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The Performance of Papaya Leaf Extract on The Corrosion Rate of Carbon Steel in 0.5 M HCl Solution

Irwan Nurdin[1,*], Zulkifli[1], Saifuddin[1], Nurlaili[2], Tsaqif Aufa Irza[3], Suhendrayatna[3], Ipan Suandi[4], Mohd Shahadan Mohd Suan[5], Asmalina Mohamed Saat[6]

[1] Chemical Engineering Department, Politeknik Negeri Lhokseumawe, 24301 Lhokseumawe, Indonesia
[2] Mechanical Engineering Department, Politeknik Negeri Lhokseumawe, 24301 Lhokseumawe, Indonesia
[3] Chemical Engineering Department, Universitas Syiah Kuala, 23111, Banda Aceh, Indonesia
[4] Electrical Engineering Department, Politeknik Negeri Lhokseumawe, 24301 Lhokseumawe, Indonesia
[5] Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal, Melaka, Malaysia
[6] Universiti Kuala Lumpur Malaysian Institute of Marine Engineering Technology (UniKL MIMET) Department, Dataran Industri Teknologi Kejuruteraan Marin, Bandar Teknologi Maritim, Jalan Pantai Remis, Lumut Perak, 32200, Malaysia

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ABSTRACT

The performance of papaya leaf extract as a corrosion inhibitor for carbon steel metal in 0,5 M HCl solution was investigated using immersion methods. The measurements were conducted in different concentrations of papaya leaf extract and immersion time. It also investigated the effect of temperature on the corrosion rate of carbon steel without and with the use of papaya leaf extract. It would enhance the corrosion inhibitor regarding these materials since the study is still rarely elaborated. The experiments were conducted using ASTM G-31-72 standard practice for laboratory immersion corrosion testing. The carbon steel corrosion rate and inhibition efficiency were examined. Results show that the concentration of papaya leaf extracts influences the corrosion rate of carbon steel. Higher papaya leaf extract concentration reduces the carbon steel corrosion rate. The increasing immersion time increases the corrosion rate. Moreover, increasing temperatures increase the corrosion rate. The inhibition efficiency increases with the increase of papaya leaf extract concentration. The highest inhibition efficiency is 73.10% which reached a concentration of 5% and immersion times of 5 days.

1. Introduction

Corrosion is the process of destroying metals or non-metals due to interactions with their environment. The use of carbon steel as a construction material is increasing nowadays in line with the development of industrialization and infrastructure [1,2]. However, the carbon steel is corroded due to interaction with a corrosive environment [3-5]. The acidic environment is one of the corrosive environments for carbon steel. One of the acidic environments commonly used in industry is hydrochloric acid.

[*] *Corresponding author.*
E-mail address: irwan_nurdina@yahoo.com (Irwan Nurdin)

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The occurrence of corrosion has a major impact on life, both from an economic and environmental perspective [6-8]. From an economic point of view, this can lead to high maintenance costs, fuel, and energy costs due to steam leaks, and production losses in the industry due to work being stopped during the repair of corrosion-affected materials.

One way to control the corrosion rate is to use corrosion inhibitors. A corrosion inhibitor is defined as a substance that, when added in small amounts to a corrosive environment, reduces the attack of environmental corrosion on metals. The use of corrosion inhibitors is increasing nowadays because they are economically cheaper than other corrosion control methods [9].

Various types of inhibitors have been developed for various environments and process conditions, which generally consist of inorganic and organic compounds, but most of these inhibitors are composed of basic chemicals that are harmful to humans and the environment such as nitrite, chromate, and other hazardous inorganic materials. so, its use is limited [10].

Therefore, the development of environmentally friendly corrosion inhibitors is an attraction for researchers to study [11-13]. The study of extracts from various plants and fruits is believed to be able to act as corrosion inhibitors because they contain long-chain organic molecules that can settle on the metal surface thereby inhibiting the interaction of metals with their environment.

Inhibitors from natural extracts are a safe and more appropriate solution because they are easy to obtain, biodegradable, low cost, and environmentally friendly [14-17]. Natural ingredient extracts, particularly those containing N, O, P, and S atoms, as well as atoms with lone pairs of electrons. Elements that contain these lone pairs of electrons can later function as ligands that will form complex compounds with metals [18,19]. Natural extracts' effectiveness as corrosion inhibitors is inextricably linked to the nitrogen content of their chemical compounds.

