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THE USE OF PANDAN LEAVES (*Pandanus amaryllifolius Roxb*.) AS IRON CORROSION INHIBITOR IN HCl MEDIUM

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ABSTRACT

Corrosion inhibitors are excellent ways to protect metals from corrosion. This research aims to determine the ability of pandan leaves (*Pandanus amaryllifolius Roxb*.) as an organic corrosion inhibitor in the type of powder, extract, and tannins. The extraction of tannin compounds in pandan leaves is carried out by the soxhletation method using a sample-to-solvent ratio of 1:25 g/mL. The inhibitor concentration used is 1%, and the variations of immersion duration in 3% HCl medium are one day, two days, three days, and four days. The parameters measured in this study are the corrosion inhibition efficiency and the corrosion rate as measured by the iron weight reduction method. The tannin compound of 1.29% is obtained at the ratio of the sample to the solvent of 1:25 g/mL. The best results obtained from the use of the three types of inhibitors are using pandan leaves tannin inhibitors with a corrosion rate of 31.046 mpy and a corrosion inhibition efficiency of 80.61%.

Keywords: Tannin, Soxhletation, Corrosion Inhibitor, Pandanus, Particle Size.

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INTRODUCTION

Corrosion is the process of metal damage caused by chemical activity or reaction with its environment. This corrosion problem often occurs in industry, which is difficult to solve completely,[1] impacting equipment maintenance costs.[2] Many studies have been carried out on preventing metal corrosion in acidic mediums using inhibitors.[3] The use of an acid medium is done because if a corrosive medium does not assist it, the observation of corrosion will last for a long time. Current research is mostly focused on organic inhibitors that are environmentally friendly and easy to produce because inorganic inhibitors are harmful to the environment.[4] Organic inhibitors work by adsorption, which forms a thin layer to prevent the rate of acid consumption and form a barrier so that the metal does not suffer damage.[5] One type of organic inhibitor that is the target of this research is tannin. Tannins are a complex mixture of non-toxic and biodegradable polyphenol components extracted from plants. Tannins are a part of polyphenolic compounds and are obtained by plant extraction.[6–9] Although the natural inhibitory ability of tannins have been identified for a long time, theoretical and experimental studies structured as metals corrosion inhibitors in various medium have only been carried out recently.[10] Pandan (*Pandanus amaryllifolius Roxb*.) is a tropical plant from the Pandanaceae family that grows widely in Indonesia. The components of pandan leaves include alkaloids, flavonoids, saponins, tannins, and polyphenols.[11] Pandan leaves are generally used as a natural coloring agent or to create a fragrant aroma in food. In this study, pandan leaves are used as an inhibitor to slow down the corrosion rate of iron because pandan leaves contain phenolic compounds.[12] Previous research on the ability of tannins obtained from plants to prevent iron corrosion has been carried out. Tan and Kassim showed that tannin extract from mangrove (*Rhizophora apiculata*) as much as 100 ppm in 1 M HCl could prevent mild steel corrosion with efficiency up to 59.7%.[13] Luo *et al*. showed that 140 ppm of acorn extract in a 3% NaCl medium prevented mild steel corrosion by an efficiency of 86.0%.[14] Tambun *et al*. also conducted several studies on preventing metal corrosion using plant-derived tannins.[15–18] This study uses pandan leaves as an iron corrosion inhibitor in the form of powder, extract, and tannins in a 3% HCl medium. Pandan leaves were extracted by the soxhletation method to obtain tannins. The soxhletation method has been commonly used to extract active components from various natural materials with faster extract recovery than conventional methods.[19,20] The method of weight loss is used to calculate the corrosion rate, and the inhibition efficiency is calculated to express the inhibitor's ability to prevent iron corrosion.

EXPERIMENTAL

Material and Methods

This study use pandan leaves as a source of tannins and 70% ethanol as a solvent. The metal sample is an iron plate of 2 cm × 1 cm × 0.05 cm. The iron plate composition used is shown in table-1. The iron plate is immersed in 3% HCl as a corrosive medium. Supporting materials are 95% ethyl acetate, aquadest, and 1% $FeCl_3$. The equipment used is sieve trays with sizes of 50 mesh, 70 mesh, 90 mesh, 100 mesh, 120 mesh, and 140 mesh, soxhlet extractor, condenser, hot plate, three-neck round flask, blender, Whatman filter paper no. 1, thermometer, analytical balance, glass beaker, cylinder glass, and others. The FTIR is used to identify the functional group of pandan leaves, and to detect iron plate surface is used the SEM-EDX.

