al Kimiya: Jurnal Ilmu Kimia dan Terapan
p-ISSN: 2407-1897, e-ISSN: 2407-1927
Vol. 10, No. 2 (64-73), December 2023/Jumada al-Akhirah 1445

A MIXTURE OF ACACIA BARK EXTRACT (*Acacia mangium* Willd) AND POTASSIUM IODIDE AS A CORROSION INHIBITOR IN SULFURIC ACID SOLUTION

DIAH RISKI GUSTI[1*], ANJELLI PUTRI GUNAWAN[1], DAMRIS MUHAMMAD[1], AND INTAN LESTARI[1]

[1]Chemistry Department, Faculty of Science and Technology, Universitas Jambi, Jambi, Indonesia

*Corresponding Author email: diahgusti@unja.ac.id

Article Information

Received: Jun 08, 2023
Revised: Nov 24, 2023
Accepted: Dec 18, 2023
Published: Dec 31, 2023

DOI: 10.15575/ak.v10i2.26187

Keywords:
Inhibitors; corrosion; potassium iodide; mild steel; acacia bark.

Abstract

Corrosion is a decrease in the quality of a metal material caused by a reaction with the environment. Corrosion cannot be eliminated, but corrosion can be slowed down in several ways by adding corrosion inhibitors and synergistic effects. Acacia bark extract (*Acacia mangium* Willd) with the addition of 0.02 M KI has the potential as a corrosion inhibitor for steel because it contains secondary metabolites, so it can provide a synergistic effect and increase the value of inhibition efficiency on steel. This research aimed to analyze the effect of a mixture of acacia bark extracts (*Acacia mangium* Willd) with the addition of KI on inhibition efficiency corrosion of mild steel in sulfuric acid media. The method used in this study is the method of weight loss, adsorption isotherms, and thermodynamic parameters, which were carried out by varying the concentration of acacia bark extract and the immersion temperature of the steel. To strengthen the research results, characterization was carried out using FTIR and SEM. The results showed that the corrosion rate of mild steel immersed in 0.75 M H_2SO_4 corrosive medium with the addition of 0.02 M KI increased with increasing immersion temperature. These results are reinforced by the results of FTIR and SEM analysis which show that there is an interaction between mild steel and acacia bark extract (*Acacia mangium* Willd) and KI 0.02 M. Based on the thermodynamic parameters, the resulting values of ΔH_{ads}, ΔG_{ads}, and ΔS_{ads} show that the adsorption process of acacia bark extract (*Acacia mangium* Willd) in corrosive medium H_2SO_4 0.75 M with the addition of 0.02 M KI took place spontaneously, showing the type of physical adsorption, adsorbed stable, the adsorption process was exothermic and the degree of irregularity in the adsorption process. The inhibition efficiency of acacia bark extract (*Acacia mangium* Willd) with the addition of 0.02 M KI was highest at 60 °C with an extract concentration of 2.5 g/L of 81%. The higher the immersion temperature, the greater the resulting synergistic effect.

INTRODUCTION

Steel is widely used as the primary material in constructing infrastructure, cars, ships, trains, weapons, and tools. In the shipping industry, carbon steel is most often used. This carbon steel has a wide application because it has good work hardening ability and destructive resistance and is easy to obtain, strong, and relatively inexpensive [1]. But besides the advantages of these steels, this material also has disadvantages, such as being easily corroded [2].

Corrosion is usually known as a rusting process which is an event of damage or a decrease in the quality of a metal material caused by a reaction with the environment [3]. The process of corrosion cannot be eliminated but can be slowed down in various ways. The ways to slow down the corrosion rate of steel are coatings, adding inhibitors, cathodic protection, and others [4].

A corrosion inhibitor is a substance that, when added in small amounts to a corrosive medium, can effectively reduce or prevent the corrosion rate of metal reactions with their environment [5]. In natural product extracts, there are a large number of chemical compounds, especially heterocyclics, which are involved in inhibiting corrosion [6]. The way these compounds work is by preventing corrosion and inhibiting the active side of corrosion by forming a protective layer on the steel surface [7].

This acacia plant is the main source of tannins in the Chinese vegetable tannin extract industry because this plant is rich in polyphenolic compounds. The content of tannin compounds present in these plants can be used as corrosion inhibitors, because they can react directly with metals to form complex compounds that can form a protective layer on metals, thereby reducing the rate of corrosion. The content of phenolic

compounds and tannins contained in acacia bark is quite large, namely 247.76 mg/g [8].

Pramudita et al [9], have conducted research using potassium iodide as a synergistic substance with a mixture of rice husk extracts. The results showed that the highest inhibition efficiency at 1,250 ppm inhibitor concentration at 313 K was 95.89%. The addition of halide ions to sulfuric acid solutions containing organic inhibitors has been found to stabilize the adsorption of organic cations, leading to increased inhibition efficiency. The synergistic effect of halides has been observed to grow in the order $Cl^- < Br^- < I^-$. Due to their large size and ease of polarization, iodides (I^-) show the highest synergistic effect.

EXPERIMENT

The research was conducted at the Final Assignment Laboratory of the Faculty of Science and Technology, University of Jambi, from September 2022 to March 2023.

Material

The materials used in this study were mild steel (Fe=98.5%, C=0.19%, and Mn=0.654%), acacia bark extract (*Acacia magium* Willd), sulfuric acid (H_2SO_4), potassium iodide (KI), distilled water, acetone, ethanol.

