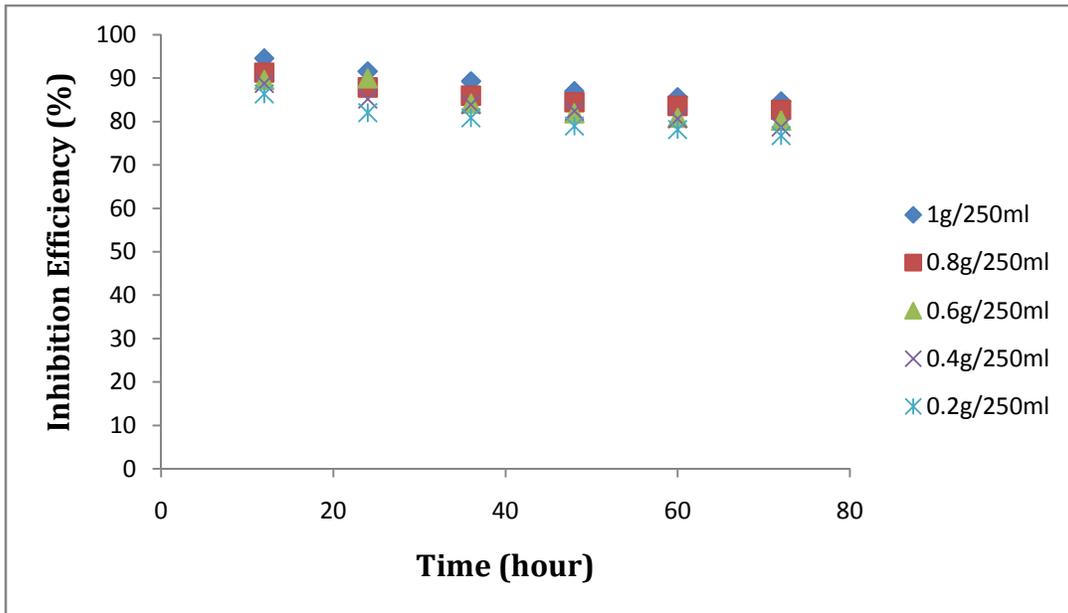


Fig. 3. Variation of inhibition efficiency of cashew gum concentrations with time (hour) for the corrosion of mild steel in 0.1M H₂SO₄

