Effect of Addition Tahongai Leaf Extract (Kleinhovia hospita Linn.) As Organic Inhibitor on 1040 AISI Steel

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Abstract
This research will study about corrosion inhibition by using tahongai leaf extract (Kleinhovia hospita Linn.) in a 3.5% NaCl environment. The inhibitor is extracted using maceration process from Tahongai leaf (Kleinhovia hospita Linn.). Testing of antioxidant activity using DPPH method gives result that antioxidant activity of tahongai leaf extract (Kleinhovia hospita Linn.) is strong antioxidant (96%) compared to vitamin C (98%), functional group test by FTIR method indicates that tahongai leaf extract (Kleinhovia hospita Linn.) contain flavonoid shown by O-H bond (3357.41 cm⁻¹), double bond C=C (1643.36 cm⁻¹), C-H bond (2922.24 cm⁻¹, 1460.69 cm⁻¹, 1375.57 cm⁻¹), Efficiency of inhibition reach 99.9825% for addition of inhibitor with concentration 200 ppm and duration of immersion 20 days. This inhibition behavior is also supported by polarization measurements where the lowest corrosion rate of 8.3x10⁻⁴ mm/year is obtained at the same concentration and immersion time.

Keywords: Antioxidant, Organic inhibitor, Tahongai leaf (Kleinhovia hospita Linn.)

1. Introduction
A corrosion inhibitor is a compound that protects metal from corrosion in various ways. Therefore, it is necessary to have a good analysis and calculation on the practice of its use in order to obtain effective results [¹]. Corrosion inhibitors are divided into two types: organic and inorganic inhibitors. Some inorganic compounds containing clusters having electron-free pairs such as phosphate, chromate, borate, nitrite, urea, phenylalin and other amine compounds are often used as corrosion inhibitors. However, these synthetic chemicals are dangerous chemicals because they are toxic, expensive, and environmentally unfriendly. For that, start looking for another alternative that is more economical and environmentally friendly [²]. One alternative that can be applied is by utilization of organic material as an environmentally friendly corrosion inhibitor. The requirement of organic material that can be used as a corrosion inhibitor is an organic material containing antioxidant compounds. Antioxidants in corrosive environments are able to inhibit the rate of material corrosion.
Natural antioxidants can be found in vegetables, fruits, and woody plants. Secondary metabolites in plants derived from alkaloids, flavonoids, saponins, quinones, tannins, steroids / triterpenoids \[3\]. One of the typical plants of East Kalimantan that grow freely in nature is tahongai plant or known by the name *Kleinhovia hospita* Linn.

Tahongai (*Kleinhovia hospita* Linn.) is a shrub with soft green leaves that grows naturally in East Kalimantan. Its habitat mostly located in the riverside. For a long time, tahongai plant has been used as medicine by Dayak people in Kalimantan. They believe the plant has various health benefits. Among others are able to lower blood sugar levels, lower cholesterol and help restore and strengthen the liver. *Kleinhovia hospita* Linn. which has various regional names such as tahongai (Dayak), paliasa (Makassar), and katimahar (Ambon) are used as traditional medicine in parts of Malaya, Indonesia and Papua New Guinea to treat scabies. The leaves and stem bark are used as hairwash for ticks, while leaf juice is used as an eye washer \[4\]. Leaves and stem bark of *Kleinhovia hospita* Linn. contains cyanogen compounds that are assumed to help kill ectoparasites such as lice. A number of fatty acids with cyclopropenyl rings such as scopoletin, and flavonoids such as kaempferol, quercetin and rutine have been isolated from the leaves \[5\].

Research conducted by \[6\] suggests that tahongai (*Kleinhovia hospita* Linn.) leaf has anti-diabetic effect with the mechanism of inhibition of active transport of glucose. Research conducted in isolating organic compounds contained in tahongai (*Kleinhovia hospita* Linn.) leaf based on several levels of solvent polarity, showed that there were at least 96 single isolates and instrumentation indicated the presence of terpenoid and phenolic group compounds \[7\]. Then the results of research conducted by \[8\] successfully identified the class of flavonoid and alkaloids. Then on the fraction of methylene chloride from the active fraction was isolated a coumarin derived compound suspected as scopoletin \[9\]. The presence of these antioxidant compounds supports the utilization of the tahongai plant (*Kleinhovia hospita* Linn.) in East Kalimantan as an organic inhibitor on the application of AISI 1040 steel pipes.

