High Temperature Effectiveness of Ginger Extract as Green Inhibitor for Corrosion in Mild Steel

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Abstract

Corrosion is one of the major problems of mild steels in acidic medium. This can be minimized by the application of corrosion inhibitors, however; the most of inhibitors are toxic in nature. Therefore inhibitors from green sources are highly desirable to maintain the sustainability of the environmental system. Consequently, in this study ginger was selected; its juice extracted mechanically and used as an inhibitor. The different concentrations of ginger extract such as 0.25ml, 0.5ml, 0.75ml and 1ml were mixed in 0.1 M HCl solution to record the effect of inhibitor on corrosion rate at room temperature and at an elevated temperature of 50^{o}C. Electrochemical linear polarization resistance (LPR) tests were carried out to determine the corrosion rates at both temperatures with different additions of the inhibitor respectively. The LPR test uses three electrodes, first electrode of AISI 1019 (mild steel), second electrode is standard electrode of saturated calomel while the third electrode consists of graphite, which is called counter electrode, to measure potential difference. The whole assembly was dipped in the solution having varying concentration of inhibitors. The corrosion rate was found to be higher in the absence of ginger extract. Conversely, the corrosion rate was dramatically reduced more prominently at 50^{o}C but was less effective at $T_{room;}$ with the trace-additions of ginger-inhibitor. So this research would be the good contribution to overcome the deterioration of mild steel and increase its life at ambient temperatures, by using economically available environmentally-friendly organic compound specially the use of locally available raw material should be focused.

Keywords: Mild Steel; Green Corrosion Inhibitor; Ginger extract; linear polarization, corrosion rate, elevated temperature.

1. Introduction

Carbon steel is commonly employed as a major construction material for pipe work in the petrochemical industries. This is due to its excellent mechanical and physical properties. . However, the major problem is its low corrosion resistance in normal corrosive environments. In particular, the acidic solutions such as sulfuric acid, hydrochloric acid and phosphoric acid have a massive use in chemical industries for wide variety of processing such as acid pickling, acidic cleaning, etc.; eventually causing serious corrosion problems.

In general, inhibitors are often used to overcome corrosion of metals and alloys particularly in acidic mediums. A number of organic compounds have been reported being effective corrosion inhibitors.

In this study, the ginger was selected to be source for corrosion inhibitor owing to its simple extraction method, nontoxic nature, low cost and presence of effective organic compounds. For corrosion rates, Linear polarization resistance LPR tests were carried out using computerized potentiosat. The effect of various concentrations of green inhibitor is studied at room temperature and 50^{o}C

But the problem is this the most of these inhibitors are highly toxic in nature which are detrimental for environment and human safety. Therefore, to resolve this issue, the non-toxic inhibitors can be obtained from natural sources, are highly preferred. . Different green inhibitors have been reported for the replacement of hazardous inhibitors, to be effective for steel in acidic solutions; e.g. artemisia oil [1], telfaria occidentalis extract [2], lawsonia extract [3], ammi majus L. fruit extracts [4] , occimum viridis extract [5], juice of prunus cerasus [6], pennyroyal oil from mentha poulegium [7], musa sapientum peels [8], shahjan, pipali and orange [9], murraya koenigii leaves [10], Polysaccharides [11], Azardirachta Indica Leaves[12], Rollinia occidentalis [13], 2-amino-3-((4-((S)-2-amino-2-carboxyethyl)-1H-imidazol-2-yl) thio) propionic acid [14], Polysaccharide from Plantago [15] , etc.

2. Experimental Procedures

2.1 Composition of samples

Carbon steel was purchased from local market and analysed using optical emission spectroscopy in order to confirm the chemical composition. The

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chemical composition of the steel is shown in Table 1. that particular grade is commonly known.

Table 1 Chemical compositions of AISI 1019 type steels (wt %).

C	Si	Mn	P	S	Cr	Mo	Ni
0.161	0.241	1.10	0.0180	0.0062	0.0156	0.0040	0.0114
Al	**Co**	**Cu**	**Nb**	**Ti**	**V**	**W**	**Pb**
0.0395	0.0055	0.0089	0.00023	0.0014	0.0018	0.017	<0.00020
Sn	**As**	**Ca**	**Sb**	**Zn**	**N**	**O**	**Fe**
0.0019	0.0012	0.0010	<0.00040	0.0010	0.0256	<0.0020	98.4

2.2 Sample Preparation

In total, the ten samples of size 10 x 10 x 5 mm were cut using abrasive cutting machine, as per the requirement of LPR test equipment. These samples were weighed before corrosion taking place. Further, these samples were soldered with electrodes, verified electrical connections and finally mounted in an epoxy resin for LPR testing; as shown in Figure 1. Now hereafter, it will be called as working electrode.