Instrumentation

The equipment used in this study included 120 mesh iron sandpaper, an analytical balance, a caliper, a beaker glass, tweezers, a grinder, nylon thread, a toothpick, a water bath, a vial, scissors, a measuring flask, a stirring rod, a hot plate, funnel, paper filters, volumetric pipettes, dropping pipettes, spatulas, aluminum foil, electric drill (Bosch Gbm 320), tissue, SEM, and FTIR.

Procedure

This test method refers to research by Sibarani et al. [10].

Preparation of Acacia Bark Extract

This study used acacia bark (*Acacia mangium* Willd) as the part of the plant to be extracted. This plant was obtained from PT. Lontar Papyrus Pulp and Paper Industry. Grind the dry acacia bark by separating the fibers, then cutting it into small pieces and macerating using ethanol for three days in a dark-colored bottle and avoiding direct light, then filtering using filter paper to obtain the ethanol extract of the bark acacia wood. The extracted result was separated from the solvent using a hotplate at 50 ℃ to get a concentrated extract. Save the concentrated extract that has been obtained into a vial before use.

Phytochemical Screening

Phytochemical screening includes tests for alkaloids, flavonoids, quinones, saponins, steroids, terpenoids, and tannins [7].

Steel Specimen Preparation

The mild steel was cut to ± (2×1) cm in size and drilled using a drill with a diameter of 3 mm. Smooth the surface of the steel using iron grade 120 mesh sandpaper, then wash it using acetone and distilled water to remove the fat adhering to the specimen. Then leave it to dry for ± 5 minutes. The length and width were measured using a vernier caliper, and then the mass was weighed using an analytical balance, and the results were expressed as the initial mass (m_1). Then an analysis was carried out using the SEM instrument.

Preparation of 0.75 M H_2SO_4 Solution

A solution of 18 M concentrated sulfuric acid (H_2SO_4) was taken as much as 41.6 mL and then diluted into a 1000 mL volumetric flask using distilled water up to the mark to obtain a 0.75 M dilute sulfuric acid solution (H_2SO_4).

Preparation of Potassium Iodide Solution

Potassium iodide was weighed as much as 3.32 g. Then it was diluted in a 1000 mL volumetric flask using 0.75 M dilute sulfuric acid (H_2SO_4) solution to obtain a potassium iodide solution with a concentration of 0.02 M [11].

Preparation of Acacia Bark Extract Inhibitor Solution

Acacia bark extract weighed as much as 1.25 g. Then the extract was diluted in a 1000 mL volumetric flask using 0.75 M dilute sulfuric acid to obtain a solution with a concentration of 2.5; 2.0; 1.5; 1.0; and 0 .5 g/L.

Testing Mild Steel with 0.75 M H_2SO_4 Solution and Potassium Iodide

The mild steel plate specimen was weighed and then immersed in 30 mL of 0.75 M dilute sulfuric acid (H_2SO_4) and with the addition of 20 mL of potassium iodide (KI), soaking time for 3 hours at various temperatures of 30, 40, 50 and 60 °C. Then, it was removed and washed using distilled water and acetone. Then the mass (m^2) is measured and repeated three times. Mild steel surface morphology was Analyzed using SEM instruments.

Soaking Mild Steel in A Mixture of Acacia Bark Extract and Potassium Iodide Solution

The prepared steel is tied with a rope and suspended in a 50 mL beaker filled with 20 mL of potassium iodide solution with a concentration of 0.02 M and 20 mL of acacia bark extract inhibitor solution (*Acacia mangium* Willd) with a concentration of 2.5; 2.0; 1.5; 1.0 and 0.5 g/L. An immersion temperature variation was measured at 30, 40, 50, and 60 °C for 3 hours using a water bath. After immersion, the steel is removed, rinsed with distilled water and acetone, and then dried. After drying, the steel is weighed, and the thickness of the steel is measured with a caliper. The weighing results are then expressed as the final mass (m^2). The data obtained can be used to determine steel's corrosion rate and corrosion inhibition efficiency.

FTIR spectroscopy and SEM Analysis

FTIR spectroscopy and SEM analysis were conducted at the University of Lampung (UNILA). The steel is immersed in a 0.75 M dilute sulfuric acid (H_2SO_4) solution with the addition of acacia bark extract and potassium iodide, which is highly efficient. Then taken, the corrosion products are attached to the steel surface and then dried. Then analyzed using FTIR and SEM instruments.

Data Analysis

To calculate the corrosion rate and inhibition efficiency can be determined using the equation of the weight loss method [12].

$$CR = \frac{m_1 - m_2}{A\ x\ t} \quad (1)$$

$$\%\ EI = \frac{Cr_1 - Cr_2}{Cr_1} \times 100\% \quad (2)$$

As for the determination of the value of synergistic and thermodynamics parameters, the following equation can be used [7] [9].

$$\frac{1 - I_1 + I_2}{1 - I'_{1+2}} \quad (3)$$

$$\ln K_{ads} = \frac{\Delta H}{RT^2} + D \quad (4)$$

$$K_{ads} = \frac{1}{999,9}\ \exp\ (-\Delta G_{ads}/RT) \quad (5)$$

$$\Delta G^{o}_{ads} = -RT \ln (55.5\ K_{ads}) \quad (6)$$

$$\Delta S_{ads} = \frac{(-\Delta H_{ads} - \Delta G_{ads})}{T} \quad (7)$$

RESULT AND DISCUSSION

Phytochemical Screening

Phytochemical screening was carried out to identify secondary metabolite compounds such as alkaloids, phenolics, flavonoids, quinones, saponins, steroids, tannins, and terpenoids contained in the extracts. The results obtained from this phytochemical screening test are shown in **Table 1**.

