

Ginger extract as green corrosion inhibitor of mild steel in hydrochloric acid solution

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Abstract. Ginger extract as corrosion inhibitor from natural resources was studied to prevent corrosion of mild steel in acid media. Ginger rhizome was extracted to produce green corrosion inhibitor (G-1) while ginger powder bought at supermarket was also extract to form green corrosion inhibitor (G-2). Effectiveness of inhibitor in preventing corrosion process of mild steel was studied in 1.0 M of hydrochloric acid. The experiment of weight loss method and polarization technique were conducted to measure corrosion rate and inhibition efficiency of mild steel in solution containing 1.0 M of hydrochloric acid with various concentration of inhibitor at room temperature. The results showed that, the rate of corrosion dropped from 8.09 mmpy in solution containing no inhibitor to 0.72 mmpy in solution containing 150g/l inhibitor while inhibition efficiency up to 91% was obtained. The polarization curve in polarization experiments shows that the inhibition efficiency is 86% with high concentration of inhibitor. The adsorption of ginger extract on the surface of mild steel was observed by using optical microscope and the characterization analysis was done by using pH measurement method. When high concentration of green inhibitor in the acid solution is used, the pH at the surface of steel is increasing.

1. Introduction

Corrosion is a deterioration of a metal alloy under the influence of its environment [1]. Corrosion is a destructive result of chemical reaction between a metal and its environment. The environment such as humid air, steam, seawater, alkaline and acids are positive towards the corrosion process. Corrosion happens because metal wants to achieve a stable state since metals are unstable after extracted from their ores.

Green corrosion inhibitor had been studying to relate to this “greenish” theme and reduce the corrosion process as well. The plants such as rosemary leaves, garlic, tamarind, tea leaves, pomegranate juice and peels, aloe leaves, mango or orange peels, and banana peels are very useful for green inhibitor application.

Organic compound that contains oxygen, sulphide and nitrogen which is basically the active center for the absorption process on the metal surface to reduce the corrosion attack on several steel has been studied recently. Corrosion prevention is very important because many industrial companies have suffered from this activity process. Environment with pollutant will cause damage to the systems and reduce machines lifetime especially equipment that uses acid solution.

In this paper, the effect of ginger extract as a green corrosion inhibitor of mild steel in 1.0M of hydrochloric acid has been studied.



2. Experimental procedures

2.1 Preparation of Ginger extract

The ginger was washed, cut, dried and ground into a fine powder. The powder is then used to soak in distilled water with the ratio of 1g of powder with 8 ml of distilled water for 20 hours at room temperature. The extract was filtered and evaporated in the oven with the temperature 40°C for about 24 hours to produce ginger extract (G-1). Another ginger extract (G-2) was prepared from ginger powder bought at supermarket. It was macerated in the distilled water and filtered. The concentration of 50g/l, 100g/l, and 150g/l of aqueous extract ginger were prepared.

2.2 Preparation of specimens

Mild steel was cut into 6.2 x 2.1 x 0.1 cm³. The steels were ground with emery paper of 180 to 1200 grits. Then, they were washed using distilled water and degreased with acetone.

2.3 Weight loss experiment

The weight of sample was measured using electronic balance before and after soaking in 100 ml of 1 M HCl. The samples were immersed in HCL solution for 22 hours at room temperature with the absence and presence of different concentrations of ginger extract (G-1) and also (G-2). To get the best result, the experiment was conducted twice. The weight loss of the test specimens were calculated by using equation (1).

$$\text{Weight loss } (\Delta w) = W_i - W_f \quad \text{Eq (1)}$$

Where W_i is the initial weight and W_f is the final weight of mild steel specimens. Corrosion rate and inhibitor efficiency can be calculated by using the equation shows in equation (2) and equation (3), respectively.

$$R = \frac{86.7 \times \Delta w}{A \times T \times \rho} \quad \text{Eq (2)}$$

$$IE = \frac{R_0 - R_i}{R_0} \times 100 \quad \text{Eq (3)}$$

Where R = Corrosion rate (*mm/yr*), Δw = Weight loss (*mg*), A = Area of metal exposed to corrosive media (*cm*²), ρ = Density of mild steel (*g/cm*³) = 7.86*g/cm*³, T = Time of immersion (*h*), R_0 = Corrosion rate without inhibitor and R_i = Corrosion rate with inhibitor.