The Procedure For Making Pandan Leaves Powder

Pandan leaves are cut into small pieces, washed, then dried in the sunlight. The leaves were blended and then sieved with variations of 50/70 mesh, 70/90 mesh, 100/120 mesh, and 120/140 mesh. The size of 50/70 mesh means that the powders pass from the 50 mesh sieve tray, but the powders do not pass through the 70 mesh sieve tray; the size of 70/90 mesh means that the powders pass from the 70 mesh sieve tray, but the powders do not pass through the 90 mesh sieve tray; the size of 100/120 mesh means that the powders pass from the 100 mesh sieve tray, but the powders do not pass through the 120 mesh sieve tray; the size of 120/140 mesh means that the powders pass from the 120 mesh sieve tray, but the powders do not pass through the 140 mesh sieve tray.

Soxhletation Method Procedure for Extracting Pandan Leaves

Pandan leaves powder with a size of 50/70 mesh is weighed 10 g, and put into a Soxhlet extractor. The ethanol is poured into a three-neck round flash with a sample-to-solvent ratio of 1:25 g/mL.[21] Extraction temperature is carried out at 75 – 80 °C for 2 hours. The extraction results are then cooled and concentrated with a rotary vacuum evaporator, and stored for further use.

Procedure for Separation of Tannins from Pandan Leaves Extract

The extract is mixed with 95% ethyl acetate and then precipitated and filtered through filter paper. The precipitate is washed until the filtrate is clear. Tannins as residue are stored for application.

Pandan Leaves Extract Qualitative Analysis Procedure

Qualitative analysis is carried out by mixing 10 g of pandan leaf extract with 10 mL of water. The mixture is heated until it boils then added 10 drops of $FeCl_3$, and the presence of tannins is indicated by a color change to blackish green.

Iron Plate Corrosion Testing Procedure

The iron plate is washed and dried, then weighed and recorded as the iron plate's initial mass. Next, 50 mL of HCl is poured into a glass beaker, then an iron plate is put into the corrosion medium. In the immersion without inhibitor, the iron plate is immersed for one day, two days, three days, and four days. After immersion, the iron plate is washed, dried, and weighed to be recorded as the final mass. In the immersion with inhibitors, inhibitors with various types (powder, concentrated extract, and tannins) from pandan leaves are added to a glass beaker as much as 1% (w/v). The iron plates also are immersed for one day, two days, three days, and four days. After immersion, the iron plate is removed and then washed, dried, and weighed to be recorded as the final mass.

Determination of Corrosion Rate and Inhibition Efficiency of Iron Plate

The calculation of the corrosion rate is done by using eqn.-1.[22]

$$CR = \frac{534W}{DAt} \tag{1}$$

CR is the corrosion rate (mpy), 534 is the coefficient, W is the difference in mass before and after immersion (mg), D is the density of the iron plate (g/cm^3), A is the iron plate surface area (cm^2), while t is the immersion time (day). Therefore, after obtaining data on the corrosion rate, the corrosion inhibition efficiency of the iron plate can be calculated by eqn.-2.[23]

$$IE = \frac{CR_0 - CR_1}{CR_0} \times 100\% \qquad (2)$$

IE is the inhibition efficiency (%), CR_0 is the corrosion rate before adding the inhibitor, and CR_1 is the corrosion rate after adding the inhibitor.

RESULTS AND DISCUSSION

Functional Group Analysis of Pandan Leaves by using FTIR

Figure-1 is an analysis of the functional group of pandan leaves using FTIR. This Fig.-1 shows that the hydroxyl group (O-H) is obtained at a wave number of 3419.07 cm^{-1}. In the range of wave numbers 2850 – 3000 cm^{-1}, there are two peaks with wave values of 2921.89 cm^{-1} and 2854.35 cm^{-1}, indicating an alkane group (C-H). In the range of wave numbers 1735 – 1750 cm^{-1}, there is a peak indicating an ester group, while in the range 1630 – 1690 cm^{-1}, there is a peak indicating an amide functional group, and in the range 1100 – 1000 cm^{-1}, there is a peak indicating a halide group. The presence of a hydroxyl functional group (O-H) indicates that pandan leaves contain tannins.[24] In this study, 1% $FeCl_3$ was also added to detect the presence of tannins as phenolic compounds in plant extracts, as indicated by a change in the color of pandan leaves extract to blackish green. These results strengthen the FTIR analysis showing tannins' presence,[16] and the tannin obtained from pandan leaves extraction is 1.29%.