Table 1. Results of phytochemical screening test of acacia bark extract.

Secondary Metabolites	Reactor	Result
Alkaloids	Mayer/Dragendorff	-/+
Flavonoids	Mg, HCl and Ethanol	+
Phenolics	$FeCl_3$ 1%	+
Quinone	NaOH 1 N	-
Saponin	Aquades	-
Steroids	Burchard	+
Terpenoids	Burchard	+
Tannins	$FeCl_3$ 1%	+

In **Table 1**, it can be seen that acacia bark extract (*Acacia mangium* Willd) gave positive results for secondary metabolites, namely alkaloids, flavonoids, phenolics, steroids, terpenoids, and tannins which indicated that this acacia bark extract contained these compounds. As for quinone and saponin, compounds showed negative results, indicating that these compounds were not present in the extract. Based on the research Gusti et al [13] revealed that compounds containing O, N, and S heteroatoms and having double bonds and lone pairs of electrons could be used as effective corrosion inhibitors because they can be adsorbed on the surface of mild steel by forming a thin layer as protection from the environment corrosive. Alkaloids, flavonoids, phenolics, steroids, terpenoids, and tannins have OH functional groups.

The Weight Loss Method

The weight loss method was carried out to determine and observe the effect of inhibition efficiency and synergistic impacts of mild steel in 0.75 M sulfuric acid (H_2SO_4) medium. In this study, mild steel was immersed in a 0.75 M H_2SO_4 solution medium and a solution of acacia bark extract (*Acacia mangium* Willd) with a concentration of 0.5; 1.0; 1.5; 2.0; and 2.5 g/L and KI with a concentration of 0.02 M for 3 hours. The purpose of varying the concentration of the extract is to determine the effect of concentration on the percentage of inhibition efficiency in mild steel.

Effect of Inhibitor Concentration and Immersion Temperature with KI on the Inhibition Efficiency of Mild Steel

Inhibition efficiency is a percentage of values that indicate how much the ability of an extract to slow down the corrosion rate. Effect 0.5; 1.0; 1.5; 2.0 and 2.5 g/L of acacia bark extract on the inhibition efficiency of mild steel during 3-hour immersion with the KI concentration used, namely 0.02 M; and also carried out variations in immersion temperature, namely 30, 40, 50 and 60 ºC can be seen in **Figure 1**.

The figure shows that the efficiency of inhibition increases with increasing concentrations of acacia bark extract (*Acacia mangium Willd*), which means that the efficiency of this inhibition is directly proportional to the concentration of inhibitors. The higher the inhibitor concentration used, the higher the value of the resulting inhibition efficiency. This is due to the content of tannin compounds present in acacia bark extract (*Acacia mangium* Willd), which forms complex compounds with Fe on the steel surface, which inhibits the corrosion process so that the corrosion rate decreases. The inhibition efficiency increases [14]. In addition, these complex compounds will prevent the attack of corrosive ions on the surface of the steel, which causes the dissolution of iron in the solution to decrease so that the corrosion rate decreases and the inhibition efficiency increases [15].

Figure 1 also shows the effect of temperature on inhibition efficiency. Where the increased temperature, the inhibition efficiency value will be higher. It indicates that acacia bark extract is more effective as an inhibitor at higher temperatures than low ones.

Based on **Figure 1**, it can be seen that the addition of 0.02 M KI has a greater inhibition efficiency value when compared to without the addition of 0.02 M KI. The highest inhibition efficiency was obtained without KI, which was 63.358%, while the addition of KI was obtained at 81%. The increase in inhibition efficiency indicates that there is a possibility of a synergistic inhibitory effect between acacia bark extract (*Acacia mangium* Willd) and halide ions [7]. According to Djellab et al. [16], adding halide ions to a solution containing secondary metabolites can increase the inhibition efficiency, as indicated by the presence of an adsorption protective layer that tends to be more stable on the steel surface.

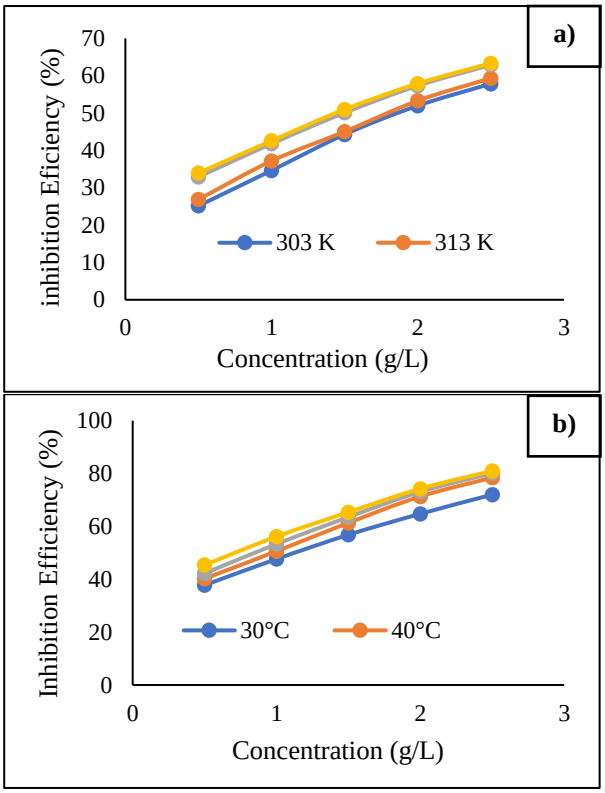

Figure 1. Effect of concentration of acacia bark extract on inhibition efficiency with variations in temperature a) In the absence of 0.02 M KI; b) With the addition of KI 0.02 M.

