Biomass Extraction as Green Corrosion Inhibitor for Low Carbon Steel in Hydrochloric Acid Solution

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Abstract. Corrosion is a degradation of metals quality caused by a chemical reaction between a metal and its ambient. The use of a green inhibitor is a natural method to control the corrosion rate of the metal. The objective of this research is to count the efficiency of the green inhibitor from biomass of tea and coffee extract, to find which variable that affect the most of corrosion rate of carbon steel, to determine the best concentration of extracts to control the corrosion rate of carbon steel. The extraction methods are the use method with a solvent ratio 1:4 of ethanol : aqua dest. Weight loss method is used to determine the rate of corrosion with 0.5g/L, 1g/L, and 1.5 g/L variance of inhibitor concentrations and 3, 6, 9, and 12 days immersed times. The lowest corrosion rate is 61.27 mpy at 1.5 g/l of tea extract inhibitor solution with 9 days immersed times and the highest efficiency is 79.02% at 1.5 g/l of tea extract inhibitor solution with 12 days of immersed times.

1. Introduction
Corrosion is a big problem in metallic materials which cannot be avoided because almost all metals are more stable in their oxidized state. This condition results in the metal’s usefulness being reduced. The impact is a disaster that can harm humans, both material, financial, and casualties, Widharto [1]. Most of the chemical industry processes involve contact between metal and acidic media which causes corrosion, so it is necessary to use a corrosion inhibitor, Fouda et al [2].

Corrosion is damage caused by a chemical reaction between a metal or metal alloy and its environment. One method to minimize corrosion is to use a corrosion inhibitor. A corrosion inhibitor is a chemical which, when added to a corrosive environment, can effectively reduce the rate of corrosion. Corrosion inhibitors are used widely in various chemical industries such as in petroleum and petrochemical refineries, Yanuar et al [3].

The process of preventing corrosion can be done in several ways, including a coating on metal surfaces, cathodic protection, adding corrosion inhibitors, and others. Corrosion inhibitor itself is defined as a substance which when added in small amounts to the environment will reduce the environmental corrosion attack on the metal. Generally, corrosion inhibitors come from organic and inorganic compounds that contain groups that have lone pairs, such as nitrite, chromate, phosphate, urea, phenylalanine, imidazoline, and amine compounds. However, the fact is that these synthetic chemicals are dangerous chemicals, expensive, and not environmentally friendly, so that small and medium industries rarely use inhibitors in their cooling systems, piping systems, and water treatment systems, to protect iron/steel from corrosion attack. The use of inhibitors that are safe, easy to obtain, biodegradable, low cost, and environmentally friendly is needed, Haryono et al [4].
The objectives of this research was to study the efficiency of tea and coffee extracts as green inhibitors, determining variables that had an effect on the corrosion rate of carbon steel, and determining the concentration of coffee and tea extracts that best inhibited the corrosion rate.

2. Methodology

2.1. Preparation of specimen and corrosion inhibitor
The materials used in this research was ASTM A36 carbon steel with a size 3cm x 2cm x 0.17cm. Hydrochloric acid solution 1M was used as a corrosive medium with immersion temperatures ranging from 25 °C – 30 °C. The biomass extracts used as green inhibitors were tea and coffee with concentrations of 0.5 g / L, 1 g / L, and 1.5 g / L, respectively. The immersion time of the specimens was carried out for 3, 6, 9, and 12 days.