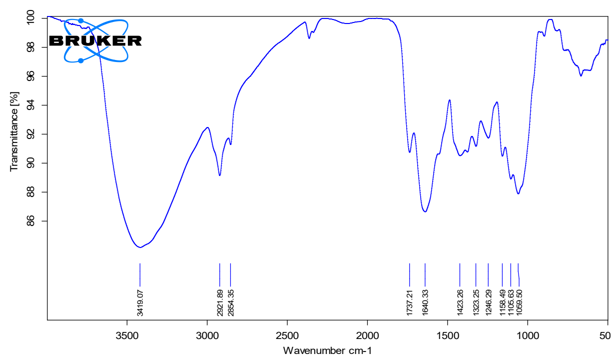


Fig.-1: Functional Group Analysis of Pandan Leaves by Using FTIR

Corrosion Rate Using Pandan Leaves Powder Inhibitor

Figure-2 presents the effect of the size of the pandan leaves powder inhibitor on the immersion time. Based on the study's results, the corrosion rate of iron using pandan powder decreased with increasing immersion time. The duration of immersion of the iron plate in the corrosion medium changes the corrosion rate, the longer the immersion, the corrosion rate will decrease. This occurs due to the creation of a strong passive protective layer at the metal surface when the metal is exposed to a corrosive medium over time.[25] Based on Fig.-2, the lowest corrosion rate of iron plate is found on day 4, which is 160.122 mpy without corrosion inhibitor and 86.547 mpy using pandan leaves powder inhibitor. Figure-2 also shows that the smaller the size of the powder used, the lower the corrosion rate. This is consistent with the theory presented by Jain *et al*. that inhibitors with smaller sizes will slow down the corrosion rate by covering the active side of the iron surface and providing resistance, strength, and thermal resistance.[26]

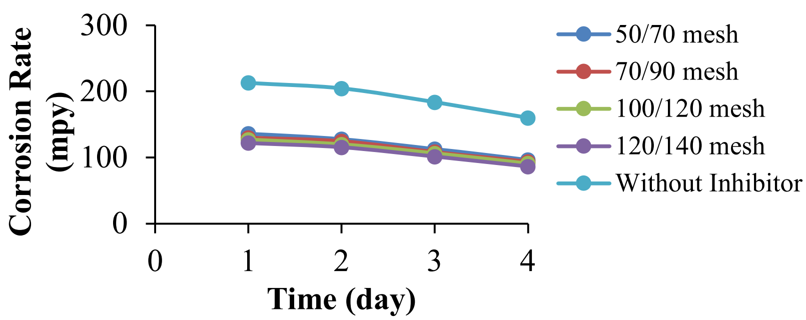


Fig.-2: Effect of Immersion Duration on Corrosion Rate on Pandan Leaves Powder Inhibitor

Corrosion Rate Using Pandan Leaves Concentrated Extract Inhibitor and Pandan Leaves Tannin Inhibitor

Figure-3 presents the effect of pandan leaves extract inhibitors and pandan leaves tannin inhibitors on the rate of iron corrosion. Based on the research that has been done, the lowest corrosion rate was obtained for tannin inhibitors with a corrosion rate of 31.046 mpy at four days of immersion, while the use of pandan leaves extract inhibitors gave the lowest corrosion rate of 47.739 mpy after four days of immersion. This study is in accordance with Tambun *et al.* which state that the longer the immersion time, the corrosion rate of metal will decrease.[16]

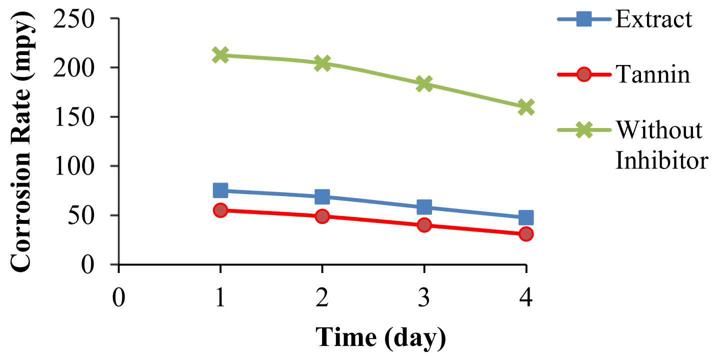


Fig.-3: Immersion Time Effect on the Iron Corrosion Rate on the Use of Pandan Leaves Extract and Tannin Inhibitors

The Efficiency of Iron Corrosion Inhibition Using Pandan Leaves Powder

Figure-4 shows that the smaller the size of the pandan leaves powder, the more the inhibition efficiency of the iron plate increases, or in other words, the corrosion rate decreases. This study found that the highest iron corrosion inhibition efficiency of 45.95% is achieved after being immersed for four days in an HCl medium and using pandan leaves powder size of 120/140 mesh. The results in this study are consistent with the research conducted by Kaku *et al.* that smaller particle size will increase the inhibitor's ability to prevent corrosion.[25] Thus, pandan leaves powder inhibitors can be considered as an alternative to iron corrosion inhibitors.