Effect of Inhibitor Concentration with KI 0.02 M on the Synergetic Effects of Mild Steel

The effect of 0.02 M KI concentration with inhibitor on the synergistic effect of corrosion of mild steel soaked for 3 hours at various temperatures, namely 30; 40; 50, and 60ºC, can be seen in **Table 2**.

Table 2 shows that the synergistic effect between 0.02 M KI and acacia bark extract showed a value of S<1 at 30 C. Based on research Marta et al [17], indicated that the adsorption of each compound did not affect the other. Whereas at a

temperature of 40 to 60 C, it shows a value of S> 1, indicating a synergistic effect in the two compounds. According to Marta et al. [17], there are three possible synergistic parameters; namely, if S<1, then the adsorption of each compound is antagonistic to the adsorption of the other. If S=1 then each compound does not affect the other, only adsorbed on the metal surface individually, and if S>1 then it shows a synergistic effect in each compound.

Table 2. Synergistic effect of mild steel corrosion in soaking acacia bark extract and 0.02 M KI.

Extract Concentration (g/L)	S (%)			
	30°C	40°C	50°C	60°C
0.5	0.896	1.498	1.619	1.638
1.0	0.910	1.392	1.446	1.476
1.5	0.933	1.275	1.343	1.395
2.0	0.937	1.211	1.264	1.320
2.5	0.925	1.178	1.223	1.277

The influence of the concentration of acacia bark is also seen in the S value obtained, the lower the concentration of acacia bark used, the higher the synergistic effect obtained. This is because halide ions play an essential role in the synergistic effect. The higher ionic radius causes the iodide ion to have greater hydrophobicity and lower electronegativity than other halide ions [18].

Adsorption Isotherm Analysis

The most frequently used adsorption isotherm is Langmuir and Freundlich adsorption isotherm. Determination of the adsorption isotherm in this study, simple linear regression analysis, can be used by looking at the correlation coefficient (r) data for each isotherm [19]. The value of the correlation coefficient (r) of acacia bark extract and KI for each adsorption isotherm can be seen in Table 3.

Based on Table 3, it can be seen that the mixture of acacia bark extract (*Acacia mangium* Willd) with KI 0.02 M follows the Freundlich adsorption isotherm, which means that the absorption of Fe metal that occurs is absorption by physisorption. It is caused by the value of the correlation coefficient (r) obtained at each temperature variation which is almost close to 1 compared to the Langmuir adsorption isotherm. The value of the correlation coefficient (r), which is close to 1, can be said that there is a more decisive influence and linkage, and there is a linear relationship between the inhibitor concentration and the degree of surface covering [19]. Freundlich adsorption isotherm explains that there is more than one surface layer, and the sides are heterogeneous, resulting in differences in bond energies on each side. The heterogeneous nature is that each active group on the steel surface has different adsorption abilities [20]. According to Yustinah et al. [21], the bonds that occur in the Freundlich adsorption process are physical (physisorption). In physisorption adsorption, the physically adsorbed molecule will not be tightly bound to the surface and usually occurs in a fast reversible process so that an inhibitor molecule can easily replace it.

Table 3. Correlation coefficient (r) obtained from various adsorption isotherms.

T (K)	Langmuir		Freundlich	
	R^2	R	R^2	r
303	0.9798	0.9898	0.9959	0.9979
313	0.9757	0.9878	0.9908	0.9905
323	0.9809	0.9904	0.9925	0.9962
333	0.9848	0.9924	0.994	0.9970

Analysis of Adsorption Equilibrium Constant, Adsorption Free Energy, Adsorption Enthalpy, and Adsorption Entropy

The thermodynamic parameters that occur when acacia bark extract (*Acacia mangium* Willd) with KI is adsorbed on the steel surface in a corrosive medium of 0.75 M H_2SO_4 were studied based on the Freundlich adsorption isotherm equation. Based on this equation, the Freundlich adsorption isotherm graph will be obtained, as shown in **Figure 2**.

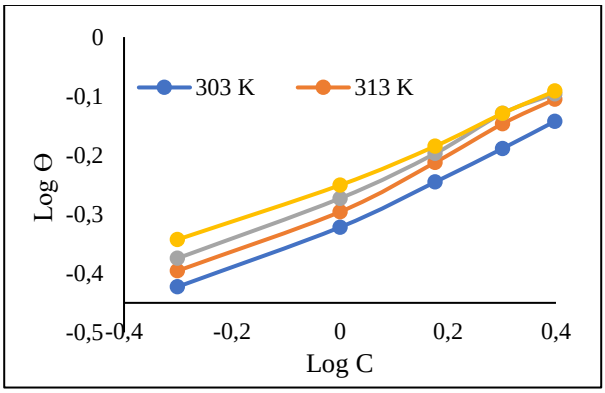

Figure 2. Freundlich adsorption isotherm for steel corrosion in H_2SO_4 medium with the addition of 0.02 M KI for 3 hours of immersion time.