2 Research Methodology

2.1 Tools and Materials

The equipment used in this study include the plastic container size of 8,000 mL, nylon yarn, wood cantilever, measuring cups capacity of 1,000 mL, measuring cups capacity of 10 mL, coarse and fine filter paper, digital scales, paper pads grade 80 to 2,000, spatula, dropper, ruler, scissors, potentiostat device, evaporator device and optical microscope. While the materials used in this study such as steel AISI 1040, technical salt solution, distilled water, and fresh tahongai (*Kleinhovia hospita* Linn.) leaves (Fig. 1) were obtained from Lempake, Samarinda, East Kalimantan.
2.2 AISI 1040 Steel Specimen Preparation

The specimen used was AISI 1040 steel with a composition (wt%): 98.6 to 99% Fe, 0.60 to 0.90% Mn, 0.370 to 0.440% C, ≤0.050% S, and ≤0.040% P. AISI 1040 steel was prepared into 2 specimen shapes. The first specimen to test weight loss cut rectangular with a size of 2 cm x 2 cm x 0.3 cm and perforated using a drill as the linking thread, while the test specimen to cut potentiostat shaped beam with a size of 2 cm x 0.5 cm x 0.4 cm for polarization testing. Coat layer is removed by grinding and polishing.

2.3 Organic Inhibitor Preparation

The process of leaf drying starts from the leaves of tahongai (Kleinhovia hospita Linn.) to further separated from the stalks and then weighed the wet weight. The leaves are then cleaned of dirt and then bonded per 20 leaves for further hanging and aerated in the open air without exposure to rain and sun for 30 days. Manufacture inhibitors done by maceration method by introducing 775 grams of tahongai leaves (Kleinhovia hospita Linn.) dry with 8,000 mL of 99.9% ethanol into a container with a capacity of 8,000 mL with immersion done for 11 x 24 hours. Then, the extraction results between the filtrate and the residue are separated using a coarse and fine paper filter. The filtrate is used as tahongai leaf extract (Kleinhovia hospita Linn.) which becomes an organic inhibitor. The concentration of inhibitor used in this study was 0 ppm, 100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm as well as variations of 10 days, 20 days, and 30 days immersion.

Fig.1 Fresh tahongai (Kleinhovia hospita Linn.) leaves 3-4 months old
Fig. 2 (A) Fresh tahongai (Kleinhovia hospita Linn.) leaf, (b) Dry tahongai (Kleinhovia hospita Linn.) leaf, (c) Immersion process with maseration method, (d) Filtering process with filter paper, (e) Evaporation process, (f) Taking extracts with acetone, (g) Extracted into small bottle before dried, (h) Drying process extract

2.4 Cluster Function Analysis

Functional group analysis using FTIR (Fourier Transform Infra Red) method was used to determine the bioactive compounds contained in tahongai leaf extract (Kleinhovia hospita Linn.). The analysis was conducted at the Material Characterization Laboratory, Department of Materials and Metallurgical Engineering, Sepuluh Nopember Institute of Technology. The test was performed using FTIR spectrophotometer (Shimadzu) with KBr pellet method.

2.5 Preparation of Electrolyte Solution

NaCl 3.5% corrosion media is made by mixing the NaCl technical salt and aquades. Calculation of inhibitor concentration: ppm (part per million) of units in mg / L, which means that in every 1 L of corrosion media there are several mg inhibitors. For example to get 100 ppm means in 1 L aquades added 100 mg inhibitor.