2.2. Weight loss study
The corrosion rate and efisiensi inhibisi was determined from specimen weight loss of carbon steel. The corrosion rate is the amount of metal that is released per unit time on a certain surface. The corrosion rate is expressed in units of mils per year (mpy). The unit of mils is the equivalent of 0.001 inches [5]. Determination of the corrosion rate referring to NACE International standard [6]. The calculation of efficiency is obtained by the percentage decrease in the corrosion rate of metals immersed with corrosion media with the addition of a corrosion inhibitor compared to the rate of metal corrosion in corrosion media that is not added with a corrosion inhibitor. The greater the efficiency of the inhibitor obtained, the better the inhibitor is to be applied

2.3. The optimum variable study
Variations in parameters are made based on the design of the experiment using the Central Composite Design (CCD) to determine the most influential variables and get the optimal conditions.
This study uses a standard design with 2 factors and 10 runs. In this study, the factors involved were the observation variables involved in the response, namely the concentration of inhibitors (tea extract and coffee extract) and contact time, while the corrosion rate was the observed response

3. Results and Discussion

3.1. Effect of contact time on corrosion rate and inhibition efficiency
Figure 1 shows the difference in the value of the corrosion rate of steel in a 1M HCl solution with the addition of tea extract as an inhibitor and without an inhibitor. The lowest steel corrosion rate was obtained in the addition of an inhibitor of 1.5 g/L with an immersion time of 9 days, namely 61.27 mpy and the highest rate of steel was obtained in the addition of an inhibitor of 0.5 g/L with an immersion time of 9 days, namely 135.33 mpy.

The high corrosion rate of steel in acid media without the addition of an inhibitor is quite significant when compared to the corrosion rate of steel in acidic media with the addition of an inhibitor. According to Caliskan and Akbas [7], the presence of H⁺ ions in the corrosive medium (HCl) results in the substance being aggressive towards metal dissolving. Observations during inhibition testing showed that more hydrogen gas was produced when immersing steel in HCl media without inhibitor than in the presence of an inhibitor. The hydrogen gas that is present on the surface of the solution indicates a corrosion process in the cathodic reaction due to the discharge of hydrogen ions from acidic solutions.
Figure 1. The corrosion rate of steel using a tea extract inhibitor with a variety of immersion time

Figure 2 shows the difference in the value of the corrosion rate at the contact time of the metal in a 1M HCl solution with the addition of a coffee extract inhibitor and without the addition of an inhibitor. The lowest corrosion rate was the addition of an inhibitor of 1.5 g/L with a contact time of 9 days of 150.22 mpy and the highest rate of corrosion was the addition of an inhibitor of 0.5 g/L with an immersion time of 3 days of 198.62 mpy.

Pardede [8] has conducted research using banana peel extract inhibitors with concentrations of 0.5 g/L, 1 g/L, and 1.5 g/L at immersion time for 3 days. The lowest corrosion rate obtained was the inhibitor concentration of 1.5 g/L of 117.465 mpy. In this study, the lowest corrosion rate was obtained at the same concentration using tea extract at 97 mpy and using coffee extract at 165.72 mpy. This shows that tea extract is better at inhibiting corrosion than banana peel extract but the coffee extract is less effective than banana peel extract. Thus it can be concluded that tea extract is the best inhibitor in inhibiting the corrosion rate of carbon steel compared to banana peel extract and coffee extract.

The more inhibitor is added, the corrosion rate decreases. This is due to the high concentration of inhibitors which increase the intensity of the interaction with the steel surface. The wider the steel surface area covered will be able to prevent corrosive attacks from the solution [9].

Figure 2. The corrosion rate of steel using a coffee extract inhibitor with a variety of immersion time
In this study, the administration of tea and coffee extract inhibitors had the effect of reducing the corrosion rate and the ability to inhibit them as measured by their efficiency values. Inhibition efficiency values can be seen in Figure 3 and Figure 4.

Based on Figure 3, it can be seen that the difference in the value of the corrosion rate at the contact time of steel in 1M HCl solution with tea extract inhibitor and without inhibitor. The highest inhibition efficiency was the addition of an inhibitor of 1.5 g/L with an immersion time of 12 days of 79.02% and the lowest inhibition efficiency was the addition of an inhibitor of 0.5 g/L with an immersion time of 3 days of 60.82%.

![Figure 3](image-url)  
**Figure 3.** Inhibition efficiency of tea extract inhibitor with various immersion time.