Figure 2 shows a graph of the relationship between log C to log θ at temperature variations of

303-333 K. In this graph, we will obtain a straight-line equation that can be used to determine the adsorption constant (K_{ads}) value of acacia bark extract (*Acacia mangium* Willd) and KI 0.02 M. In Figure 2, it can be seen that the log θ increases with increasing temperature. It means that the degree of surface covering (θ) of steel will decrease, and the desorption process will increase [22]. Kads and $\Delta G°_{ads}$ values can be seen in **Table 4.**

The K_{ads} value indicates the adsorption strength between inhibitors of acacia bark extract (*Acacia mangium* Willd) and KI 0.02 M on a mild steel surface [7]. **Table 4** shows that the K_{ads} value obtained increases with increasing temperature. The findings in these results follow a report in Akbar's study [23] which stated that a high Kads value indicates the stability and interaction of secondary metabolites of an extract with Fe^{2+} on the surface of mild steel gets more potent with increasing temperature. The standard adsorption-free energy or Gibbs-free energy ($\Delta G°_{ads}$) is also presented in **Table 4**.

Table 4. Freundlich isotherm adsorption parameters.

T (K)	K_{ads} (g/L)	ΔG_{ads} (kJ/mol)
303	0.49	-15.60
313	0.53	-16.30
323	0.55	-16.94
333	0.57	-17.59

Gibbs free energy ($\Delta G°_{ads}$) can be determined from the Kads value through equation (5). Based on the study of Pramudita et al. [9], a negative value of $\Delta G°_{ads}$ indicates that the adsorption reaction occurs spontaneously, and the adsorbed extract layer is stable on the steel surface. A value of $\Delta G°_{ads}$ less than -20 kJ/mol is related to physical adsorption; if more than -40 kJ/mol or more negative, it is known to be related to chemical adsorption, and a value between the two indicates a combination of physical and chemical adsorption. Based on the results obtained with increasing temperature, the value of the Gibbs free energy is increasingly negative. It explains that the reaction proceeds spontaneously, the adsorption is stable, and the adsorption of the inhibitor molecule involved is physical adsorption.

Figure 3 shows a graph of the relationship between T and $\Delta G°_{ads}$, the equations used to calculate the values of $\Delta H°_{ads}$ and $\Delta S°_{ads}$. Based on the literature by Akinbulumo et al. [24], a positive $\Delta H°_{ads}$ value indicates endothermic adsorption of inhibitor molecules onto the steel surface and involves chemical adsorption. In contrast, a negative $\Delta H°_{ads}$ value indicates exothermic adsorption and involves physisorption, chemisorption, or a mixture of processes—both of them.

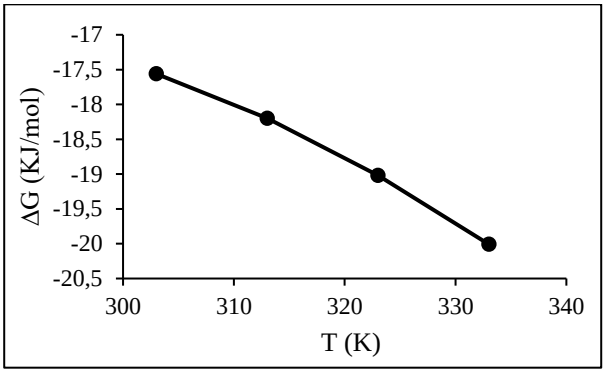

Figure 3. The relationship between T and ΔG°ads.

Figure 3 shows a graph of the relationship between T and $\Delta G°_{ads}$, the equations used to calculate the values of $\Delta H°_{ads}$ and $\Delta S°_{ads}$. Based on the literature by Akinbulumo et al. [24], a positive $\Delta H°_{ads}$ value indicates endothermic adsorption of inhibitor molecules onto the steel surface and involves chemical adsorption. In contrast, a negative $\Delta H°_{ads}$ value indicates exothermic adsorption and involves physisorption, chemisorption, or a mixture of processes—both of them.

Table 5. Enthalpy values ($\Delta H°ads$) and adsorption entropy ($\Delta S°ads$).

T (K)	ΔH_{ads} (kJ/mol)	ΔS_{ads} (J/mol K)
303	-0.026	51.404
313	-0.026	51.996
323	-0.026	52.361
333	-0.026	52.734

Based on **Table 5** it can be seen that the ΔHads value obtained is -0.548 kJ/mol. This value indicates that the adsorption process of inhibitor molecules of acacia bark extract (*Acacia mangium* Willd) with KI 0.02 M onto the steel surface is exothermic, i.e. releases energy involving a physisorption process. Besides showing the enthalpy values (ΔH_{ads}), **Table 5** also shows the ΔS_{ads} values obtained.

Based on **Table 5**, it is known that the $\Delta S°_{ads}$ value obtained is positive at each temperature variation. A positive $\Delta S°_{ads}$ value indicates a substitution process that is associated with an increase in solvent entropy where the increase in entropy caused by the adsorption of inhibitor molecules replaces water molecules that are more

absorbed. The positive $\Delta S°_{ads}$ value is due to a large number of water molecules desorbed on the steel surface from one inhibitor molecule. Conversely, a negative adsorption entropy indicates an inhibitor accompanied by little desorption of water molecules from the mild steel surface [25].