2.6 Weight Loss Corrosion Testing

This test is intended to look at corrosion products and to know the weight loss produced by the sample when immersed in a 3.5% corrosive NaCl medium. Testing is done by varying the concentration of inhibitor (0 ppm, 100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm) and soaking time (10 days, 20 days and 30 days). Corrosion testing with weight loss method is done by repeating three times. Percentage inhibition efficiency (IE%) is calculated using the following equation:

\[ \text{IE}\% = \left( \frac{W - W_i}{W} \right) \times 100 \]

Where:
- \( W \) = Weight loss without inhibitor (0 ppm)
- \( W_i \) = Weight loss with inhibitor (100, 200, 300, 400, 500 ppm)
2.7 Potential Testing

Potentiostat tests were performed using the PGSTAT101 Autolab device at the Materials and Metallurgy Laboratory, the Materials Engineering and Metallurgy Study Program, the Kalimantan Institute of Technology. OCP (Open Circuit Potential) testing is performed to obtain data about corrosion rate. In the method of potentiodynamic polarization there are 3 electrodes, the comparative electrode Ag / AgCl, platinum auxiliary electrode, and AISI 1040 steel working electrode. This test is based on the concentration of inhibitor (0 ppm, 100 ppm, 200 ppm, 300 ppm, 400 ppm, and 500 ppm) and immersion time of 10, 20, and 30 days.

2.8 Macrostructural Observations

The observations on macrostructure were performed using Carl-Zeiss microscope in the Materials and Metallurgy Laboratory, the Material and Metallurgical Engineering Study Program, Kalimantan Institute of Technology to compare macrostructural changes and the protective layer formed on the surface of AISI 1040 steel after weight loss corrosion test with or without the addition of inhibitor on various variations of immersion and concentration.

3. Results and Discussion

3.1 Analysis of Functional Groups

*Kleinhovia hospita* Linn. leaf methanol extract showed strong antioxidant activity (96%) compared with vitamin C (98%) with DPPH and activity was measured based on extracts from the methanol extract of 48.9% for n-hexane, 74.0% for diethyl ether, 84.3% for ethyl acetate, and 77.1% for residuals. MTT assay showed HepG2 cells in 14%, 76%, and 80% at each concentration of 50 g/mL, 87.5 mg/mL, and 125 mg/mL (White, 2009). From the results of FTIR testing on corrosion inhibitor materials, there are various contained links shown in the peak form (Fig. 4).

Based on the results of the test analysis FTIR (Fourier Transform Infra Red) against tahongai (*Kleinhovia hospita* Linn.) leaf extract obtained bond O-H at wave number 3357.41 cm\(^{-1}\), the double bond carbon-carbon C=C at wave number 1643.36 cm\(^{-1}\), a single bond carbon-hydrogen C-H at wave number 2922.24 cm\(^{-1}\), at wave number 1460.69 cm\(^{-1}\), and the wave number 1375.57 cm\(^{-1}\). In addition, the presence of electronegative atoms (ie, N and O) and the double bonds of the alkene and alkaline groups gives the potential of the extract as a corrosion inhibitor (Kurniawan, 2015). Indicated that flavonoid compounds contained in tahongai (*Kleinhovia hospita* Linn.) leaves extract saw bond contained in flavonoids include several functional groups, including the double bond carbon-carbon C=C, double bond carbon - oxygen C=O, single carbon-oxygen bond C-O, single carbon-hydrogen bond C-H, and single-oxygen-hydrogen O-H (Robinson, 1995).
Fig. 3 Flavonoid

Rafizar \cite{10} in his research confirmed the presence of several organic compounds such as saponins, antrakinon, cardenolin and bufadienol contained within *Kleinhovia hospita Linn* leaf extract with 70% alcohol through chromatography test.

