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The use of strawberry and arabic gum blend as an inhibitor for the corrosion of aluminum in an acidic medium

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ABSTRACT

The manuscripts entails the use of plant gum blends prepared with gum Arabic and strawberry gum, to inhibit the corrosion of aluminum immersed in concentrated sulfuric acid solution. The miscibility tests of the blended gums (Arabic and strawberry) were carried out using Ostwald viscometer. Following the ratio of gum Arabic to strawberry gum, the ratio 0.2:0.8 has the highest relative viscosity and thus more viscous than all the other blends prepared in this work, and due to its viscosity strength the 0.2:0.8 ratio was used. In addition, the inhibitive and adsorption properties of Arabic and strawberry gums were studied using gravimetric method. The results obtained indicated that the blend of Arabic and strawberry gums are effective in the corrosion inhibition of aluminum in H_2SO_4 solutions. The adsorption of the inhibitor on the Aluminum surface is spontaneous and supports the Langmuir adsorption model, the data was also subjected to other isotherms and thermodynamic models.

1. Introduction

Corrosion is a gradual process of destruction of materials or simply degradation of metals by chemical or electrochemical reaction with their environment. The environment could be atmospheric, natural water, sea water. Corrosion causes plants shut down, waste of valuable resources, reduction in efficiency [1-5].

Corrosion of materials (metals/alloys) is one of the greatest problems in the industries, constructions, agricultural equipment, oil and gas, as well as medical services. Corrosion causes great harm to the nation`s economy. The main ways to control corrosion of Aluminum, mild steel or any metal under investigation is to separate the metal from the corrosive environment, and this can be achieved by using corrosion inhibitors [1, 6]. The use of inhibitors such as silicates and chromates has come under severe criticism due to high toxicity, expensive and environmental problems associated with it. Attention has shifted to naturally occurring substances because they are environmental friendly. Plant extracts are considered to be rich in naturally synthesize chemical compounds which are not only biodegradable, nontoxic, cheap but are also renewable much of these natural products have been used by many researchers as corrosion for different metals and in different environment. Amino acids are derived from living things [7]. They are nontoxic, cheap and can be readily produced and purified to high quality [8]. Therefore, this work would attempt to check the possibility of using strawberry gum and Arabic gum for the Inhibition of the corrosion of Aluminum in solution of 2M H_2SO_4.

Aluminum is considered as to be the top metal of choice for manufacturing industry professionals. This is due in part of its corrosion resistance, high strength, and low–density properties. Aluminum is also non–toxic which makes ideal for any application which involves the packaging of food items etc [9].

Due to their industrial applications, several inhibitors have either been synthesized or chosen from organic compounds having heteroatom in their molecular structures. In addition, various protective methods have been adopted. One of the frequently used measures is

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the use of organic compounds containing nitrogen, oxygen and sulphur atoms [10]. These compounds either can form strong co-ordination bond with metal atom or form passive film on the surface. There is still a continuous search for better inhibitors to meet the demand of the industry [11].

2. Methodology

2.1. Preparation of specimen

The solution of the blended gums were prepared by dissolving the mass ratio of Arabic gum and strawberry gum (0.2:0.8, 0.2:0.8, 0.2:0.) g in 80, 90 and 100mL of warmed distilled water, (0.8:0.2, 0.8:0.2, 0.8:0.2) g in 80, 90 and 100mL of warmed distilled water and (0.5:0.5, 0.5:0.5, 0.5:0.5)g in 80, 90 and 100mL of warmed distilled water.

2.2. Viscometry method

This is the process of the measurement of the viscosity of liquids (solution). From this method relative viscosity (η_{rel}), specific viscosity (η_{sp}), reduced viscosity (η_{red}) and intrinsic viscosity (η) are calculated from the following equation bellow:

$$\eta_{rel} = \frac{t_1 - t_0}{t_0}$$

$$\eta_{sp} = \frac{t}{t_0}$$

$$\eta_{red} = \eta_{sp} / C$$

η = the slope obtained from the graph of relative viscosity against concentration

2.3. Preparation of the specimens

The Aluminum samples were obtained from Department of Chemistry, Ahmadu Bello University, Zaria. The Aluminum was mechanically press-cut into 4.8cm × 3.9cm. The Aluminum samples were polished using sand paper, washed with distilled water, dipped into acetone for air dried, and weighed using the weighing balance to know the initial weight before immersion and stored in desiccator.