Many investigations have been done on mild steel corrosion and using organic compounds as corrosion inhibitors in hydrochloride solutions [20-22]. Organic inhibitors are naturally occurring molecules that contain heteroatoms, such as oxygen, sulfur, or nitrogen and are therefore less expensive and less hazardous to the environment than synthesized organic inhibitors.

The investigation of plant extracts as low-cost and ecologically friendly corrosion inhibitors has piqued the interest of many researchers due to the environmental implications [23-25]. Many papers describe the use of parts of plant extracts as mild steel corrosion inhibitors in diverse media. Various natural materials have been investigated as raw materials for the manufacture of environmentally friendly corrosion inhibitors, including papaya leaf extract. The phytochemical analysis of papaya extract detected that papaya leaf extract contains alkaloids, flavonoids, glycosides, reducing sugar, saponin, steroids, and tannins [26]. Moreover, papaya leaf contain a significant amount of tannin, N-Acetyl-Glucosamide compounds, and amino acids, which are useful inhibitor compounds that function as protection from corrosion reactions [27,28]. Hence, they are a good choice for use as a corrosion inhibitor. As a result, the investigation of papaya leaves as corrosion inhibitors will provide an alternative method of utilizing papaya leaves in the future.

To investigate the use of Carica papaya leaf extract as a bio-corrosion inhibitor for mild steel applications in a marine environment, the weight loss method was used. The bio-corrosion medium was made by dissolving the solid residue of Carica papaya leaf extracts in the seawater filtrate solvent in two-liter glass bottles at room temperature at a concentration of 10 grams per liter. In both uninhibited and inhibited conditions, the weight loss of the samples and the pH of the media were measured every seven (7) days for a period of forty-nine (49) days. In a marine environment, the results demonstrated that Carica papaya leaf extract effectively inhibits the biocorrosion of both untreated and treated mild steel. However, the annealed sample exhibited the most significant resistance to bio-corrosion activities for both conditions [29].

Gravimetric analysis was utilized to evaluate the inhibition of aluminum corrosion by C. papaya leaf extract in 1.0 M H_2SO_4 at 303 K, 313 K, and 313 K at varying concentrations and temperatures. Scanning Electron Microscope (SEM) and Fourier Transform Infrared (FT-IR) spectroscopy were used to characterize the samples. The samples were characterized using scanning electron microscopy (SEM) and Fourier transform infrared (FT-IR) spectroscopy. In addition, the Gibbs energy, entropy, and temperatures of adsorption were calculated, along with kinetic parameters such as activation energy and entropy of activation. All of them agreed with the adsorption of physical inhibitors into the surface of the aluminum [30].

The studies conducted regarding the use of papaya extract as a corrosion inhibitor still do not have complete data regarding the corrosion behavior of this inhibitor. Lack of study regarding the examination of papaya leaf extract for corrosion inhibitor in the fields. Hence this study was conducted to see the effect of the concentration of papaya leaf extract, immersion time, and temperature on the corrosion rate of carbon steel in a corrosive solution of 0.5 M HCl. The experiment also determines the inhibition efficiency of papaya leaf extract on the corrosion rate of carbon steel in 0.5 M HCl solution.

2. Methodology

The measurement of the corrosion rate in this study used the immersion method with metal weight loss data by ASTM G31-72 [31]. It is possible to define the corrosion rate as the relation of the mass loss of the metals to the area of the samples multiplied by the amount of time they have been submerged. Gravimetric measurements were carried out on rectangular mild steel specimens with dimensions of 50x30x2 mm and composition (weight percent) of 0.047 percent carbon, 0.158 percent manganese, 0.025 percent silicon, 0.014 percent phosphorous, 0.003 percent sulfur, 0.01 percent chromium, 0.004 percent molybdenum, 0.013 percent copper, 0.031 percent aluminum, and the remainder iron. Abrasive papers with silicon carbide grits ranging from 400 to 1200 were used to abrade the surfaces of the specimens in this experiment. The sample was then cleaned with acetone, washed with a water stream, and allowed to air-dry before being immersed in a 0.5 M HCl solution in the absence and presence of an inhibitor, as appropriate.

Before use, the pre-cleaned specimens were weighed with 0.1 mg precision on an analytical scale. The samples were then immersed for varying amounts of time in a corrosive liquid with and without inhibitors. After being rinsed, cleaned with acetone, dried with hot air, and weighed, the specimens were then weighed. Using the mean weight loss of three identical specimens, the corrosion rate and inhibitor efficiency were estimated.