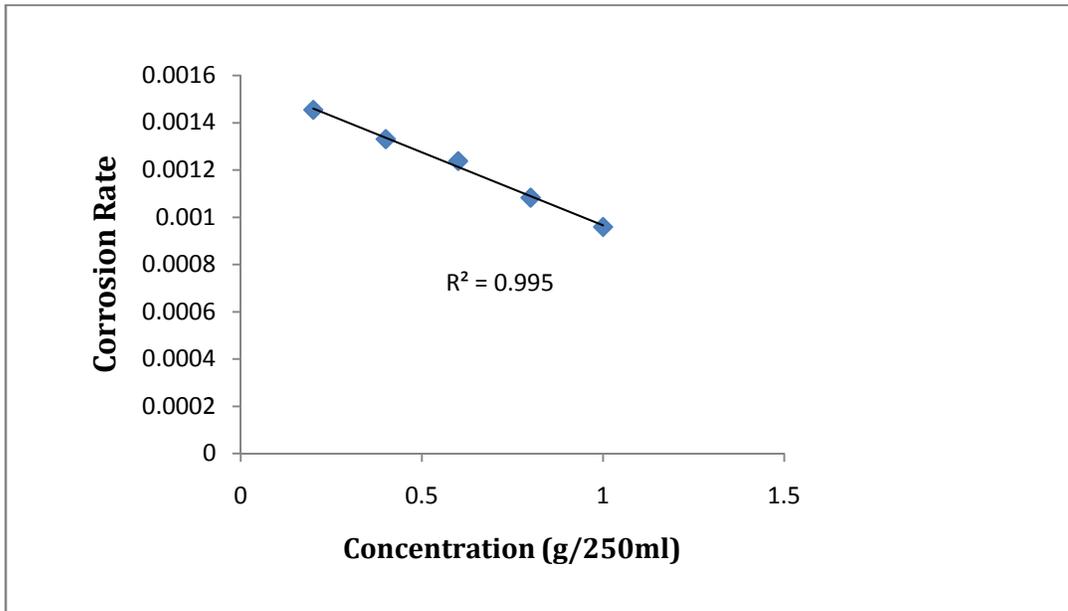


Fig. 4. Variation of corrosion rate of cashew gum with concentration for the corrosion of mild steel in 0.1M H₂SO₄

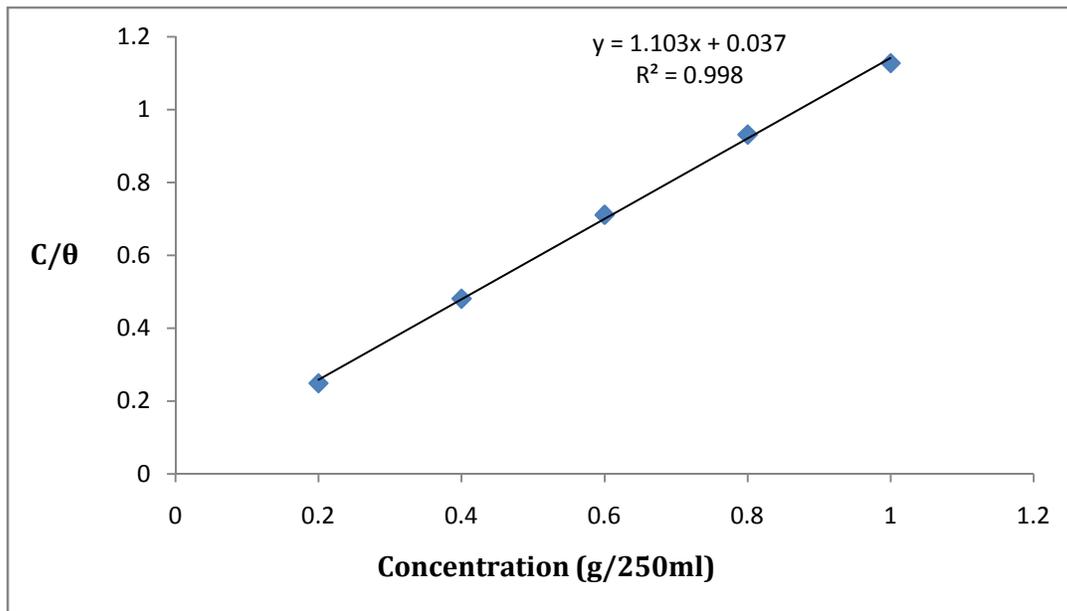


Fig. 5. Langmuir isotherm for the adsorption of cashew gum on mild steel surface

Where ΔG_{ads}^0 is the free energy of adsorption of the inhibitor, R the gas constant and T the temperature at 303K. In Table 2 the free energies are negatively less than the threshold value (-40KJmol^{-1}) required for chemical adsorption.

Table 2. Langmuir adsorption parameters for the inhibition of the corrosion of mild steel by cashew gum

System	Slope	1/ K	$\Delta G^0(\text{KJmol}^{-1})$	R^2
Cashew gum solution	1.1035	0.0373	-18.41	0.9989

Therefore, the adsorption of cashew gum on mild steel surface is spontaneous and supports the mechanism of physical adsorption.

4. CONCLUSION

The experimental results show that cashew gum is a good corrosion inhibitor for mild steel in acid media, and its inhibition efficiency or potential increases with increase of concentration of the gum, while its corrosion rate decreases with increase addition of the gum. The adsorption of gum on mild steel surface is spontaneous attributing that fact to its low value of energy of adsorption and supports the mechanism of physical adsorption.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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