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POTENTIAL OF KEPOK BANANA CORM EXTRACT (MUSA PARADISIACA L.) AS A NATURAL CORROSION INHIBITOR ON ST-37 STEEL IN 3.5% NACL SOLUTION AND WATER MEDIA

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ABSTRACT

Corrosion is a form of damage to metals caused by electrochemical reactions between the material and its environment, resulting in a decline in the metal's quality. One method that can be used to reduce the corrosion rate of metals is the use of inhibitors. This study aims to determine the corrosion rate and inhibition efficiency of St-37 steel in a 3.5% NaCl corrosive medium and water with the addition of an ethanol extract of kepok banana (Musa Paradisiaca L.) stems. Extraction was performed using the maceration method, and the corrosion rate was calculated using the weight loss method. Based on the weight loss test results, it was shown that the banana stem extract affects the corrosion rate, with the lowest corrosion rates observed at an optimal concentration of 10% in 3.5% NaCl solution and water, respectively 0.0206 and 0.0340 mm/year, with inhibition efficiencies of 90.1994% and 77.4199%, respectively. SEM-EDX results also indicate that the surface of St-37 steel without the addition of a banana stem extract inhibitor exhibits more uniform degradation and pitting across the entire surface, whereas the surface of St-37 steel treated with a 10% banana stem extract inhibitor has a smoother surface and fewer pitting locations. Additionally, there was an increase in Fe content and a decrease in O content in the steel treated with the 10% inhibitor, proving that the ethanol extract of kepok banana stems is capable of forming a protective layer to prevent corrosion on the surface of St-37 steel.

KEYWORDS: St-37 steel, kepok banana stems, variation of inhibitor concentration, variation of corrosive media, corrosion rate.

INTRODUCTION

Corrosion is the process of metal degradation due to interaction with the environment through oxidation and reduction reactions, which can cause economic losses and endanger human safety.[1] ST 37 steel is a low-carbon steel widely used in industrial and construction equipment, but it is highly susceptible to corrosion, especially in electrolyte environments such as NaCl solutions and water.[2] One effective method of corrosion control is the use of inhibitors because they can form a thin protective layer on the metal surface and reduce the corrosion rate.[3]

Organic corrosion inhibitors from natural materials are more widely developed than synthetic inhibitors because they are environmentally friendly, biodegradable, safe, and economical.[4] Natural materials that can be used as inhibitors generally contain active compounds such as tannins, flavonoids, alkaloids, and saponins that can bind to metal surfaces.[5] Previous research has shown that cocoa husk extract has an inhibition efficiency of 93.39% in 3% NaCl media.[6] Pandanus leaf extract has also been shown to reduce the corrosion rate of steel by up to 89.90%.[7] Mangosteen peel extract demonstrated an inhibition efficiency of 57.22% in 0.5 M HCl solution.[8] Meanwhile, kepok banana peel extract was able to inhibit steel corrosion with an efficiency of up to 56.63%.[9]

However, some natural inhibitors still have limitations such as suboptimal efficiency, instability at high temperatures, and limited raw material availability.[10] Therefore, kepok banana stems are considered as an alternative natural inhibitor because they are abundant agricultural waste and contain tannins with high adhesion potential to metals.[11] The tannin content in kepok banana stems has been proven through phytochemical tests, which showed a characteristic color change in tannin compounds.[12] Furthermore, kepok banana stem extract is also known to contain flavonoids, saponins, and alkaloids that have potential as corrosion inhibitors.[13]

However, research on the use of kepok banana stem extract as a natural inhibitor for ST 37 steel is still limited, so further research is needed to evaluate its effectiveness at various concentrations and corrosive media.

MATERIALS AND METHOD

Research tools and materials

The materials used were kepok banana stump, 70% ethanol, filter paper, 1% FeCl3, ST 37 steel plate measuring 2 × 3 cm with a thickness of 0.1 cm, 3.5% NaCl, distilled water, tannic acid (p.a), tissue, thread, chopsticks and cotton.

The tools used in this study were, measuring flask, Erlenmeyer flask, beaker, measuring cup, spray bottle, dropper, funnel, filter, knife, blender, ruler, volume pipette, filler, micro pipette, stirring rod, oven, rotary vacuum evaporator, stopwatch, maceration bottle, sample bottle, cup, analytical balance, drill, grinding machine, 80 and 800 grid sandpaper, wooden clamp, oven, desiccator, hairdryer, UV-Vis Shimadzu, LC-MS/MS with UPLC ACQUITY H-Class system with Xevo G2-XS QT of mass spectrometer, SEM-EDX Thermoscientific type Quanta 650.

Research Procedures

The kepok banana stems were washed, cut into small pieces, dried out of direct sunlight for four days, then ground and sieved into a powder. The moisture content of the powder was determined using an oven method at 105°C until constant weight. Extraction was carried out using a maceration method with 70% ethanol for 24 hours and remaceration three times. The filtrate was then evaporated using a rotary evaporator to obtain a thick extract.