| Compound  | Description                                                                 | Structure                                                                 |
|-----------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Saponin   | In saponin compounds there is no O-H structure and aromatic ring as obtained in FTIR test results. This means that the compound obtained from the FTIR test *Kleinhovia hospita Linn.* leaves not a saponin compound. | ![Saponin Structure](image) |
| Antrakinon| In anthrakinon compound there is a functional group C = O, whereas based on FTIR test results there is no known functional group C = O. This means that the compound obtained from the FTIR test *Kleinhovia hospita Linn.* leaves not an anthracin compound. | ![Antrakinon Structure](image) |
| Flavonoid | The flavonoid functional groups include the C = C double bond, the C = O double bond, the C-O single bond, the single C-H bond, and the O-H single bond. From the obtained FTIR results, the widest area of the O-H hydroxyl group function. In addition to O-H there are also functional groups C-H and C = C. | ![Flavonoid Structure](image) |
Table.2 FTIR Analysis Results in Tahongai Leaf Inhibitors

| Wave Number (cm\(^{-1}\)) | Frequency Range (cm\(^{-1}\)) | Bond | Functional Group |
|---------------------------|-----------------------------|------|------------------|
| 3357.41                   | 3200 – 3600                 | O – H| Hydroxyl         |
| 2922.24                   | 2850 – 2970                 | C – H| Alkane           |
| 2118.95                   | 2100 – 2260                 | C ≡ C| Alkyn            |
| 1643.36                   | 1610 – 1680                 | C = C| Alkene           |
| 1460.69                   | 1340 – 1470                 | C – H| Alkane           |
| 1375.57                   | 1340 – 1470                 | C – H| Alkane           |
| 1237.70                   | 1180 – 1360                 | C – N| Amine, Amide     |

3.2 Calculation Result of Corrosion Efficiency by Weight Loss Method

Corrosion testing with weight loss method was performed with and without addition of inhibitor. The variable used is the level of inhibitor concentration and the duration of immersion. The test is done with three repetitions and then taken on average for the difference in weight.

From the calculation of weight loss can be seen that the efficiency of inhibition of tahongai (*Kleinhovia hospita* Linn.) leaves Highest in the solution of NaCl 3.5% is at a concentration of 200 ppm and at 20 days of soaking time with an efficiency value of 99.9825%. While the lowest efficiency is at a concentration of 300 ppm and on a 20-day immersion period with an efficiency value of 59.1916%.

The decrease in inhibitory efficiency occurring in the indication occurs due to the passive layer of the extract not being able to cover the entire surface of the steel, so that in the uncovered Fe part can be ionized and corrosion occurred. The highest efficiency was achieved in the addition of 200 ppm long-period immersion inhibitors due to the formation of a strong protective layer to the maximum capable of covering the entire metal surface.
### Table 3 Efficiency Calculation Data

| Inhibitor Concentration (ppm) | Immersion Time (days) | Start Weight (grams) | End Weight (grams) | Weight Difference (grams) | IE % |
|-----------------------------|-----------------------|----------------------|--------------------|---------------------------|------|
| 0                           | 10                    | 11.6833              | 9.9735             | 1.7148                    | -    |
|                             | 20                    | 12.9417              | 9.4037             | 3.5830                    | -    |
|                             | 30                    | 12.3133              | 9.2992             | 3.5830                    | -    |
| 100                         | 10                    | 11.7631              | 11.2582            | 0.5049                    | 83.2487 |
|                             | 20                    | 12.5765              | 12.2957            | 0.2808                    | 92.0633 |
|                             | 30                    | 13.2082              | 12.7924            | 0.4158                    | 88.2476 |
| 200                         | 10                    | 14.4097              | 14.0278            | 0.3819                    | 89.2058 |
|                             | 20                    | 10.3001              | 10.2998            | 0.0003                    | 99.9825 |
|                             | 30                    | 7.7774               | 7.2648             | 0.5126                    | 82.9933 |
| 300                         | 10                    | 12.5099              | 12.1384            | 0.3715                    | 87.6746 |
|                             | 20                    | 10.7576              | 9.3138             | 1.4438                    | 59.1916 |
|                             | 30                    | 10.1478              | 9.8856             | 0.2622                    | 91.3009 |
| 400                         | 10                    | 13.0628              | 13.0519            | 0.0109                    | 99.6919 |
|                             | 20                    | 12.1307              | 11.8302            | 0.3005                    | 82.4761 |
|                             | 30                    | 8.5465               | 8.4445             | 0.1020                    | 94.0518 |
| 500                         | 10                    | 14.8427              | 14.8037            | 0.0390                    | 97.7257 |
|                             | 20                    | 12.5765              | 12.2957            | 0.2808                    | 92.0633 |
|                             | 30                    | 11.2216              | 11.0452            | 0.1764                    | 94.1475 |