FTIR (Fourier Transform Infra Red) Analysis

FTIR (Fourier Transform Infra Red) analysis is used to qualitatively identify functional groups in a chemical compound present in a natural product, namely acacia bark extract (*Acacia mangium* Willd). Tests were carried out at wave numbers in the IR region of 4000 to 900 cm^{-1}. The FTIR spectrum of acacia bark extract (*Acacia mangium* Willd) can be seen in **Figure 4** and the FTIR spectrum comparison data is in **Table 6**.

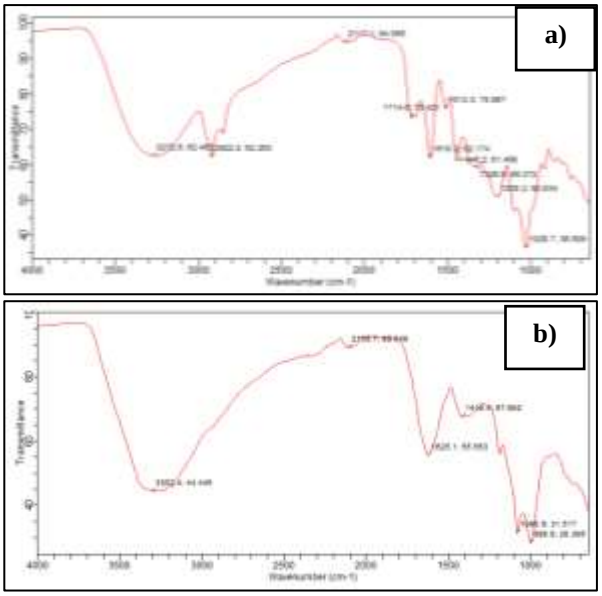

Figure 4. FTIR spectrum a) Acacia bark extract (*Acacia mangium* Willd) b) Corrosion products of mild steel in a solution of inhibitor of acacia bark extract (*Acacia mangium* Willd) 2.5 g/L + KI 0.02 MM.

Figure 4a shows a similar pattern to **Figure 4b**. Changes in wavenumber shifts are indicated by the IR spectrum, namely the O-H functional group with wave number 3272.6 cm^{-1} shifted to wave number 3302.4 cm^{-1}. Then the C=O (ester) active group with a wave number of 2117.1 cm^{-1} shifted to a wave number of 2109.7 cm^{-1}. The functional group C=C (aromatic) with a wave number of 1610.2 cm^{-1} shifts to a wave number of 1625.1 cm^{-1}. Then the alkane C-H functional group with wave number 1446.2 cm^{-1} shifted to wave number 1416.4 cm^{-1}, and the C-O functional group at wave number 1200.2 cm^{-1} shifted to wave number 1080.9 cm^{-1}. The shift in wave numbers that occur in the IR spectrum indicates that there is an interaction between acacia bark extract (*Acacia mangium* Willd), which has the functional groups OH, C=O, and C-O of single OH with Fe^{2+} on the steel surface by forming a thin layer which can reduce the rate of mild steel corrosion [6]. Based on research conducted by Miralrio and Vázquez [2], secondary metabolites have functional groups -OH, -COOH, =CO, -CO-, C-H, -C=C-, -C-Cl, -C=N, or functional groups that have lone pairs of electrons can be adsorbed on the surface of mild steel so that it is effectively used as a corrosion inhibitor on mild steel.

Table 6. Comparison of the FTIR spectrum with the literature.

Spectrum 4a (cm^{-1})	Spectrum 4b (cm^{-1})	Reference (Sanjiwani dan Sudiarsa, 2021))	Functional Groups
3272.6	3302.4	3000-3750	O-H
2117.1	2109.7	2000-2300	C=O (ester)
1610.2	1625.1	1500-1675	C=C (aromatic)
1446.2	1416.4	1350-1470	C-H alkanes
1200.2	1080.9	1080-1300	C-O

SEM (Scanning Electron Microscopy) Analysis

SEM (Scanning Electron Microscopy) analysis in this study provides information about the morphology present on the steel surface. **Figure 5** shows the morphological structure of the steel surface before and after treatment with a magnification of 1000 times.

Figure 5a shows that the surface of mild steel before treatment is still smooth, even, and non-porous because there is no interaction with a corrosive environment. **Figure 5b** shows the surface of mild steel that has been soaked in 0.75 M H_2SO_4, which has undergone corrosion characterized by a rough, hollow, and uneven surface. This can occur due to the attack of corrosive ions from the acid solution, which causes the steel surface to corrode [27]. **Figure 5c** shows the mild steel surface, which looks more covered than **Figure 5b**, although there are lumps and small holes that are not evenly distributed. This is caused by the presence of secondary metabolites in acacia bark extract (*Acacia mangium* Willd) which are adsorbed on the steel surface by forming a thin

layer [28]. **Figure 5d** shows the more covered mild steel surface, but there are few pores on the steel surface. **Figure 5e** shows a non-porous surface of mild steel with only a few lumps and voids. This is due to the secondary metabolites contained in acacia bark extract (*Acacia mangium* Willd) and KI adsorbed on the surface of the steel and based on research by Cang et al. [29] and Ulikaryani et al. [30], who said that the addition of plant extracts with iodide ions could effectively provide synergistic inhibition to reduce the occurrence of corrosion rate processes and increase the percentage of inhibition efficiency.