2.4. Preparation of inhibitor solution

Mass concentration of the inhibitors (Arabic gum and Strawberry gum) were prepared by dissolving (0.2, 0.4, 0.6, 0.8, 1.0, 1.2) g of the inhibitors in 250mL of 2M H_2SO_4 solution.

2.5. Gravimetric or Weight loss method

The weight loss study of strawberry gum and Arabic gum were done by dipping the pre-cleaned Aluminum into 250mL of the test solution at room temperature. The weight loss was determined by retrieving the Aluminum at 24 hrs interval progressively for 168hours. Prior to measurement, each retrieved Aluminum was immersed in a solution of 2M H_2SO_4, scrubbed with brittle brush several times with NaOH solution, rinsed with acetone and air dried before re-weighing. The difference in weight was taken as the weight loss of the Aluminum. A control experiment was equally set up by considering the weight loss of Aluminum in 2M H_2SO_4 in the absence of the inhibitor. From the weight loss, the inhibition efficiency of the inhibitor (I %), degree of surface coverage (θ) and corrosion rate (CR) of the steel were calculated.

2.6. Determination of corrosion rate

$$(IE) = (R_0 - R_1 | R_0) \times 100$$

$$(\theta) = \frac{1 - M_0}{M_1}$$

$$CR = \frac{1 \times 10^4 M}{At}$$

Where, $M_0$and M_1 = Weight losses (g), A =Area of the Aluminum (cm^2), T =Exposure time (hour).

3. Results and Discussions

3.1 Viscosity measurement of the blended gums in different concentration i.e. ratio of A:B (Strawberry gum and Arabic gum)

A: strawberry gum,

B: Arabic gum

Table (1 and 2) shows relative viscosity (n_{rel}), specific viscosity (n_{sp}) and intrinsic viscosity (n). It was observed that the relative viscosity decreases from mass ratio of the gums (A:B) of 0.2:0.8, 0.5:0.5 to 0.8:0.2 indicating that ratio 0.2:0.8 has the highest relative viscosity and thus more viscous than any ratio. Which means, is a good inhibitor for corrosion study of Aluminum in H_2SO_4.

Table 1. Time taken of the readings from viscometer

Mass ratio A:B (g)	Distilled water(ml)	t°(s)	t(s)
0.2:0.8	100	8.64	11.35±0.22
0.2:0.8	90	8.64	13.16±0.02
0.2:0.8	80	8.64	13.38±0.12
0.5:0.5	100	8.64	10.96±0.08
0.5:0.5	90	8.64	11.96±0.11
0.5:0.5	80	8.64	11.94±0.62
0.8:0.2	100	8.64	11.12±0.02
0.8:0.2	90	8.64	10.75±1.02
0.8:0.2	80	8.64	11.70±0.52

3.2 Effect of Inhibitor Concentration on Corrosion Rate

It was observed that corrosion rate of Aluminum in 2.0M H_2SO_4 decreased with increasing concentration of inhibitor (Arabic gum and Strawberry gum), as shown in fig. (4), this is due to the increase in weight loss of the

Aluminum. Similar observation has been made by several researchers [12-15]

Table 2. The relative viscosity, specific viscosity and intrinsic viscosity in different concentration for the blended gums.