Qualitative tannin testing was performed using 1% $FeCl_3$, while tannin levels were analyzed quantitatively using UV-Vis spectrophotometry using the Folin-Denis method and a tannic acid standard curve. Identification of extract compounds was performed using LC-MS/MS QToF with ESI positive mode, and data analysis was carried out using MassLynx and the PubChem database.

The corrosive medium used was 3.5% NaCl and distilled water. Inhibitor solutions were prepared from the stem extract at varying concentrations of 0–16% (w/v). ST 37 steel samples were cut, ground, cleaned, dried, and weighed as the initial mass.

They were immersed in a corrosive medium with and without inhibitors for 6 days. The samples were then cleaned, dried, and reweighed to determine the corrosion rate and inhibition efficiency. Surface characterization was performed using SEM-EDX to determine the morphology and elemental composition before and after corrosion.

RESULT

Table 1: Water Content of Kepok Banana Weevil.

Replication	Empty Porcelain Crucible Mass (W_0) (g)	Porcelain Crucible + Sample Mass (W_1) (g)	Porcelain Crucible + Sample After Drying Mass (W_2) (g)	Moisture Content (%)
I	34.52	37.52	37.32	6.67
II	34.52	37.52	37.32	6.67
III	34.50	37.50	37.30	6.67
Average				**6.67**

Table 2: Tannin Content.

Extract	Absorbance	Total Tannin (mg TAE/100 g)	Average Tannin Content (mg TAE/100 g)
Concentrated extract of Kepok banana stem	0.3805	1003.04	999.79
	0.3791	999.35	
	0.3782	996.97	

Table 3: Tannin Compounds Detected by LC-MS/MS.

RT	Area (%)	m/z	Molecular Formula	Compound Name	Compound Classification
4.02	8.37	170.120	$C_7H_6O_5$	3,4,5-Trihydroxybenzoic acid	Gallic Acid
7.89	2.91	302.230	$C_{14}H_{10}O_9$	2,3,7,8-Tetrahydroxy-chromeno[5,4,3-cde]chromene-5,10-dione	Ellagic Acid
8.66	0.47	940.670	$C_{41}H_{32}O_{26}$	β-1,2,3,4,6-Penta-O-galloyl-D-glucopyranoside	β-PGG

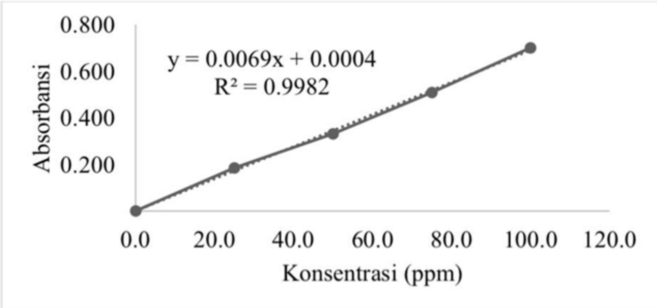


Figure 1: Standard calibration curve graph of tannic acid.

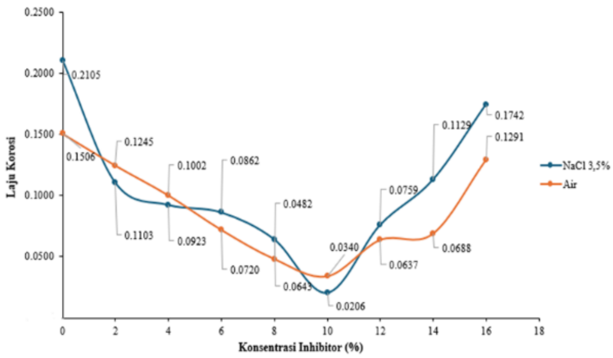


Figure 2: Graph of the relationship between inhibitor concentration and the reduction in corrosion rate in corrosive media of 3.5% NaCl and water.

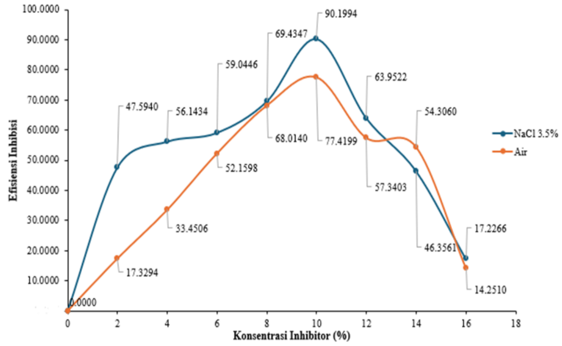
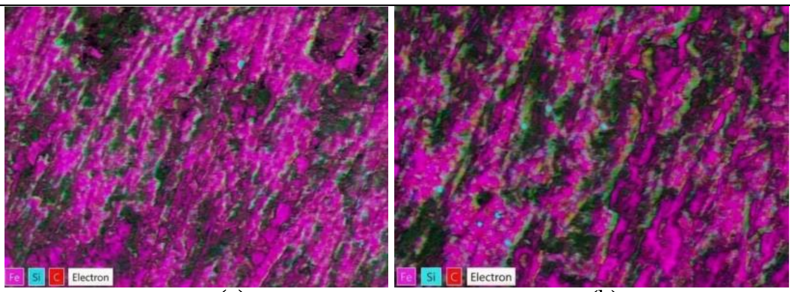
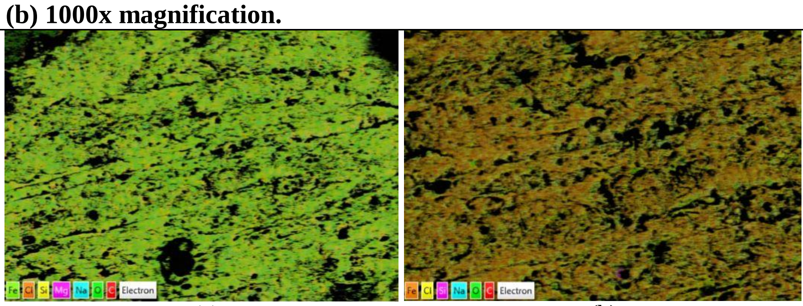


