Determining efficiency of inhibition of johar flower ethanol extract (Cassia siamea Lamk.) in the corrosion reaction of A36 Steel (ASTM)/SS400 (JIS) in 3% NaCl solution

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Abstract. The investigation about determining the efficiency of inhibition of johar flower ethanol extract in the corrosion reaction of A36 steel (ASTM)/SS400 (JIS) in 3% NaCl solution has been done. This research aims to determine the immersion time and concentration of johar flower ethanol extract in inhibiting the rate of corrosion on steel plates with the highest value of inhibition efficiency. Making the inhibitor is done by extracting the johar flowers using the maceration method. The extract was mixed into the 3% NaCl corroding media with variations in concentrations of 0, 1000; 2000; 3000 and 4000 ppm, then immersed steel plate samples with a size of 50×20×3 mm for the variation of immersion time 5; 10; 15 and 20 days. Corrosion testing is carried out using the weight loss method. The test results showed that secondary metabolite compounds in johar flower ethanol extract could function as a corrosion inhibitor by inhibiting the rate of corrosion on the steel plate. The inhibition efficiency for johar flower ethanol extract was found in the concentration of 3000 ppm with immersion time for 15 days, amounting to 33.49%.

1. Introduction
Corrosion is the damage to metal materials caused by electrochemical reactions with the environment [1]. One of the easily corroded metals is low carbon steel [2-10]. This steel material is the most widely available and very diverse in its use.

Corrosion is defined as damage or deterioration in the metal’s quality due to a reaction between the metal and its environment. This corrosion reaction is a natural process that continues to occur as long as the material is still interacting with its environment. Corrosion can cause a lot of losses in tools that use metal iron material; this is because corrosion can reduce the service life of the tool, system failure/shutdown, and damage to equipment [5]. However, the corrosion reaction can be minimized the process of damage [11]. In essence, corrosion can be prevented by converting ferrous metal into stainless steel, but this process is considered too expensive for most iron [12,13].

Some other ways that can be done to inhibit corrosion reactions include such as coating metal surfaces, cathodic protection and adding corrosion inhibitors [14-16]. Types of corrosion inhibitors are divided into two, namely organic and inorganic inhibitors. Some inorganic compounds that are used as corrosion inhibitors in metals are phosphate, chromate, dichromate, silicate, borate, molybdate, and arsenate compounds. However, those compounds is a dangerous material; the price is relatively expensive and not environmentally friendly [17]. The chemical compounds used in organic inhibitors are heterocyclic types like N, O, P, S, and some atoms which contained free electron pairs. These free electron pairs will bind to the metal and form complex compounds [15,16].
Based on research conducted by Stupnisek-Lisac [18], the most effective organic composition is used as a corrosion inhibitor. Organic compounds that are currently being developed are Green Inhibitors. Plants and seeds are a source of Green Inhibitors.

The compounds contained in corrosion inhibitors are types of secondary metabolites. The content of secondary metabolites in organic inhibitors can inhibit corrosion reactions on metals. According to Kurniawati [16] ethanol extract of johar flowers (Cassia siamea L.) has flavonoid compounds, tannins and alkaloids. The content of secondary metabolites found in johar flower extract makes this plant potentially inhibit the rate of corrosion reaction of low-carbon steel (mild carbon steel). Apart from that, the cost is much cheaper and more environmentally friendly than synthetic inhibitors.

Based on previous research on the use of Green Inhibitors, namely Indrayani [9] on water hyacinth ethanol extract as an inhibitor on SS400 steel which inhibits corrosion rate 0.20 M concentrations in acidic and basic environments. Research conducted by Ali, et al. [6] regarding guava leaf extract as SS304 steel corrosion inhibitor which has activity in inhibiting corroding rate at a concentration of 1000 ppm in a medium of 3% NaCl solution and 3% HCl with inhibition efficiency of 56.29%.

The advantages of johar plants have not been investigated for many benefits, which have been useful as a bioindicator of acid-base, where the compounds that play a role are flavonoids, as asthma and anti-dandruff drugs, and as natural antioxidants [6,20].