2.4 Polarization test

Polarization test uses three types of electrodes which are working electrode, counter electrode and the reference electrode with the mild steel, graphite, and the silver/silver chloride electrode respectively. These three electrodes were connected to the Autolab potentiostat. The scan rate of 0.5mV/s was set up on the setting option. The curve was set to start at -800mV until -200mV at room temperature. The inhibition efficiency can be calculated and known based on the formula:

$$IE = \frac{I_{corr}^0 - I_{corr}}{I_{corr}^0} \times 100 \quad \text{Eq (4)}$$

2.5 Surface analysis

The surface of the mild steel was analysed by using Nikon Model Epiphot 200 optical microscope. The analysis was conducted after the experiment of weight loss was done. The samples after

immersing in 1M HCl with different concentration of ginger extract were collected to be observed using the optical microscope.

3. Results and Discussion

3.1 Weight loss measurement

Experiment was conducted to study the corrosion rates and the percentage of inhibition efficiency from four samples of mild steels in the absent and presence of different concentration of ginger extract inhibitor. The concentration of 50g/l, 100g/l and 150g/l of inhibitors at room temperature were used in this experiment as shown in table 1.

Table 1. Effect of ginger extract (G-1) concentration on corrosion rate of mild steel.

Inhibitor Concentration (g/l)	Corrosion rate (mmpy)	Inhibition Efficiency (%)
0	8.09	-
50	1.04	87
100	0.96	88
150	0.72	91

The weight loss experiment also has been conducted on ginger extract that produced from the source of ginger powder product (G-2). The result is shown on the table 2.

Table 2. Effect of ginger extract (G2) concentration on the corrosion rate of mild steel.

Inhibitor Concentration (g/l)	Corrosion rate (mmpy)	Inhibition Efficiency (%)
0	6.91	-
50	0.94	86
100	0.85	88
150	0.66	90

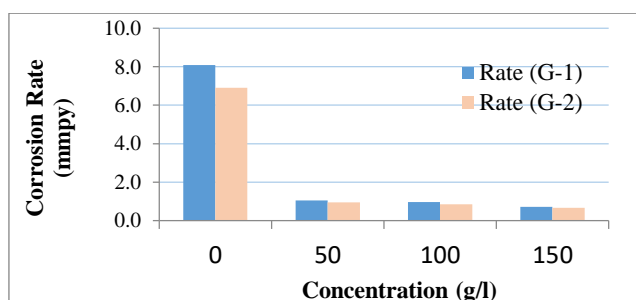


Figure 1. Corrosion Rate of mild steel in various inhibitor concentrations.

From the graph shown in this experiment, the line is increasing where the higher concentration of inhibitor used, the higher the inhibition efficiency. The inhibitor was absorbed in the steel and forming the layer on the surface of the steel. The layer which is like the coating, prevents the contact of the acid to the surface of the steel. The corrosion process will not happen when there is thick protection layer on the surface.

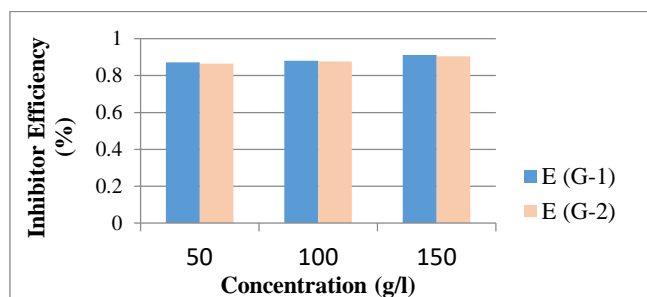


Figure 2. Inhibitor Efficiency in various inhibitor concentrations

The graph in figure 2 clearly shows the trend of the inhibition efficiency. The efficiency of inhibition of is 91% at concentration of inhibitor of 150g/l. Inhibition efficiency of 50g/l and 100g/l inhibitor is 87% and 88% respectively which showed slightly increasing in inhibition efficiency.

From the results, when comparing between G-1 and G-2, it shows that G-1 produced higher percentage in inhibition efficiency of the inhibitor that can prevent corrosion process of mild steel in 1M HCl better than G-2. But the trend from both aqueous ginger extract show same pattern which is the inhibition efficiency is increasing when the higher concentration of the extract was used.

3.2 Polarization test

The polarization curve is presented in figure 3. The data of the test used which is 1M HCl without inhibitor and 1M HCl with different concentration are summarized in the table 3. The corrosion potential (E_{corr}), corrosion current density (I_{corr}) and corrosion rate were obtained from the curve. The inhibition efficiency was calculated using equation 4.