3. Results

3.1 Effect of Inhibitor Concentration on Corrosion Rate

The effect of inhibitor concentration on corrosion rate is given in Figure 1. It can be seen that the higher the inhibitor concentration, the lower the metal corrosion rate. It also can be seen that the largest corrosion rate without the use of inhibitors was at 5 days of immersion, which was 169.7697 mpy. Meanwhile, with the use of a 5% volume of papaya leaf extract inhibitor, the corrosion rate decreased to 45.6773 mpy, resulting in a decrease of 3.7 times. This phenomena also occured for other concentration of papaya leaf extract. The decrease in the corrosion rate is due to the inhibitor effect which inhibits the corrosion rate. It can be explained that the organic inhibitor affects the corrosion rate with the formation of the layer on the surface of metals due to the adsorption process.

Hence, increasing the inhibitor concentration increase of layer formed in the interface of metal that reduces contact between metal and the environment.

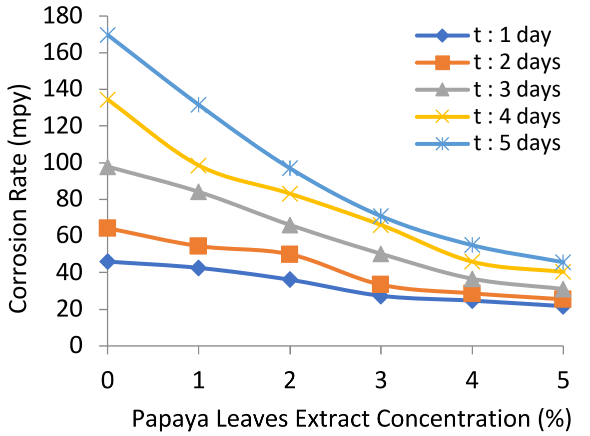


Fig. 1. Effect of papaya leaf extract concentration

3.2 Effect of Immersion Time on Corrosion Rate

The effect of immersion time on the corrosion rate of carbon steel in a 0.5 M HCl environment is shown in Figure 2. It can be seen that the longer the immersion time, the higher the metal corrosion rate. From Figure 2, it can also be seen that the corrosion rate without the use of inhibitors at 1 day immersion time was 46.0261 mpy. With an immersion time of 5 days, the corrosion rate increased to 169.7697 mpy, increasing 3.7 times the corrosion rate. The increase in the corrosion rate is due to the increase in contact time between the corrosive solution and the metal which increases the metal corrosion reaction.

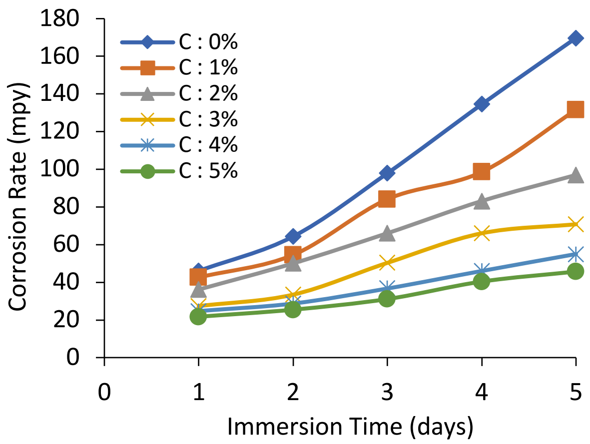


Fig. 2. Effect of immersion time

3.3 Effect of Temperature on Corrosion Rate

Figure 3 depicts the effect of temperature on the corrosion rate of carbon steel in a 0.5 M HCl solution using papaya leaf extracts. The figure shows the effect of temperature on the corrosion rate both without and with using papaya leaf extract inhibitor. It reveals that the corrosion rate of carbon steel increases with increasing temperature for both conditions. This is because an increase in temperature will increase the mobility of metal ions so that the rate of metal corrosion increases.

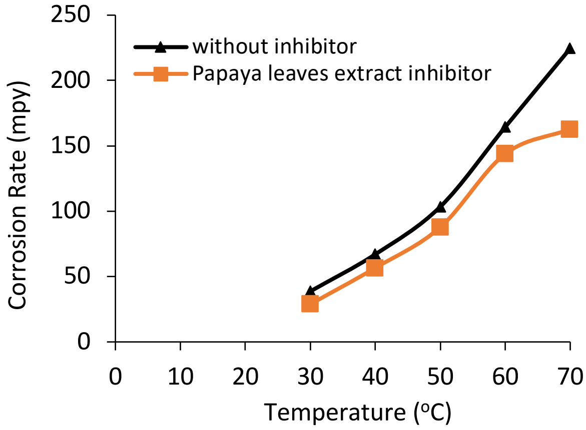


Fig. 3. Effect of temperature

3.4 Inhibition Efficiency

The inhibition efficiency of papaya leaf extracts against carbon steel corrosion in a 0.5 M HCl environment is shown in Figure 4. From Figure 4, the inhibition efficiency of papaya leaf extracts against corrosion of carbon steel in 0.5 M HCl solution increases from 22.48% at 1 day immersion time to 73.10% at 5 days immersion time for 5% papaya leaf extract concentration. This indicates an increase in the inhibition efficiency of 50.62%.