Figure 1 as-repared working electrodes

The samples were further ground using silicon carbide papers of 240, 320, 400, 600, 800 and 1000 grit to remove the scale from the front surface to be tested, and polished to achieve the mirror finish surface which is the standard requirement of the LPR test.

as mild steel (AISI-1019).

2.3 Acid environments

2.3.1 HCL 0.1 M 32% concentrated

The HCL provided in laboratory was 37% concentrated. To make it 32% concentrated, the 1.6ml distilled water was taken in a beaker, and then 10ml of 37% concentrated HCl was poured and solution was transferred through a pipette and dropped in another beaker containing 990 ml distilled water.

2.4 Ginger Extract

One kilogram of ginger was purchased from local market . Ginger was first to cut into small pieces; next their skin was peeled off and finally compressed in a machine to extract their juice. The juice was stored in a bottle for later application.

2.5 Computerised Potentiostat

2.5.1 Working Electrode

There are five ports in the computerized potentiostat cell. The central port is used for the working electrode which is the material of interest i.e. AISI 1019. Green and blue leads are connected to the working electrode.

2.5.2 Reference Electrode

The Reference electrode is made up of saturated calomel electrode. It acts as a standard. White lead is attached to this electrode.

2.5.3 Counter Electrode

This electrode consists of graphite which is used to count the potential difference between the working electrode and the reference electrode. Red and orange leads/wires were attached to this electrode as shown in
Figure 3 LPR measurement using computerized potentiosat
. The black lead remains unattached to any of the electrode and serves as a ground wire.

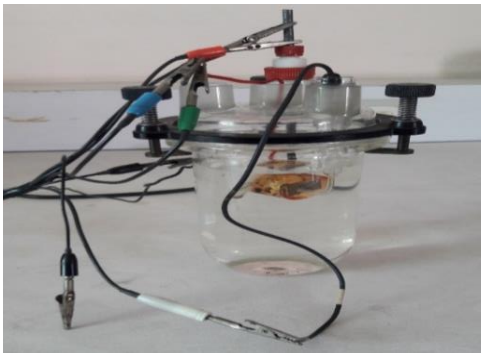

Figure 3 LPR measurement using computerized potentiosat

2.6 Process Parameters

The test was done by soaking an AISI 1019 sample in HCl solution of 0.1 M concentration, at room temperature, without the addition of an inhibitor for 1 hour. Then the sample was tested in potentiostat using linear polarization mode. Similarly, the above experiment was repeated for 0.25, 0.50, 0.75 and 1 ml of ginger extract at room temperature and at 50 $^{\circ}$C. The parameters are given in Table *2*.

Table 2 LPR test parameters.

Parameters	Values									
Initial E	-0.02 V									
Final E	0.02 V									
Sample Period	2 sec									
Density	7.87 g/cm^3									
Sample Area	1 cm^2									
Scan Rate	0.125 mV/s									
Temperature	Room temperature					50^{o}C				
Concentration of inhibitor	0 ml	0.25 ml	0.5 ml	0.75 ml	1.0 ml	0 Ml	0.25 ml	0.5 ml	0.75 ml	1.0 Ml

3. Results and discussion

LPR technique was applied to investigate the metal/electrolyte interface and corrosion that occurred in the presence and absence of ginger extract in the electrolyte. LPR was carried out from cathodic potential of −0.02V(vs. Open Circuit Potential-OCP) to an anodic potential of +0.02 V. Sweep rate of 0.125 mV per second was used to study the polarization resistance (Rp). The above experiment was then repeated for 0.25, 0.50, 0.75 and 1ml formulations of ginger extract at room temperature and at 50 $^{\circ}$C respectively, as described in Figure3-6