Based on the above, it is necessary to conduct research on determining the efficiency of inhibition of ethanol extracts of johar plant flowers (Cassia siamea L.) on the corrosion rate of steel A36 (ASTM) / SS400 (JIS) in 3% NaCl solution based on immersion time and concentration level of inhibitor.

2. Materials and methods

2.1 Materials

The material used in this research is the flower of the johar plant. Methanol (p.a), NaCl (p.a), distilled water, aluminum foil, filter paper, A36 (ASTM)/SS400 steel plate, sandpaper Grade 80 and 120.

The tools used are analytical balance, vacuum rotary evaporator, volumetric flasks, 60 mesh sieve, Buchner funnel, micrometre screw glassware which are generally used in laboratories and blenders.

This research was conducted in factorial completely randomized design (RALF) with two factors, namely immersion time consisting of 4 levels of treatment (A) and a concentration factor of johar flower ethanol extract inhibitors consisting of 5 levels of treatment (B). The experimental unit in this study was a combination of factors in all treatment stages. So in this study, there were 20 experimental units. This research was carried out twice. The experimental model can be seen in the following table:

| Immersion time | Inhibitor Concentration |
|----------------|-------------------------|
| A1             | A1B0 A1B1 A1B2 A1B3 A1B4 |
| A2             | A2B0 A2B1 A2B2 A2B3 A2B4 |
| A3             | A3B0 A3B1 A3B2 A3B3 A3B4 |
| A4             | A4B0 A4B1 A4B2 A4B3 A4B4 |

Annotation: A1 = 5 days B0 = 0 ppm A2 = 10 days B1 = 1000 ppm A3 = 15 days B2 = 2000 ppm A4 = 20 days B3 = 3000 ppm B4 = 4000 ppm

This research was carried out in five stages, johar flowers preparation, extraction of johar flowers using maceration method, preparing of A36 steel plate (ASTM)/SS400 (JIS), making of 3% NaCl corrosion media and corrosion testing.

2.2 Johar flowers preparation

Separated johar flower petals, then sliced into small pieces and dried and then mashed using a blender.
2.3 Extraction of Johar flowers
Extraction was carried out using a maceration method using ethanol solvent. A sample extraction of 48.8 grams of Johar flowers was put into a container, then 600 ml of ethanol was added. The mixture is stored for 3 x 24 hours, then filtered by vacuum filtering. The resulting filtrate was separated by a rotary vacuum evaporator to obtain a thick Johar flower extract. The thick Johar flower extract was weighed as much as 1 gram and dissolved into 100 ml technical ethanol and obtained a Johar flower extract solution with a concentration of 10000 ppm. The Johar flower extract solution was further diluted to obtain concentrations of 1000 ppm, 2000 ppm, 3000 ppm and 4000 ppm.

3. Making corrosion media 3% NaCl and corrosion testing
Dissolved 30 grams of NaCl with distilled water and then put the solution into a 1000 mL volumetric flask and then dissolved again with distilled water to mark the limit. According to the American Society for Testing and Material (ASTM), the minimum standard for laboratory-scale corrosion testing is 0.2 mL / mm² of the surface area of a steel plate sample.

Steel plate samples were made in 50 x 20 x 3 mm using an LVD hydraulic steel cutting machine. The top of the steel plate is perforated with a drilling machine with a diameter of 3 mm so that it can be hung during immersion in corroding media. The steel plate is cleaned using grade 80 sandpaper, followed by grade 120. The steel plate is then washed using distilled water, then dried and weighed to determine the steel plate’s initial weight.

The steel plate immersion container was filled with 3% NaCl solution of 900 mL each. Inhibitor solutions with various concentrations of 0, 1000, 2000, 3000 and 4000 ppm were added to the containers as much as 20 mL. Steel plates are inserted into each immersion container. Furthermore, the time immersed in steel plate immersion varied from 5, 10, 15 and 20 days. After immersion, the steel plate samples were rinsed with distilled water and ethanol to remove the remaining rust on the steel plate and continued using acetone and dried. After that, the steel plate is re-weighed as the final weight. The corrosion rate is calculated using the formula:

\[
\text{Corrosion Rate} = \frac{(K \times W)}{(A \times T \times D)}
\]

where:
- \(K\): Constant \((8.74 \times 10^4)\)
- \(T\): Immersion time (Hour)
- \(A\): Surface area (cm²)
- \(W\): Weight loss \((W_0 - W_i)\) (gram)
- \(D\): Steel plate density (g/cm³)