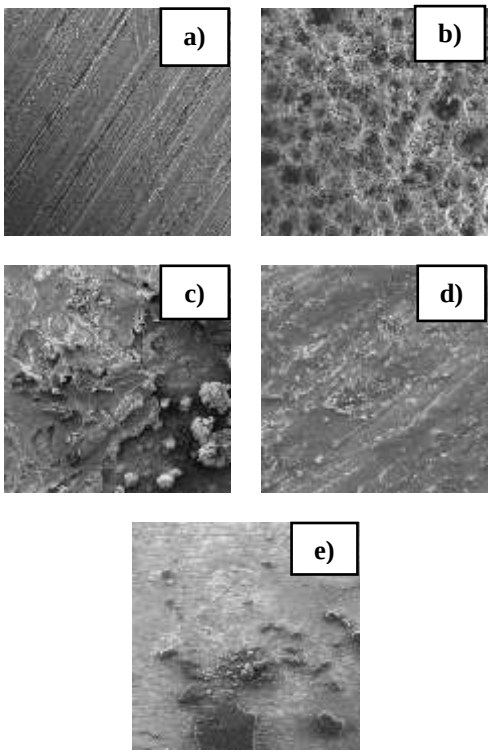

Figure 5. Surface morphology of mild steel a) Before treatment b) After soaking in 0.75 M H_2SO_4 c) After soaking in a solution of acacia bark extract inhibitor (*Acacia mangium* Willd) d) After soaking in 0.75 M H_2SO_4 + KI 0 .02 M e) After soaking in a solution of inhibitor extract of acacia bark (*Acacia mangium Willd*) + 0.02 M KI.

.

CONCLUSION

Based on the research that has been done, it is obtained adding a mixture of acacia bark extract (*Acacia mangium* Willd) with 0.02 M KI into 0.75 M sulfuric acid can effectively increase the efficiency of corrosion inhibition on mild steel. The highest inhibition efficiency was obtained by adding an inhibitor of acacia bark extract, which was 81.001% at 60 ºC. FTIR analysis shows a shift in wave number after and before immersion. SEM analysis revealed differences in morphology which showed a non-porous surface, a few lumps, and holes, and looked more covered compared to mild steel soaked in acacia bark extract inhibitor and 0.75 M H_2SO_4 corrosive medium. Based on thermodynamic parameters, the adsorption process of acacia bark extract mixture with KI 0.02 M took place spontaneously and stably; related to physical adsorption, the adsorption process was exothermic and showed a degree of irregularity in the adsorption process on the steel surface.

ACKNOWLEDGEMENT

Thanks to the Faculty of Science and Technology, University of Jambi. Thanks to all those who have helped when this research was carried out.

REFERENCES

[1] D.J. Purnomo, S. Jokosisworo, and U. Budiarto, "Analysis of the effect of holding time tempering on hardness, tenacity, toughness and microstructure in st 70 steel", *J. Tek. Shipping*, **7**(1), 49–58, 2019.

[2] A. Miralrio and A. E. Vázquez, "Plant extracts as green corrosion inhibitors for different metal surfaces and corrosive media: A review", *Processes*, **8(**8), 2020.

[3] A.G. Bedir, M. Abd El-Raouf, S. Abdel-Mawgoud, N.A. Negm, and N. M. El Basiony, "Corrosion inhibition of carbon steel in hydrochloric acid solution using ethoxylated nonionic surfactants based on schiff base: electrochemical and computational investigations", *ACS Omega*, **6**(6), 4300–4312, 2021.

[4] N.K.Y. Sari and N.L.U. Sumadewi, "Potential of acacia leaf extract (acacia auriculiformis) as an antifungal against candida albicans and identification of its compound groups", *J. Biol. Sc.*, **6**(2), 143–147, 2019.

[5] H. Kaco et al., "Enhanced corrosion inhibition using purified tannin in hcl medium", *Malaysian J. Anal. Sc.*, **22**(6), 931–942, 2018.

[6] P.N. Alam, C.M. Rosnelly, J.A. Karo karo, A. Ilhamdi, R. Soekarno, and I.N. Aslam, "Utilization of natural extracts as corrosion inhibitors in the seawater environment", *J. Engineering Kim. Circle.*, **16**(2), 68–74, 2021.

[7] P. Untari, Emriadi, M. Efdi, and Azuxetullatif, "Synergistic effects of guava bol leaf extract (syzygium malaccense) and iodide on steel corrosion in acid solution", *Chempublish J.*, **5**(2), 179–193, 2020.

[8] A.R. Permanasari, T. R. Saputra, A. Nurul'Aina, and S. Liska, "Determination of the best solvent in tannin extraction of acacia bark and its effect as a corrosion rate inhibitor on carbon steel," *J. Tek. Kim. and Environment*, **4**(1), 52–57, 2020.

[9] M. Pramudita, S. Sukirno, and M. Nasikin, "Synergistic corrosion inhibition effect of rice husk extract and KI for mild steel in H_2SO_4 solution", *Bull. Chem. react. Eng. & Catal.*, **14**(3), 697–704, 2019.

[10] R.G. Sibarani, P. Ramadhanti, G. KurniawanSyah, and R. Gusti, "Exploration of pineapple skin waste as a biomaterial in overcoming corrosion problems in steel", *J. BiGME*, **1**(1), 38–45, 2021.