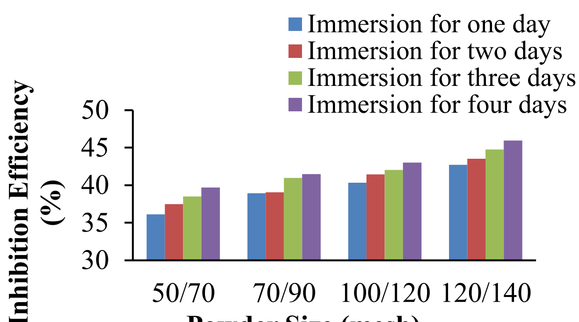


Fig.-4: Effect of Pandan Leaves Powder Size on Corrosion Inhibition Efficiency

Corrosion Inhibition Efficiency Using Extract and Tannin of Pandan Leaves

Figure-5 presents the corrosion inhibition efficiency of iron using pandan leaves extract and tannins as an inhibitor. In the use of both inhibitors, the efficiency of inhibition increased with time. The highest efficiency in using both inhibitors is 70.19% in using pandan leaf extract as an inhibitor, and 80.61% in using pandan leaves tannins as an inhibitor. These results are from previous studies which stated that increasing tannin levels increased iron inhibition efficiency.[10,14,16]

SEM-EDX Analysis of Iron Plate Surface

Figure-6 (a) is a photo of the iron plate surface using SEM with a resolution of 64×64 pixels. The picture shows that the iron surface is still in good condition because the plate has not been affected by a corrosive environment, namely the HCl medium. Figure-6 (b) shows the iron plate surface photo by using SEM after immersion in the HCl medium for three days without an inhibitor. In the picture, it can be seen that the surface of the iron plate becomes rough due to the corrosion that occurs. Figure-6 (c) is the iron plate surface photo using SEM after being placed in the HCl medium for three days with pandan leaves powder size 120/140 mesh as a corrosion inhibitor.

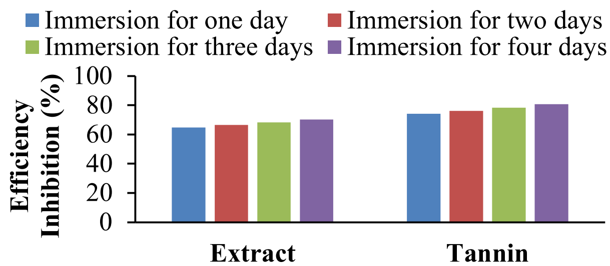
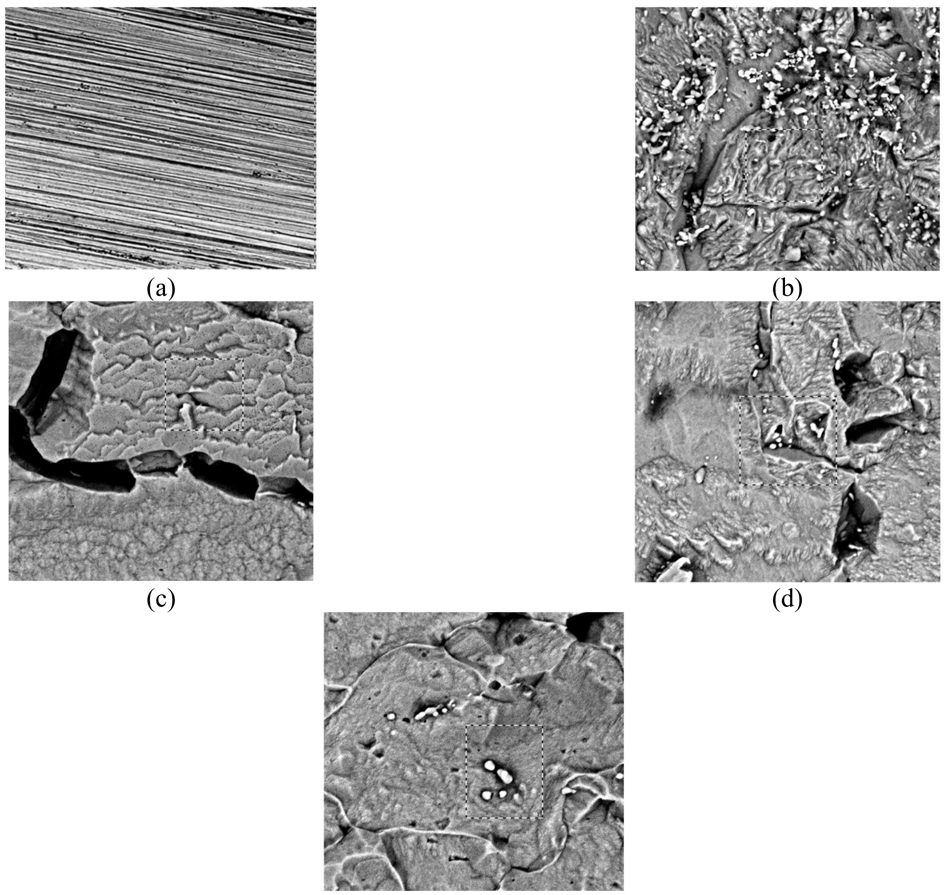