Mass ratio A:B (g)	Conc. (g/ml)	n_{rel}	n_{sp}
0.2:0.8	0.01	1.314±0.042	0.314±0.042
0.2:0.8	0.0111	1.523±0.011	0.523±0.011
0.2:0.8	0.0125	1.548±0.002	0.548±0.002
0.5:0.5	0.01	1.268±0.004	0.268±0.004
0.5:0.5	0.0111	1.385±0.052	0.385±0.052
0.5:0.5	0.0125	1.358±0.202	0.358±0.202
0.8:0.2	0.01	1.287±0.054	0.287±0.054
0.8:0.2	0.0111	1.244±0.402	0.244±0.402
0.8:0.2	0.0125	1.354±0.132	0.354±0.132

3.3 Effect of Inhibition Efficiency on Inhibitor Concentration

Figures 5 and 6, shows that the inhibition efficiencies (%IE) of arabic gum and strawberry gum inhibitors in 2.0M H_2SO_4 increase with increasing inhibitor concentrations. This indicated that arabic gum and strawberry gum are good inhibitors. From literature, similar trends was observed [16].

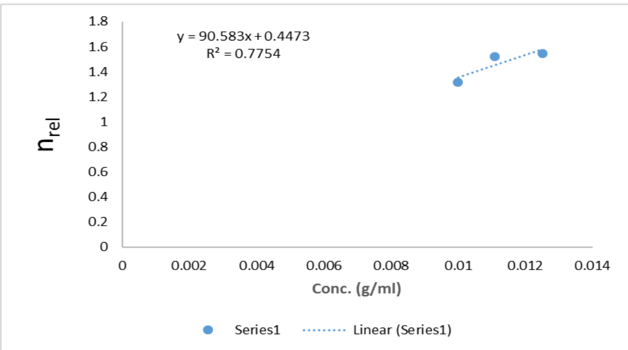

Figure 1. Variation of relative viscosities versus different concentrations of the mass ratio of strawberry gum to Arabic gum (0.2:0.8)

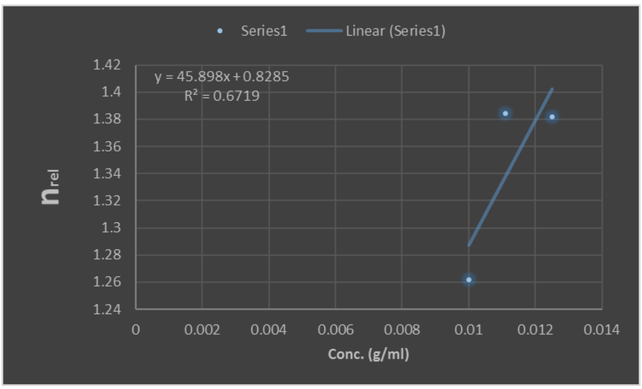

Figure 2. Variation of relative viscosities versus various concentrations of the ratio of strawberry gum to Arabic gum (0.5:0.5)

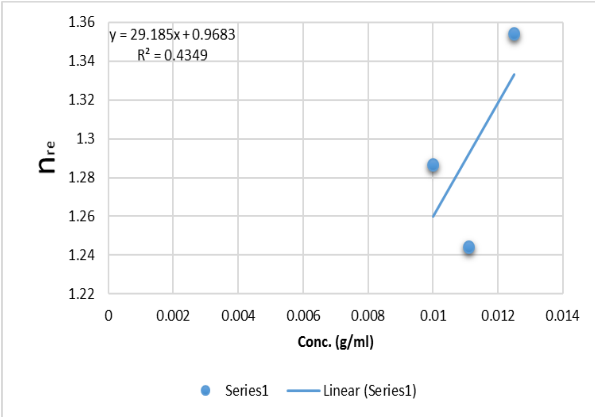

Figure 3. Variation of relative viscosities versus various concentrations of the ratio of strawberry gum to Arabic gum (0.8:0.2).