[11] A.E.A.S. Fouda, H.H. Al-Zehry, and M. Elsayed, "Synergistic effect of potassium iodide with cassia italica extract on the corrosion inhibition of carbon steel used in cooling water systems in 0.5 M H_2SO_4", *J. Bio-Tribo- Corrosion*, **4**(2), 1–17, 2018.

[12] S. Prasetyo, U. Budiarto, and W. Amiruddin, "Corrosion rate analysis of aluminum 5083 material using seawater media as a ship hull material application", *J. Tek. Shipping*, **7**(4), 161–167, 2019.

[13] D.R. Gusti, H.F. Aritonang, and S. Azis, "The effect of adding succinic acid in inhibiting steel corrosion in sulfuric acid solution", *Chem. Prog.*, **1**(1), 36–42, 2019.

[14] S.R.S. Rodrigues, V. Dalmoro, and J.H.Z. dos Santos, "An Evaluation of Acacia Mearnsii Tannin as an Aluminum Corrosion Inhibitor in Acid, Alkaline, and Neutral Media," Mater. Corros., vol. 71, no. 7, 2020.

[15] G. Priyotomo, H. Sumada Sitepu, and Y. Dwiyanti, "The effect of adding taro leaf extract inhibitor concentration on the corrosion rate of fire steel 5L X-52 with corrosive media H_2SO_4 0.5 M", *Widyariset*, **5**(1), 30, 2019.

[16] M. Djellab, H. Bentrah, A. Chala, H. Taoui, S. Kherief, and B. Bouamra, "Synergistic effect of iodide ions and bark resin of schinus molle for the corrosion inhibition of API5L X70 pipeline steel in H_2SO_4", *Matt. Corros.*, **71**(8), 1276–1278, 2020.

[17] P. Marta, S. Sukirno, and M. Nasikin, "Synergistic corrosion inhibition effect of rice husk extract and iodide for mild steel in H_2SO_4 solution", *Bull. Chem. react. Eng. & Catal.*, **14**(3), 697–704, 2019.

[18] A.D. Pradina, M.R. Prasetio, D.R. Gusti, and I. Lestari, "Science Research Journal," *J. Researcher. Science*, **25**(1), 1–8, 2023.

[19] H. Apriyanti, I.N. Candra, and E. Elvinawati, "Characterization of adsorption isotherms of iron (Fe) metal ions in soil in bengkulu city", *J. Educator. and Kim Science.*, **2**(1), 14–19, 2018.

[20] I.E. Wijayanti and E.A. Kurniawati, "Kinetic studies of adsorption isotherms of the langmuir and freundlich equations on abu gosok as an adsorbent", *Edu Chemia (Journal of Kim. and Education)*, **4**(2), 175, 2019.

[21] Yustinah, Hudzaifah, M. Aprilia, and Syamsudin, "Batch adsorption of heavy metals (Pb) with diatomite earth adsorbents", *J. Conversion*, **9**(1), 17–28, 2019.

[22] A.D. Anugrahita, A. Infantono, and M.S. La Ore, "The inhibitor effect of guava leaf extract (psidium guajava) on the corrosion rate of 7.62 mm ammunition shells in CH3COOH and HCl media", *Pros. Monday. Nas. Techno Science. and Inov. Indonesia.*, **3**, 323–332, 2021.

[23] S.A. Akbar, "Utilization of psidium guajava fruit extract as a green inhibitor for iron corrosion in sulfuric acid solution", *Cakra Kim. (Indonesian E-Journal Appl. Chem.*, **7**(1), 28–33, 2019.

[24] A.O. Akinbulumo, O J. Odejobi, and E.L. Odekanle, "Thermodynamics and adsorption study of the corrosion inhibition of mild steel by euphorbia heterophylla L. extract in 1.5 M HCl", *Results Mater.*, **5**, 2020.

[25] G. Vengatesh and M. Sundaravadivelu, "Non-toxic bisacodyl as an effective corrosion inhibitor for mild steel in 1 M HCl: thermodynamic, electrochemical, SEM, EDX, AFM, FT-IR, DFT, and molecular dynamics simulation studies", *J. Mol. Liq.*, **287**, 2019.

[26] N.M.S. Sanjiwani and I.W. Sudiarsa, "Analisis gugus fungsi obat sirup batuk dengan fourier transform infrared", *J. Pendidik. dan Konseling*, **4**(2), 339–345, 2021.

[27] M.V. Fiori-Bimbi, P.E. Alvarez, H. Vaca, and C.A. Gervasi, "Corrosion inhibition of mild steel in HCl solution by pectin", *Int. J. Corros.*, **92**, 192–199, 2015.

[28] D.R. Gusti, Emriadi, A. Alif, and M. Efdi,

"Corrosion inhibition of ethanol extract of cassava (manihot esculenta) leaves on mild steel in sulfuric acid", *Int. J. Chemtech Res*., **10**, (2), 163–171, 2017.

[29] H. Cang, Z. Tang, H. Li, L. Li, J. Shao, and H. Zhang, "Study on the synergistic effect of iodide ion with the extract of artemisia halodendron on the corrosion inhibition", *Int. J. Electrochem. Sci.*, **12**(11), 10484–10492, 2017.

[30] U. Ulikaryani, I. Fadlilah, and U.S. Jati, "Pengaruh penambahan ekstrak kulit buah nipah sebagai green corrosion inhibitor terhadap laju korosi pada baja karbon ST37", *J. Rekayasa Mesin*, **17**(3), 495–502, 2022.