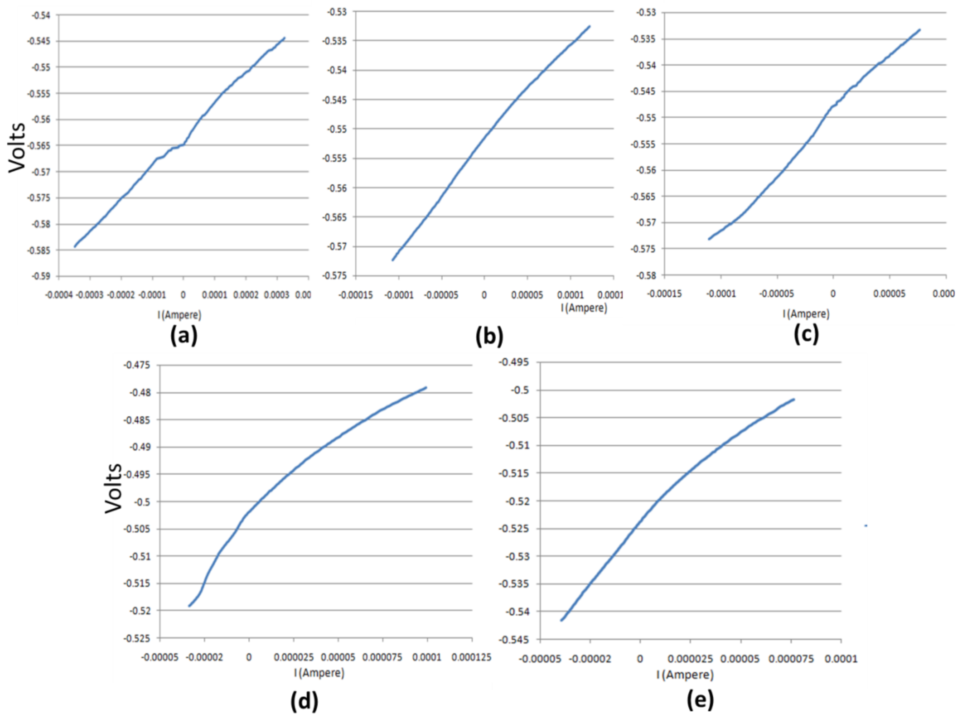

Figure 2 LPR plots of carbon steel recorded in 0.1 M HCL at room temperature; (a) without Inhibitor (b) 0.25ml Inhibitor (c) 0.5ml Inhibitor (d) 0.75ml Inhibitor and (e) 1ml Inhibitor

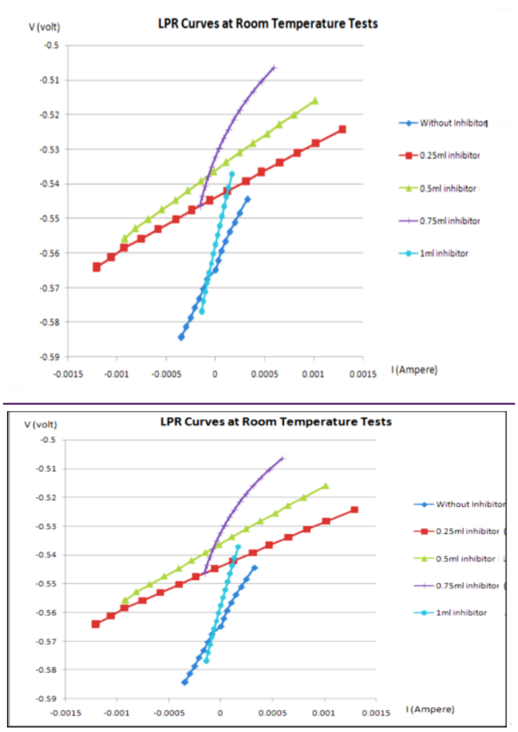

Figure 3 LPR plot of carbon steel recorded in 0.1 M HCL at room temperature at different concentrations of inhibitor

Whereas the Figure3 graphs were plotted to illustrate the I_{corr-} vs. V_{corr-} behaviours separately at T_{room}. As concentration of inhibitor increased, the ratio of voltage and current increased, thus the resistance to corrosion enhanced, as compared in Figure4 The corrosion rates that were obtained at room temperature are; 59.20 mpy, 17.93 mpy, 13.37 mpy 11.15 and 10.97 mpy at zero inhibitor, 0.25ml inhibitor, 0.5ml inhibitor, 0.75ml inhibitor, and 1ml inhibitor, respectively. Consequently, the corrosion rate at T_{room} with addition of different concentrations of ginger juice were not too much effective as compared to the higher temperature results. That is, the two-similar kind of slopes with less difference in corrosion rate; of zero-inhibitor and 1ml-inhibitor could be obtained from figure4.

The oxidation rates observed at 50^{o}C were 405.7 mpy, 224.7 mpy, 180.2 mpy 68 mpy and 30.47 mpy at zero-inhibitor, 0.25ml inhibitor, 0.5ml inhibitor, 0.75ml inhibitor, and 1ml inhibitor respectively.