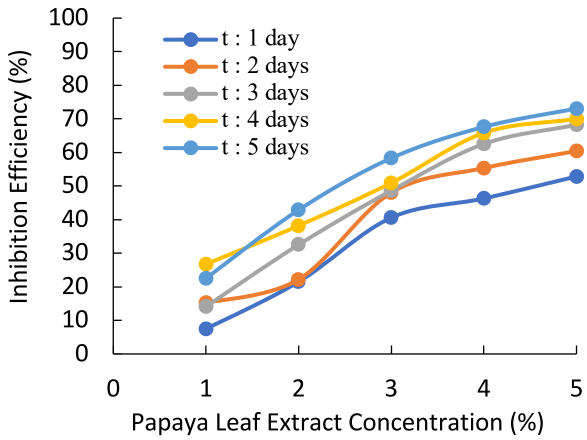
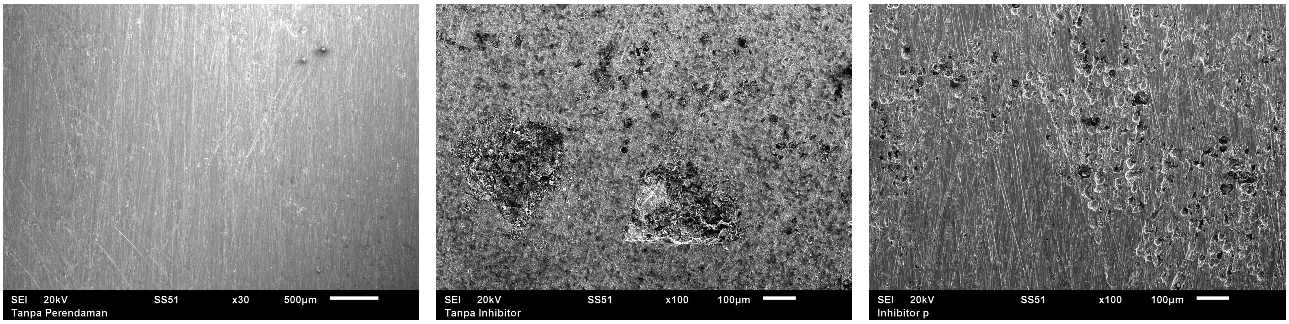


Fig. 4. Inhibition efficiency

3.5 Morphological Analysis

Morphological analysis of carbon steel metal using SEM is shown in Figure 5. Figure 5(a) shows a sample of carbon steel that has been prepared without going through the immersion process. From the picture, there are scratch lines due to sanding, this shows that the sanding process is not good. Figure 5(b) shows the SEM of carbon steel in 0.5 M HCl solution which was immersed for 5 days. The metal undergoes degradation, namely the dissolution of the metal due to corrosion. While Figure 5(c) shows a sample of carbon steel immersed in a corrosive solution of 0.5 M HCl added with 5% papaya leaf extract inhibitor. From the picture the appearance of corrosion on the metal surface is not very visible, this is indicated by the metal surface is not rough and has holes. The same thing also happened in Figure 5(c) where the metal was immersed in a corrosive solution which was added with papaya leaf extract inhibitor. It is seen that the appearance of the metal surface is smoother. This shows that the corrosion that occurs has been covered by a layer formed as a result of inhibitor adsorption on the metal surface.



(a) (b) ©

Fig. 5. SEM image of samples

4. Conclusions

The concentration of papaya leaf extract, as well as immersion time and temperature, affect the corrosion rate of carbon steel in 0.5 M HCl solution. The rate of corrosion decreases as the concentration of papaya leaf extract increases. However, the corrosion rate of carbon steel increases with the immersion time and temperature. The effectiveness of the extract's inhibition increases as the concentration of the extract increases. The highest efficiency was obtained at a 5 percent extract concentration, which is 73.10 percent. The SEM results show that the inhibitor covers the metal's surface. Studies show papaya leaf extract can prevent mild steel corrosion in 0.5 M HCl.

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