Table 3: Data from polarization experiment for mild steel in Ginger extract

Concentration (g/l)	E_{corr} (V)	I_{corr} (mA/cm ²)	Rate (mmpy)	I.E (%)
-	-0.411	0.394	1.412	-
50	-0.424	0.135	0.495	65
100	-0.411	0.109	0.401	72
150	-0.409	0.054	0.195	86

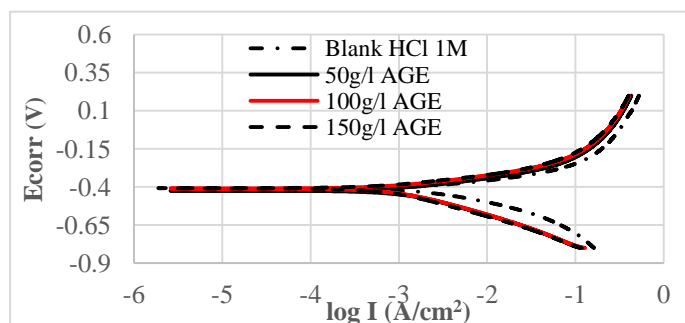


Figure 3: Polarization curve of mild steel in 1M HCl with different inhibitor concentration

From the graph in below, the colour lines are called observed polarization curve. In this curve, there is partial current for forward reaction, known as the anodic reaction and the partial current for reverse reaction known as the cathodic reaction. The both partial currents are precisely equal and

opposite. Since there is no net current flow, the potential shift from their equilibrium value with the help from the external current is called polarization. In this experiment, the value started from -0.8V and the curve shifted at the point about -0.4V until the reaction is fully utilized. Anodic reaction occurred at the curve after the observed polarization curve was shifting to the positive values. The Tafel slopes can be sketch by putting the tangent line to the both anodic and cathodic polarization curves. The data can be shown that the values for Tafel slopes decrease when the higher concentration of aqueous ginger extract was used in 1M HCl at room temperature. As the corrosion potential is increase towards positive, corrosion current density, I_{corr} decrease with higher concentration of aqueous ginger extract in 100ml of 1M HCL solution.

3.3 Surface analysis

The microstructure of sample was observed to identify the reaction of the inhibitor with mild steel in 1M of HCl . The microstructure of the mild steel experiences the corrosion process in the solution containing only 1M HCl is presented in figure 4(a). The corrosion formed darker appearance than the original mild steel. When the 50g/l concentration of the inhibitor was mixed in the acid solution, the microstructure of the layer of the mild steel changed as shown in figure 4(b). It can be observed when comparing the mild steel microstructure in HCl solution with the microstructure of mild steel mixed with the 50g/l concentration of inhibitor where the corrosion process retard in certain places because the inhibitor prevents the corrosion. In figure 4(c) and (d), the brighter in color indicates the inhibitor on the surface of the mild steel where there is no corrosion process happens. Figure 4(c) and (d) show the effect of inhibitor concentration to the microstructure of the mild steel in 1M HCl . It can be said that the inhibitor was absorbed into the mild steel to produce a protective layer to prevent the corrosion process on the surface.

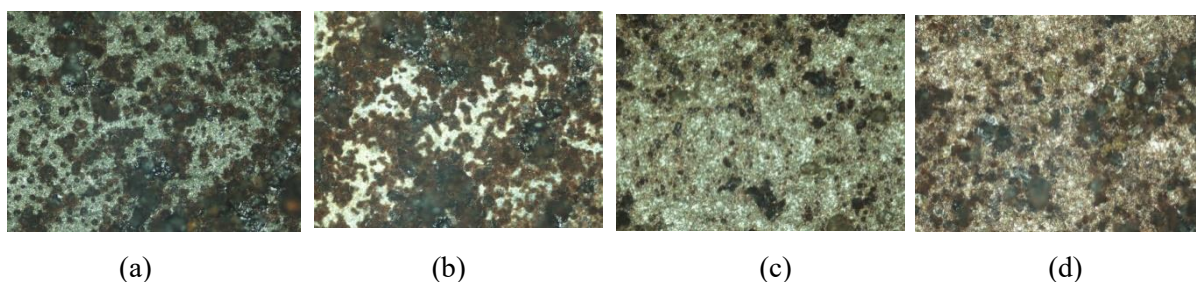


Figure 4. (a) Mild steel in 1M HCl , (b) Mild steel in $1\text{M HCl} + 50\text{ g/l}$ Inhibitor, (c) Mild steel in $1\text{M HCl} + 100\text{ g/l}$ Inhibitor, (d) Mild steel in $1\text{M HCl} + 150\text{ g/l}$ Inhibitor.

4. Conclusion

Ginger extract can be used as corrosion inhibitor for mild steel in hydrochloric acid solution. The higher concentration of inhibitor is the lower corrosion rate and the higher corrosion inhibition efficiency. Weight loss experiment shows that maximum inhibition efficiency of the high concentration of inhibitor is 91% . The surface analysis has carried out to observe the microstructure of mild steel in the absence and presence of inhibitor. Polarization experiment also shows similar results to that of weight loss experiment. It showed that the ginger extract from rhizome (G-1) and the ginger extract from powder (G-2) have same effectiveness in preventing corrosion of mild steel in hydrochloric acid solution. The efficiency both of them is about 90% .

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