![Graph of Efficiency Comparison of 10, 20, and 30 days](image)

#### 3.3 OCP Polarization Testing Results (Open Circuit Potential) Based on Concentration

The measurement of corrosion rate of OCP (Open Circuit Potential) method using AISI 1040 steel and with variation of inhibitor 0, 100, 200, 300, 400, and 500 ppm and 10, 20 and 30 day immersion period.

From OCP results at various concentrations of inhibitors (0, 100, 200, 300, 400, and 500 ppm) at the time of immersion 0 days obtained the highest corrosion rate at 0 ppm concentration of $8.2 \times 10^{-3}$ and the lowest corrosion rate at 500 ppm with a value of 2.3x10^-3.
From the OCP results at various concentrations of inhibitors (0, 100, 200, 300, 400, and 500 ppm) at the 10-day immersion period obtained the highest corrosion rate at 0 ppm concentration of $1.4 \times 10^{-2}$ and the lowest corrosion rate at 400 ppm with a value of $2.3 \times 10^{-3}$.

From OCP results at various concentrations of inhibitors (0, 100, 200, 300, 400, and 500 ppm) at 20 days of submersion, the highest corrosion rate was obtained at a concentration of 300 ppm at $1 \times 10^{-2}$ and the lowest corrosion rate at 400 ppm of $8.4 \times 10^{-4}$.

From OCP results at various concentrations of inhibitors (0, 100, 200, 300, 400, and 500 ppm) at 30 days of maximum immersion, the highest corrosion rate at 0 ppm concentration was $7.3 \times 10^{-3}$ and the lowest corrosion rate at 500 ppm with a value of $3.4 \times 10^{-3}$.

The values $E_{\text{corr}}$, $J_{\text{corr}}$, $I_{\text{corr}}$ and CR (Corrosion Rate) respectively show the potential difference values of corrosion between metals soaked in electrolytes provided with standard reference electrodes, corrosion current densities or corrosivity rates, corrosion currents and corrosion rate values.

### Table 4 Comparison of corrosion rate at 0 days

| Inhibitor Concentration (ppm) | $E_{\text{corr}}$ (mV) | $J_{\text{corr}}$ ($\mu$A/cm$^2$) | $I_{\text{corr}}$ ($\mu$A) | CR (mm/year) |
|-----------------------------|----------------------|--------------------------|-----------------|-------------|
| 0                           | -589.32               | 711.79                    | 2.5909          | 0.0082709   |
| 100                         | -466.42               | 339.78                    | 1.2368          | 0.0039482   |
| 200                         | -513.92               | 361.40                    | 1.3155          | 0.0041995   |
| 300                         | -529.49               | 265.21                    | 965.38          | 0.0030818   |
| 400                         | -516.89               | 226.76                    | 825.42          | 0.0026350   |
| 500                         | -542.44               | 200.29                    | 729.05          | 0.0023273   |

### Table 5 Comparison of corrosion rate at 10 days

| Inhibitor Concentration (ppm) | $E_{\text{corr}}$ (mV) | $J_{\text{corr}}$ ($\mu$A/cm$^2$) | $I_{\text{corr}}$ ($\mu$A) | CR (mm/year) |
|-----------------------------|----------------------|--------------------------|-----------------|-------------|
| 0                           | -530.03               | 1.2494                    | 4.5478          | 0.0145180   |
| 100                         | -524.93               | 460.80                    | 1.6773          | 0.0053544   |
| 200                         | -402.78               | 376.13                    | 1.3691          | 0.00437060  |
| 300                         | -478.17               | 420.41                    | 1.5303          | 0.0048852   |
| 400                         | -484.47               | 198.24                    | 721.58          | 0.0023035   |
| 500                         | -517.28               | 213.80                    | 778.22          | 0.00248430  |
Table 6: Comparison of corrosion rate at 20 days