Figure 3: Graph of the relationship between inhibitor concentration and inhibition efficiency in corrosive media of 3.5% NaCl and water.



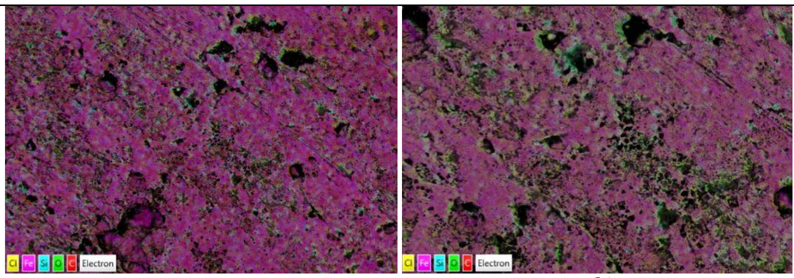
(a) (b)

Figure 4: SEM results without treatment with image (a) 500x magnification and image (b) 1000x magnification.



(a) (b)

Figure 5: SEM results of 0% inhibitor concentration with image (a) 500x magnification and image (b) 1000x magnification.



(a) (b)

Figure 6: SEM results of 10% inhibitor concentration with image (a) 500x magnification and image (b) 1000x magnification.

Table 1 shows that the average water content in Kepok banana stems is 6.67%, which is in accordance with the water content quality standards set by the Indonesian Ministry of Health (<10%).

Table 2 showed that the average tannin content in kepok banana stems is 999.79 mgTAE/100g or 1%, which means that in every 100 grams of kepok banana stem extract, there are tannin compounds equivalent to 999.79 mg of tannic acid.

Table 3 showed that the kepok banana stem extract contained several phenolic compounds from the tannin group, namely 3,4,5-trihydroxybenzoic acid (gallic acid), ellagic acid, and β-1,2,3,4,6-penta-O-galloyl-D-glucopyranoside (β-PGG).

Figure 1 showed that the tannin concentrations in the samples were 55.0870, 54.8841, and 54.7536 ppm, respectively. These concentration values were then converted to tannin content in mgTAE/100 g.

Figures 2 and 3 demonstrate the relationship between inhibitor concentration and corrosion rate and inhibition efficiency in the corrosive media of 3.5% NaCl and water. Figure 4 shows that the corrosion rate decreases with increasing inhibitor concentration until it reaches an optimum level of 10%. However, after exceeding this concentration, the corrosion rate increases again in both corrosive media.

Based on Figure 4-6, it can be seen that in steel without inhibitor, Cl^- ions from NaCl damage the passive layer so that Fe is oxidized to Fe^{2+} and triggers pitting corrosion characterized by the formation of small holes and a decrease in Fe content. Conversely, in steel with inhibitor, tannin compounds from banana stem extract form a protective layer on the metal surface. This layer inhibits Cl^- ions and reduces the rate of Fe oxidation, so that corrosion occurs less severely with less pitting.

CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the extract of kepok banana stem has the potential to be used as a corrosion inhibitor on ST-37 steel, which is indicated by a decrease in the corrosion rate and an increase in inhibition efficiency as the extract concentration is increased in the corrosive medium. Variations in inhibitor concentration have been shown to affect the corrosion rate, where increasing the extract concentration reduces the corrosion rate until it reaches an optimum concentration of 10%, which shows the highest effectiveness in inhibiting corrosion in 3.5% NaCl media and water. LC-MS/MS analysis identified the presence of tannin compounds that act as inhibitors, namely 3,4,5-trihydroxybenzoic acid (gallic acid), ellagic acid, and β-1,2,3,4,6-penta-O-galloyl-D-glucopyranoside (β-PGG). In addition, the results of SEM-EDX characterization showed that the sample with the highest inhibition had a smoother surface and less pitting compared to the sample without inhibitor, while the control surface only showed scratches due to the sanding process.

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