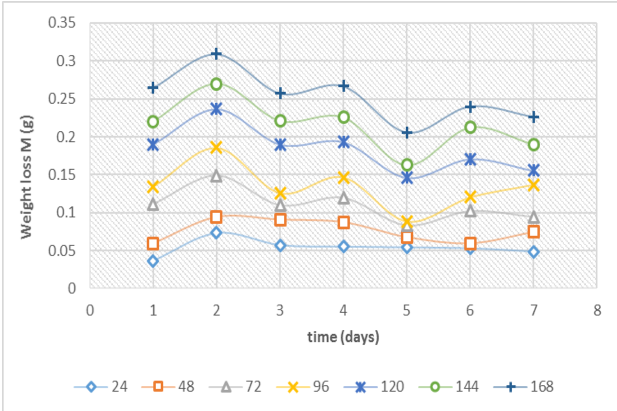

Figure 4. Variation of weight loss (M) with time for the corrosion of Aluminum in 2.0M H_2SO_4 containing various concentration.

3.4 Effect of period of immersion on the inhibition efficiencies of the blended gums.

In order to test the stability of the inhibitors over a period of time, inhibition efficiencies of the inhibitors were calculated for every 24 hours of immersion and were used to developed plots of inhibition efficiency versus time. Figure 6 shows the variation of inhibition efficiencies of the blended gums with the period of immersion respectively. From the figures, it can be seen that both inhibitors can retain more than 60% of their efficiencies after 168 hours of immersion. Hence, they are good inhibitors.

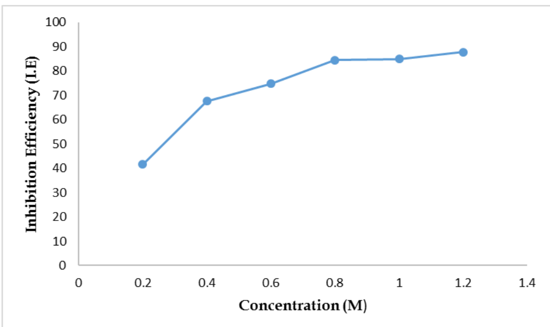

Figure 5. Variation of inhibition of efficiency of the blended gums with concentration for the corrosion of Aluminum in 2.0 M H_2SO_4

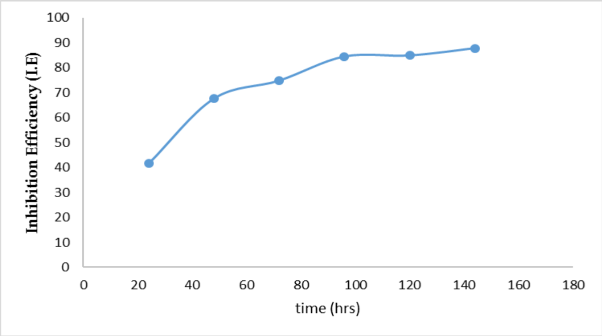

Figure 6. Variation of inhibition efficiency of the blended gums with time

3.5. Adsorption/thermodynamic considerations

In order to study adsorption characteristics of blended Arabic and strawberry gums on Aluminum surface, data obtained for degree of surface coverage were used to fit curves for different adsorption isotherms including Langmuir, Temkin, Flory-Huggins, Frumkin, Freundlich and El-awady adsorption isotherms [17, 18].

3.5.1. Langmuir isotherm model

This model relates the degree of surface coverage of inhibitor (θ) to its concentration as follows [12, 19].

$$\theta = KC \times 1/(1 + KC)$$

Where K is the adsorption equilibrium constant and C is the concentration of the inhibitor in the bulk solution. Rearrangement of the equation

$$^{1}/_{K} + C = {}^{K}/_{\theta}$$

$$\log(C/\theta) = \log C - \log K$$

Using equation the, plots of log(C/ θ) versus logC were linear which indicates that the assumptions establishing the Langmuir adsorption isotherm are valid for the presence study. Figure 6 shows Langmuir isotherm for the adsorption of the blended Arabic and strawberry gums on Aluminum surface. Values of adsorption parameters deduced from the plots are presented in the table 3. From the results obtained, it can be seen that the slope and R^2 values are very close to unity. It's simply means that, there is strong adherence of the adsorption of the studied inhibitors to the Langmuir model.