| Inhibitor Concentration (ppm) | $E_{corr}$ (mV) | $J_{corr}$ (µA/cm²) | $I_{corr}$ (µA) | CR (mm/year) |
|-------------------------------|-----------------|---------------------|-----------------|--------------|
| 0                             | -554.220        | 893.600             | 3.25270         | 0.01038400   |
| 100                           | -540.740        | 337.640             | 1.22900         | 0.0039233    |
| 200                           | -531.890        | 71.8710             | 261.610         | 0.00083514   |
| 300                           | -531.500        | 945.080             | 3.44010         | 0.010982     |
| 400                           | -442.650        | 72.7250             | 264.720         | 0.00084506   |
| 500                           | -539.060        | 630.600             | 2.29540         | 0.0073276    |

Table 7: Comparison of corrosion rate at 30 days

| Inhibitor Concentration (ppm) | $E_{corr}$ (mV) | $J_{corr}$ (µA/cm²) | $I_{corr}$ (µA) | CR (mm/year) |
|-------------------------------|-----------------|---------------------|-----------------|--------------|
| 0                             | -397.700        | 629.530             | 2.29150         | 0.0073151    |
| 100                           | -414.990        | 404.920             | 1.47390         | 0.0047051    |
| 200                           | -509.630        | 547.640             | 1.99340         | 0.0063635    |
| 300                           | -386.120        | 349.040             | 1.27050         | 0.0040558    |
| 400                           | -395.910        | 328.100             | 1.19430         | 0.0038126    |
| 500                           | -500.390        | 291.260             | 1.06020         | 0.0033845    |

Fig. 6: Tafel curve of tahongai leaf extract inhibitor on (a) 0 days, (b) 10 days, (c) 20 days, (d) 30 days
From the result of the obtained polarization test, the highest corrosion rate was found at 0 ppm concentration with 20 days of soaking time of $1 \times 10^{-2}$ mm/year, while the lowest corrosion rate was at 200 ppm with 20 days of soaking period of $8.4 \times 10^{-4}$ mm/year. The overall polarization measurement results were in accordance with the weight loss corrosion test results where the lowest corrosion rate and highest efficiency was achieved in the addition of 200 ppm concentration inhibitor with 20 days of soaking time.

3.4 Mechanism of Corrosion Inhibitors

Identifying the mechanism of organic inhibitors is certainly not an easy thing. This is due to the large number of organic compounds contained in the plant. Each of these compounds will cause different reactions to each other. In this study, the focused organic compounds observed were flavonoid compounds found in tahongai (*Kleinhovia hospita Linn.*) leaf. Based on the previous polarization curve it is known that there has been a cathodic reaction which is seen from the value of $E_{\text{corr}}$ and $I_{\text{corr}}$ in the cathodic polarization region. It shows the inhibition of the reaction at the cathode in polarization. Here's what happens: Reduced oxygen levels in 3.5% NaCl solution, causing a redox reaction in solution. The decrease in oxygen levels will further decrease the formation of Fe$^{2+}$ corrosion product. This leads to inhibition of corrosion products and reduced corrosion rate. This mechanism is called the scavenger oxygen mechanism. Judging from the various factors that may affect the reaction, the mechanism is not the only possible mechanism for the use of tahongai leaf inhibitors (*Kleinhovia hospita Linn.*) in this study.

4 Conclusion

Based on the research that has been done, it can be concluded that the lowest corrosion rate at 20 days 200 ppm with the value of $8.3 \times 10^{-4}$ mm/year and the efficiency value of 99.9825%, the highest corrosion rate at 20 days 400 ppm with a value of $6.9 \times 10^{-3}$ mm/year and efficiency value of 59.1916%, and medium highest corrosion rate without inhibitor at 20 days and concentration 0 ppm with corrosion rate value of $1 \times 10^{-2}$ mm/year. The results of macro photographs obtained the best results on specimens with a 20-day immersion period of 200 ppm and the worst at 20 days 300 ppm. The mechanism of corrosion inhibition is indicated as a scavenger oxygen mechanism.

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