Figure 4 it can be seen that the difference in the value of the corrosion rate at the contact time of the steel in the 1M HCl solution with the addition of coffee extract inhibitor and without inhibitor. The highest inhibition efficiency was the addition of an inhibitor of 1.5 g/L with an immersion time of 12 days of 51.44% and the lowest inhibition efficiency was the addition of an inhibitor of 0.5 g/L with an immersion time of 3 days of 36.76%.

Efficiency increases with increasing inhibitor concentration. The greater the concentration of inhibitor added and the longer the immersion time of the steel plate, the higher the inhibition efficiency, and vice versa [10].

Figure 3 and Figure 4 it can be seen that the highest inhibition efficiency occurs in tea extract inhibitors when compared to coffee extract inhibitors. This happens because there are more compounds that can coat the carbon steel in the tea extract when compared to the coffee extract. In tea extract, there are polyphenolic compounds such as catechins (13-31%) and flavanols (3-4%) which can coat carbon steel [11]. While in the coffee extract, the compound that can coat carbon steel is caffeine (0.4-2.4%).

The increase in inhibition efficiency in this study showed that tea and coffee extracts were able to act as corrosion inhibitors. The ability of the inhibitor to protect the steel from corrosion will disappear or run out at a certain time, this is because the longer the immersion time, the more the inhibitor will be attacked by the solution.
3.2. Design and analysis of tea and coffee biomass extracts

Response graphs are used to explain the effect of variables on response. The corrosion rate response can be described in a 3-dimensional curve and contour plot. A contour plot is a 2-dimensional plot which is a cross-section of a 3-dimensional curve. Contour plots are useful for analyzing the effects of interactions between factors on responses. The 3-dimensional curve of tea extract can be seen in Figure 5.

Figure 5 illustrates the depiction of the effects of these two variables on the corrosion rate. The points on the contour plots represent the process conditions under study. From the 3-dimensional curve, it can be seen that the higher the inhibitor concentration and contact time, the corrosion rate response value will also increase. This can be seen from the color change that occurs on the contour plot, where the corrosion rate is getting better as the value of concentration and time increases, which is indicated by a change in color to green. However, in Figure 5 the optimum value from the experiment is not found. In the application used, the critical value of this variation is obtained when the inhibitor concentration is 2.94 g/L with an immersion time of 21.8 days. This means that to get the optimum value from this research, the value of concentration and time needs to be increased

Figure 4. Inhibitor efficiency of coffee extract with variation of immersion time

Figure 5. Response surface curves for tea extract inhibitors
Figure 6 shows a depiction of the effects of both variables on the corrosion rate. The points on the control plot indicate the process conditions under study. From the 3-dimensional curve, it can be seen that there is an optimum point from the experiment. On the contour plot, it was found that the optimum point occurred at a concentration distance of 1 g/L - 1.5 g/L and at a time of 9 days - 15 days. In the application, it was found that in this variation the critical value was obtained when the inhibitor concentration was 1.18 g/L with an immersion time of 11.8 days. So it can be said that the optimum value for this variation occurs at that point.

Figure 6. Response surface curves for coffee extract inhibitors

4. Conclusion
The highest inhibition efficiency of tea extract was obtained at a concentration of 1.5 g/L with an immersion time of 12 days with an inhibition efficiency value of 79.02%. In the acid solution with the addition of coffee extract as an inhibitor, the highest inhibition efficiency was obtained at a concentration of 1.5 g/L with an immersion time of 12 days with an inhibition efficiency value of 51.44%. In the HCl solution with the addition of tea extract as an inhibitor, the lowest corrosion rate was 61.27 mpy at an inhibitor concentration of 1.5 g/L and an immersion time of 9 days. Meanwhile, the lowest corrosion rate in acid solution with the addition of coffee extract as an inhibitor was obtained at an inhibitor concentration of 1.5 g/L and immersion time for 9 days with a corrosion rate of 150.22 mpy.

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