Calculation the efficiency of steel plate inhibition using the equation:

\[
\%E = \frac{(CR1 - CR2)}{CR1} \times 100
\]

\(\%E\): Inhibition efficiency

\(CR1\): Non-inhibited corrosion rate

\(CR2\): Inhibited corrosion rate

4. Results and Discussion
4.1 Corrosion testing by addition of Johar flower ethanol extract inhibitor
The Corrosion rate is a measure to determine the amount of metal material degradation due to corrosion with the environment. The greater the corrosion rate’s value, the degradation of metal material due to corrosion is also greater [20, 21]. Determination of the rate of corrosion using the weight loss method. The principle of this method is to calculate the amount of metal material lost or lost weight after the immersion test.

The solution of 3% NaCl was chosen as the medium in the steel plate corrosion reaction. The selection of 3% NaCl in this study was based because the solution was strong electrolyte, which
contained a lot of dissolved sodium (Na⁺) and chloride (Cl⁻) ions when compared to distilled water (H₂O). The nature of an electrolyte solution is that its molecules can dissociate to form charged ions so that corrosion occurs more quickly in a solution of sodium chloride (NaCl). According to ASM Handbook [12], chloride ions are corrosion reaction factors on steel plates. The selection of NaCl concentration was based according to research by Jones [15] because, at that concentration, the oxygen conditions in the 3%NaCl solution are well aerated.

Visual observation was carried out after immersion of the steel plate sample by observing the condition of the corroding media in the jar container where the immersion of the steel plate sample in the corroding media solution without the addition of a Johar flower extract inhibitor was slightly clearer. However, there was a sediment/reddish-brown corrosion product, whereas with the addition of the inhibitor Ethanol extract of Johar flower is slightly turbid, the sediment/corrosion products produced are also less when compared with immersion without inhibitors. As seen in Figure 1, the most amount of deposition of corrosion results was found in soaking for 15 days without the addition of inhibitors, and the least amount of deposition was found in soaking for 15 days with the addition of inhibitors at concentration 4000 ppm.

According to Hammouda, et al. [11], corrosion products that are formed in the dipping of low carbon steel (low carbon steel) in a 3.5% NaCl solution are Oxy-hydroxide layers/deposits which include magnetite (Fe₃O₄) and lepidocrocite (γ-FeOOH). So from the results of observations made, the type of rust formed is magnetite and lepidocrocite compounds, where these deposits are more present in the corrosive media without the addition of inhibitors. Whereas a smaller amount of sludge is produced in the corrosive media with the addition of inhibitors. It is due to the content of secondary metabolite compounds in the Johar flower ethanol extract which can form a stable thin layer on the surface of the steel plate sample that can inhibit the rate of formation of magnetite and lepidocrocite in excess. Soaked steel plate samples are then visually observed for each change that occurs. The results obtained in Figure 1 show that there were no noticeable changes between the samples with the addition of inhibitors and without inhibitors after immersion. Judging from the shape of the surface, the corrosion that occurs is a type of uniform corrosion. All of them together form a deposit or a brownish layer of the sample. However, the viscosity of the deposit varies. The coating of the sample in the system with the addition of an inhibitor is not easily removed when compared to the system without the addition of an inhibitor whose layer is easily removed when cleaning the steel plate sample or pickling as shown in Figure 2. In the deposited system, the deposit/layer does not disappear immediately if cleaned so it can be said that the deposit/layer contained in the sample is well adhered to, so it becomes more stable.

**Figure 1.** Visual observation of steel plate after immersion in 3% NaCl media with addition of inhibitors from various concentration: (a) 0 ppm; (b) 1000 ppm; (c) 2000 ppm; (d) 3000 ppm; (e) 5000 ppm).