In figure5, the I_{corr-} vs. V_{corr-} plots were shown to elaborate the potential decrease in corrosion rate with ginger extract at 50 ^{o}C. In theory the rate of corrosion should be higher at higher temperature, that's why, converse to the T_{room} the rate at 50 ^{o}C was 405.5 mpy without incorporation of inhibitor, Figure6. Further to this, the ginger-product into electrolyte at higher temperature played vital role to decrease the oxidation of mild steel obviously with big margin from 405.5 mpy to 30.47 mpy, refer the figure6 for the information. In result, the reduction in corrosion rate was observed dramatically at 1ml at 50 ^{o}C which is better resistive rate than T_{room} corrosion was, as in figure7.

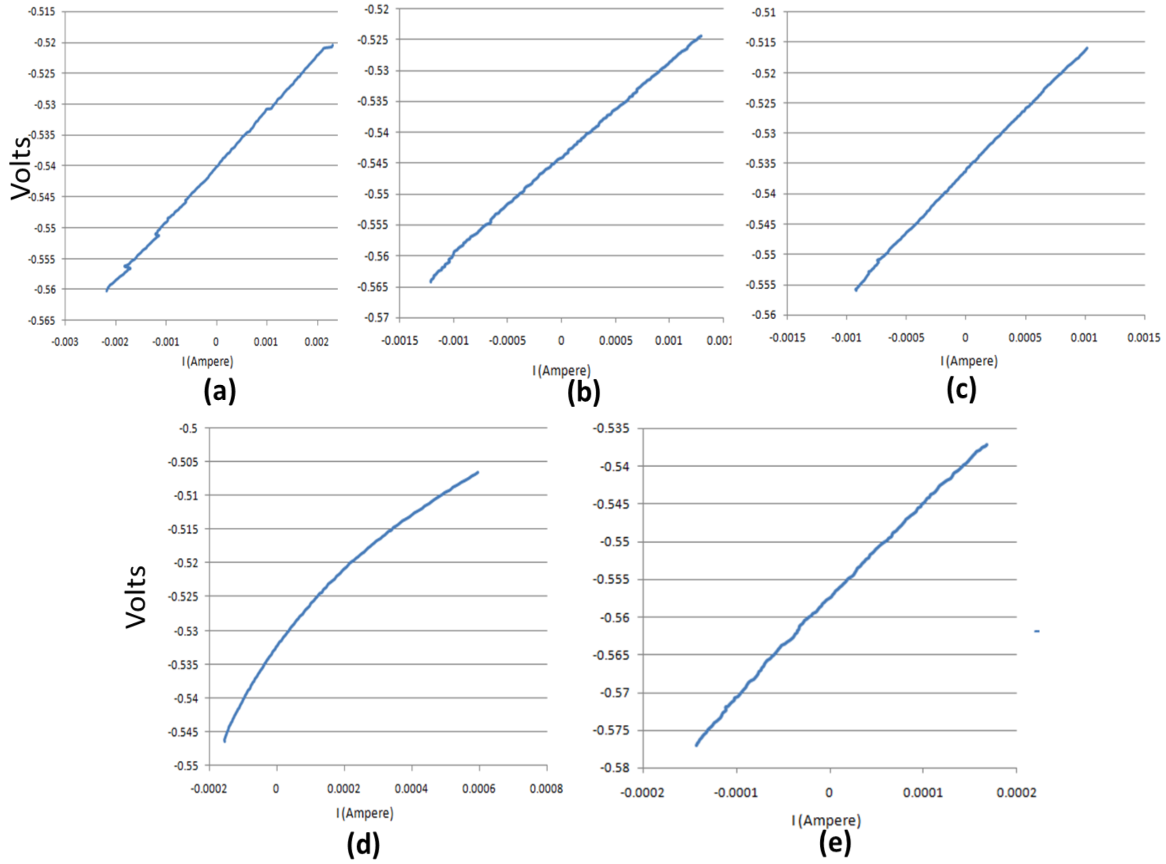

Figure 4 LPR plot of carbon steel obtained in 0.1 M HCL at 50^{o}C temperature (a) without Inhibitor (b) 0.25ml Inhibitor (c) 0.5ml Inhibitor (d) 0.75ml Inhibitor and (e) 1ml Inhibitor.