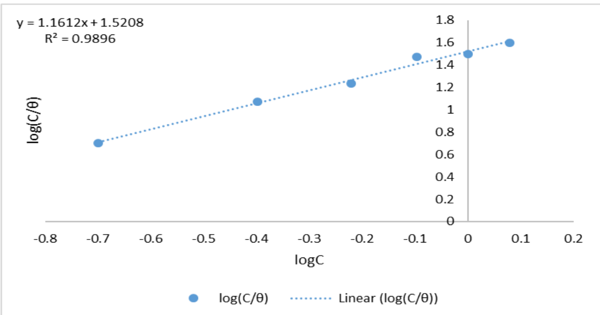

Figure 7. Langmuir isotherm for the adsorption of the blended Arabic and strawberry gums on Aluminum surface.

Table 3. Langmuir adsorption of parameters for the inhibition of the corrosion of Aluminum by blended Arabic and strawberry gums

	Slope	logK	R^2
Blended gums	1.1612	1.5208	0.9896

3.5.2. The Flory-Huggins adsorption isotherm

In this isotherm a plot of $\log(\theta/C)$ versus $\log(1-\theta)$ should provide a straight line graph if the adsorption of the inhibitor is consistent with Flory-Huggins adsorption isotherm [20, 21].Values of adsorption parameters deduced from the plots are presented in the table 4 for the isotherm.

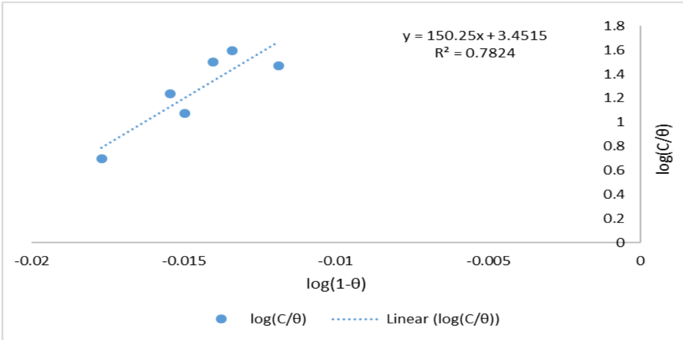

Figure 8. Flory-Huggins isotherm for the adsorption of the blended Arabic and strawberry gums on Aluminum surface.

The flory-huggins isotherm was done for the adsorption process and was plotted in Figure 8. The isotherm is occasionally to derive the degree of surface coverage characteristics of adsorbate onto adsorbent, since the regression value suggest a good plot, this suggest that the nature of the adsorption process here is feasible and spontaneous.

Table 4. Flory-Huggins adsorption of parameters for the inhibition of the corrosion of Aluminum by blended Arabic and strawberry gums

	Slope	logK	R^2
Blended gums	150.25	3.4515	0.7824

3.5.3. Temkin adsorption isotherm

Temkin adsorption isotherm is excellent for predicting the gas phase equilibrium systems, on the other hand difficult adsorption systems containing the liquid-phase adsorption isotherms are sometimes tested to assess the behavior of highly volatile liquid.

In this isotherm a plot of θ versus logC should provide a straight line graph with slope equals to 2.303a/2 [22]. Values of adsorption parameters deduced from the plot in figure 9 are presented in the table 5 below. For the isotherm. The value of a, was derived from the equation 2.303a/2=slope.

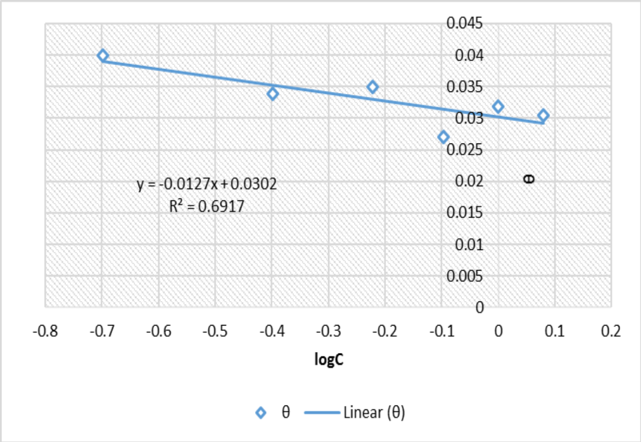

Figure 9. Temkin isotherm for adsorption of the blended Arabic and strawberry gums on Aluminum surface.