Fig.-5: Effect of Extract and Tannin of Pandan Leaves on Iron Corrosion Inhibition Efficiency



(a) (b) (c) (d) (e)

Fig.-6: Results of SEM-EDX Analysis of Iron Plate Surface

The figure shows that the surface of the iron plate is slightly better than the iron plate surface without an inhibitor. This is due to the corrosion resistance that occurs due to the presence of pandan leaves powder which plays an active role as an inhibitor of iron plate corrosion. Figure-6 (d) shows the iron plate surface using SEM after being placed in an HCl medium for three days with pandan leaves extract as a corrosion inhibitor. The figure shows that the iron plate surface is better than the surface of the iron plate with pandan leaves powder as a corrosion inhibitor. This is due to the ability of pandan leaf extract to prevent corrosion, which is indicated by a higher inhibition efficiency than pandan leaves powder as a corrosion inhibitor. Figure-6 (e) shows the iron plate surface using SEM after being placed in the HCl medium for three days with pandan leaves tannins as inhibitors. The results indicate that the iron plate surface is better than the iron plate surface with pandan leaf extract as an inhibitor. This is due to the ability of pandan leaves tannins to prevent corrosion, which is indicated by the higher efficiency of iron corrosion inhibition than the use of pandan leaf extract as an inhibitor. The test of the chemical element composition of the iron plate in this study has a target element of iron (Fe). The components in the samples tested using EDX are divided into major, minor, and trace value components. The major components are carbon (C), iron (Fe), and oxygen (O) elements. Minor components are elements of calcium (Ca) and silicon (Si). Trace value in the form of elements sodium (Na), chlorine (Cl), potassium (K), and aluminum (Al).[27] The results of the EDX analysis on the iron plate can be seen in Table-1.

Table-1: Composition of Iron Plates Before and After Immersion

Element	Composition before immersion (%)	Composition after immersion (%)			
		Without inhibitor	Using pandan leaves powder inhibitor	Using pandan leaves extract inhibitor	Using pandan leaves as tannin inhibitor
Fe	89.7	42.6	47.9	52.3	54.4
F	8.9	40.9	37.8	35.0	32.0
O	1.4	13.0	10.9	9.8	10.1
N	-	2.4	2.0	2.1	2.1
C	-	1.1	1.4	0.8	1.4

The results of the EDX test in Table-1 show that the iron plate before immersion had a Fe content of 89.7% and decreased after immersion in a 3% HCl medium, both without inhibitor and with inhibitor. This iron content decrease indicates corrosion has occurred on the iron plate. The results show that the addition of pandan leaves inhibitor can slow down the decrease in iron levels. The slowest decrease is obtained when using pandan leaves tannin inhibitors. The slowest decrease of Fe content is obtained when using pandan leaves tannins as inhibitors.

CONCLUSION

According to the study's results, pandan leaves containing 1.29% tannin could be applied as an iron corrosion inhibitor in a 3% HCl solution. These pandan leaves can be used as an inhibitor of iron corrosion in the form of powder, concentrated extract, and tannins. The results showed that the corrosion rate decreased and the inhibition efficiency increased along with the increase in the immersion duration. The lowest corrosion rate of 31.046 mpy and the highest corrosion inhibition efficiency of 80.61% are obtained by using pandan leaves tannin as a corrosion inhibitor. Therefore, pandan leaves can potentially be used to prevent iron corrosion in the industry.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

CONTRIBUTION OF AUTHORS

All the authors contributed significantly to this manuscript, participated in reviewing/editing, and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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