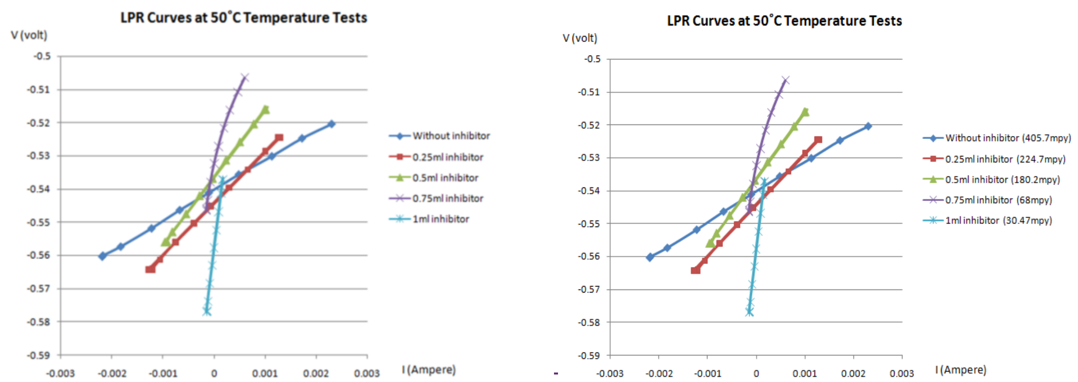

Figure 5 LPR plot of carbon steel recorded in 0.1 M HCL at 50^{o}C temperature at different concentrations of inhibitor

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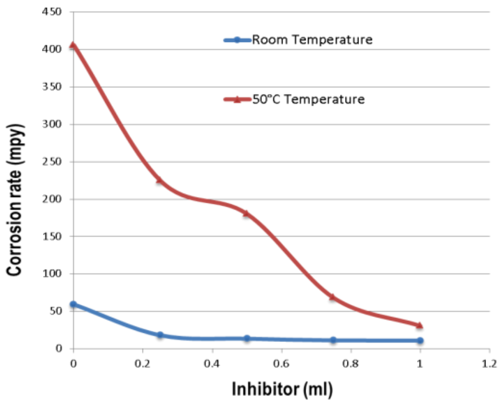

Figure 6 LPR plot of carbon steel recorded in 0.1 M HCL at room temperature and50°C temperature at different concentrations of inhibitor

To certain extent corrosion rate decreased as inhibitor concentration increased and thereafter it remains constant at T_{room}. Inverse to this, at higher temperature the reduction in corrosion rate was more prominent than that recorded with room temperature.

Furthermore, the initial step in the corrosion inhibition of metals in acid solutions consists of adsorption of the inhibitor on the oxide-free metal surface followed by retardation of the cathodic and/or the anodic electrochemical corrosion reactions [16]. Gomaa et. al. 2015, reported the peaks of carbon, nitrogen, chloride, silicon and sulphur in their EDS analysis of corrosion product when high concentration of ginger extract inhibitor was used [17]. The combination of these elements should be responsible to make the complex composition which is resistant to the corrosion. . Since the presence of some of these compounds are indicated in the analysis of ginger, as Tao, Y., et al. 2009 discussed.[18]. This indicates that the adsorption of ginger extract on the walls of metal played the shielding phenomena to resist the oxidation in mild steel at low cost with lower concentration of ginger product.

4. Conclusions

The ginger extract could be obtained from a conventionally cheap method, successfully used as corrosion inhibitor. The different concentrations of ginger extract such as 0.25ml, 0.5ml, 0.75ml and 1ml were mixed in 0.1 M HCl solution to record the effect of inhibitor on corrosion rate at room temperature and at an elevated temperature of 50°C. Electrochemical linear polarization resistance (LPR) tests were carried out to determine the corrosion rates at both temperatures with different additions of the inhibitor respectively. The LPR test uses three electrodes, first electrode of AISI 1019 (mild steel), second electrode is standard electrode of saturated calomel while the third electrode consists of graphite, which is called counter electrode, to measure potential difference. The rate of corrosion was higher when corrosion inhibitors were not used. The addition of corrosion inhibitor decreased the rate. The corrosion rate become constant at room temperature after addition of 250 ppm of inhibitor and no reduction in corrosion rate was observed at higher concentration. The decrease in corrosion rate was more prominent at 50 °C, there after a high value of corrosion rate was observed in the absence inhibitor. The corrosion rate kept on decreasing with increasing the percentages of inhibitor and approaching to very low values at the highest concentration. It is concluded that at room temperature a small quantity of 250 ppm is sufficient to decrease the corrosion rate while for higher temperature higher concentrations of inhibitors are required. Adsorption of the inhibitor-compound on the surface of metal was suggested to be the mechanism of corrosion inhibition. Effect -of ginger extract on Mild steel is considered in this research but other materials, especially alloy steels should be studies in further research. In future it is suggested to consider ginger peel as corrosion inhibitor for further decrease the cost of inhibitor. Higher temperature, above 50°C, should also be considered.

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