Table 5: Temkin adsorption of parameters for the inhibition of the corrosion of Aluminum by blended Arabic and strawberry gums

	Slope	logK	R^2	a
Blended gums	-0.0127	0.0302	0.6917	-0.0110

3.5.4 Frumkin adsorption isotherm

Frumkin isotherm was used to investigate the thermodynamics of adsorption of Aluminum surface by Arabic-strawberry gum blend in an acid medium. In this isotherm a plot of log $\theta/(1-\theta)$ versus θ should provide a straight line graph, if the isotherm is obeyed [23]. The isotherm plot can be seen in figure 10. Values of adsorption parameters deduced from the plots are presented in the table 6. The coefficient of determination was found to be the highest when compared with any of the other isotherm considered. The coefficient of determination confirms that fremkin isotherm best fits the data for the corrosion inhibition study carried out by the gum blend on the Aluminum surface.

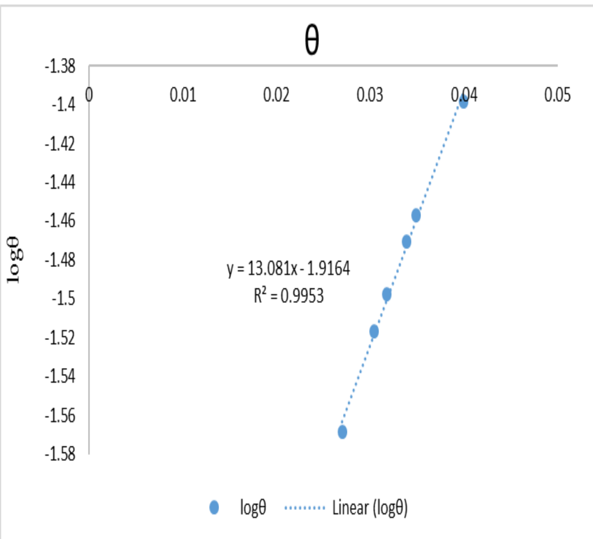

Figure 10. Frumkin isotherm for adsorption of the blended Arabic and strawberry gums on Aluminum surface.

Table 6. Frumkin adsorption of parameters for the inhibition of the corrosion of Aluminum by blended Arabic and strawberry gums

	Slope	logK	R^2
Blended gums	13.081	- 1.9164	0.9953

3.6. Freundlich adsorption isotherm

In this isotherm a plot of log $\theta/(1-\theta)$ versus θ should provide a straight line graph, if the isotherm is obeyed [24]. Values of adsorption parameters deduced from the plots shown in figure 11 are presented in the table 7.

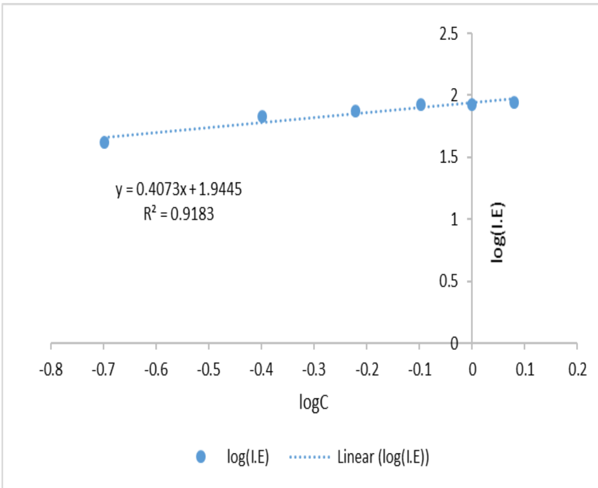

Figure 11. Freundlich isotherm for adsorption of the blended Arabic and strawberry gums on Aluminum surface.