**Figure 2.** Steel plate surface after cleansing using **pickling** method: (a) 0 ppm; (b) 1000 ppm; (c) 2000 ppm; (d) 3000 ppm; (e) 5000 ppm)
After the steel plate sample is cleaned, the final weight is weighed as a weight difference before and after immersion in the corrosive media. The purpose of weighing is to determine the weight difference of steel plates after immersion in the corrosive media with the addition of inhibitors and without the addition of ethanol extract inhibitors of Johar flowers. After that, the steel plate corrosion rate is calculated to determine the effect of the addition of Johar flower ethanol extract inhibitors in inhibiting the steel plate corrosion rate, as presented in Figure 3.

![Figure 3](image)

**Figure 3.** Effect of Johar flower ethanol extract concentration on corrosion rate of A36 (ASTM) / SS400 (JIS) steel plate

Figure 3 shows that the addition of Johar flower ethanol extract inhibitors affects the corrosion rate of A36 / SS400 steel plate samples. It can be seen in the picture above that the addition of 0 ppm or without the addition of inhibitors has the highest corrosion rate when compared to those given the addition of an ethanol extract of Johar flowers which tends to be lower. Corrosion rate rises fluctuatively from 5 to 15 days at 0 ppm or without the addition of inhibitors at 0.1678 mm/year. It is since the 3% NaCl media is highly corrosive so that it can damage the surface of steel plate samples that are not protected by inhibitors so that the mass of the steel plate decreases and the corrosion rate increases. Decrease in corrosion rate at the time of soaking for 20 days or 480 hours without the addition of johar flower ethanol extract inhibitors, according to Plorentino [20]. The rate of corrosion of metals in neutral / slightly alkaline conditions is determined by the rate of oxygen diffusion (O\(_2\) / H\(_2\)O) into the metal surface. The longer the immersion time, the more rust deposits on the surface of the metal are formed so that it prevents the diffusion of oxygen (O\(_2\) / H\(_2\)O) into the metal surface, so the rate of corrosion is decreased. As seen in the yellow line graph that is immersion time for 15 days or 360 hours that the inhibitors of Johar flower ethanol extract dissolved in 3% NaCl media work optimally at each concentration, where after the addition of ethanol extract Johar flower inhibitors the corrosion rate tends to decrease where the corrosion rate The lowest is in the 5th-day immersion and the concentration of 4000 ppm inhibitors is 0.1075 mm/year. According to Möller [19] the inhibitor requires a long time to fully dissolve in this 3% NaCl solution so that it can form protection on the metal surface that can inhibit the corrosion rate of steel plate samples

4.2 Determination of inhibition efficiency of Johar flower ethanol extract

Based on the calculation of the corrosion rate of the steel plate then the inhibition efficiency is calculated. Calculation of inhibition efficiency is needed so that the ability of inhibitors to inhibit corrosion rate can be known. So that the data obtained is presented in Figure 4.

Figure 4 shows the value of inhibition efficiency inversely proportional to the corrosion rate. The highest inhibition efficiency was found in the addition of the concentration of johar flower ethanol extract inhibitors.
extract as much as 3000 ppm which was 33.4923%. Besides that, the graph on the 15 days or 360 hour immersion shows a reasonably stable graph and a slight decrease in the addition of 4000 ppm johar flower ethanol extract inhibitors. According to Uhlig [21], the addition of inhibitors to the 3% NaCl corroding media will occur the corrosion reaction rate to be lower, so that the working time of the inhibitor to protect the metal becomes longer. The ability of an inhibitor to protect the metal from corrosion will disappear or run out at a certain time, that is because the longer the time the inhibitor will be more depleted by the environment. According to Ali, et al. [6] the optimum point of inhibitor concentration occurs when a protective layer that is formed has completely coated the metal surface, when experiencing saturation of the inhibitor concentration the corrosion rate will also increase again. In addition, other factors such as the ability of the 3% NaCl corroding media to corrode steel plates and the ability of the inhibitor to 3% NaCl can also affect the value of inhibition efficiency.

**Figure 4.** Effects of various concentration of Johar flower ethanol extract on corrosion inhibition efficiency on A36 (ASTM)/SS400 (JIS)

5. **Conclusion**

Optimum immersion time and concentration of johar flower ethanol extract in inhibiting corrosion of A36 (ASTM) / SS400 (JIS) steel plates in 3% NaCl corroding media were 15 days and 3000 ppm with inhibition efficiency of 33.49%.

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