Table 7. Freundlich adsorption of parameters for the inhibition of the corrosion of Aluminum by blended Arabic and strawberry gums

	Slope	logK	R^2
Blended gums	0.4073	1.9445	0.9183

Freundlich adsorption isotherm is one of the first acknowledged affiliation defining the non-ideal and reversible adsorption, not constrained to the creation of monolayer. This realistic model can be applied to multilayer adsorption, with non-uniform distribution of adsorption heat and affinities over the heterogeneous surface. In this work, Freundlich isotherm was applied in a heterogeneous system of highly interactive species on metal surface. The value of the slope is reported in table 12 as 0.4073, it is a measure of adsorption intensity or surface heterogeneity, in this case since the value is closer to 0, it indicates a high adsorption intensity. The value of the slope (1/n) can also be used to identify the type of sorption taking place in the system, since its value is below unity, it infers chemisorptions process.

3.7. El-Awady thermodynamic adsorption isotherm

El-awady thermodynamic isotherm is a plot of log θ/(1-θ) versus logC. The presence a straight line graph confirms, if the thermodynamic-kinetics isotherm is obeyed [18]. Values of adsorption parameters deduced from figure 12 are presented in the table 8.

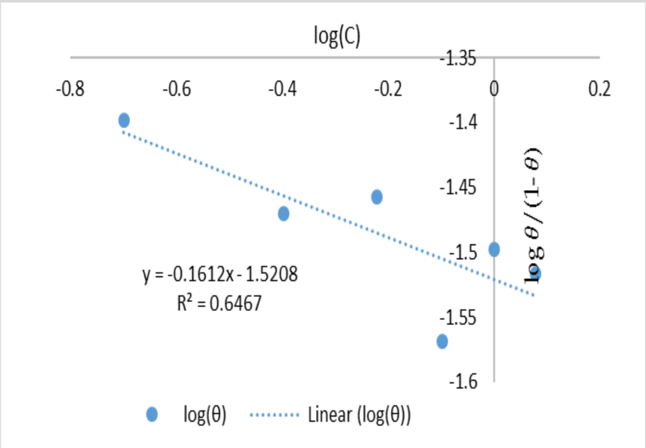

Figure 12. El-awady isotherm for adsorption of the blended Arabic and strawberry gums on Aluminum surface.

Table 8. El-Awady adsorption of parameters for the inhibition of the corrosion of Aluminum by blended Arabic and strawberry gums

	Slope	logK	R^2
Blended gums	-0.1612	- 1.5208	0.6467

The experimental data was defined by the El-Awady kinetic/thermodynamic adsorption isotherm. The specific equation of this model is given by

$$log\left(\frac{\theta}{1-\theta}\right) = logK + ylogC$$

where C is the concentration of the inhibitors, θ is the degree of surface coverage, Kads is the equilibrium constant of the adsorption process, and Kads = $K^{1/y}$. In this model, the number of active sites is referred to as y in the model. When the values of 1/y less than one suggest multilayer adsorption, while 1/y greater than one implies that a giving inhibitor molecule occupies more than one active site. Curve fitting of the data to the thermodynamic/kinetic model is shown in Figure 12. The plot did not give a straight lines which obviously indicates that the data was not properly fitted in to the isotherm, and so this isotherm cannot be used to explain the adsorption process.

4. CONCLUSIONS

The study reveals that Arabic (**acacia gum)** and strawberry (**Eucalyptus olida***)* gums are good inhibitors for the corrosion of Aluminum in H_2SO_4 solutions. The inhibitors are adsorption inhibitors because their inhibition efficiencies increase with increasing concentration. The adsorption characteristics of the inhibitors are best described by the Langmuir adsorption isotherm. The adsorption of the inhibitors on Aluminum surface is spontaneous and support the mechanism of physical adsorption.

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