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The Effect of Cacao Leaf Extract as An Inhibitor with A Concentration Variation of 0%, 3%, 5%, And 7% on The Corrosion Rate of St 37 Steel with Immersion Time of 3 Days And 6 Days in NaCl Corrosive Medium 3%

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Abstract

This study aims to determine the effect of adding inhibitors of cacao leaf extract with concentrations of 0%, 3%, 5%, and 7% in 3% NaCl corrosive medium on the corrosion rate of St 37 steel, knowing the effect of cacao leaf extract in inhibiting the corrosion rate of St 37 steel in NaCl solution and knowing the microstructure, phase, and corrosion products on St 37 steel after immersion in NaCl solution. The weight loss method was carried out to determine the value of the resulting corrosion rate. The Fourier transform infrared (FTIR) analysis showed the presence of tannins in the cacao leaf extract. The X-ray Diffraction (XRD) result shows that the formed phase is pure Fe. It is reinforced by the Energy Dispersive Spectroscopy (EDS) result, which shows that the more lumps on the steel surface, the fewer Fe elements, and the more FeO corrosion product. Scanning Electron Microscopy (SEM) results show the presence of lumps of various sizes and black holes resulting from corrosion.

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Abstract

Penelitian ini bertujuan untuk mengetahui pengaruh penambahan inhibitor ekstrak daun kakao dengan konsentrasi 0%, 3%, 5% dan 7% dalam medium korosif NaCl 3% terhadap laju korosi pada baja St 37, mengetahui pengaruh ekstrak daun kakao dalam menghambat laju korosi pada baja St 37 dalam larutan NaCl dan mengetahui struktur mikro, fasa dan produk – produk korosi yang dihasilkan pada baja St 37 setelah direndam dalam larutan NaCl. Metode kehilangan berat dilakukan untuk mengetahui nilai laju korosi yang dihasilkan. Hasil analisis Fourier Transform Infrared (FTIR) memperlihatkan bahwa fasa yang terbentuk merupakan fasa Fe murni. Hasil Scanning Electron Microscopy (SEM) memperlihatkan adanya gumpalan dengan berbagai ukuran dan lubang hitam yang merupakan hasil korosi. Hal ini diperkuat dengan adanya hasil Energy Dispersive Spectroscopy (EDS) yang memperlihatkan bahwa semakin banyaknya gumpalan pada permukaan baja menyisakan unsur Fe yang semakin sedikit dan produk korosi FeO yang semakin banyak.

1. Introduction

Corrosion is a severe problem in the material world and is very detrimental because it can reduce the ability of contraction in the molecular load (Hermawan et al., 2012). Corrosion or rust that occurs on metal is a decrease in metal's ability due to the environment or chemical substances that affect it (Ronberge, 2008). Corrosion can be defined as a decrease in the quality of a metal due to an electrochemical reaction with the environment, which causes the metal weight to decrease and decompose from the alloy (Afandi, 2015). Corrosion is a big problem for buildings and equipment that use metal base materials (Sasono, 2014).

Coating the metal surface with a layer, such as the addition of an inhibitor, can prevent the corrosion process because, so far, it is a natural phenomenon that cannot be stopped but can be prevented. The addition of inhibitors

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is a simple method and requires relatively low costs, so the addition of inhibitors is one of the most effective ways to prevent corrosion (Ilim, 2008). The inhibitor is a chemical compound in small amounts but can inhibit the corrosion reaction of steel metal with its environment (Ludiana et al., 2012). Compounds used as inhibitors contain oxygen, nitrogen, sulfur, phosphorus, and double-bond compounds (Erna et al., 2011). Tannin compounds inhibit steel corrosion reactions in acid and salt solutions (Asdim, 2007). There are two types of corrosion inhibitors, organic and anorganic inorganic inhibitors, which are quite effective in inhibiting the corrosion rate but are toxic. In addition, anorganic inhibitors are not environmentally friendly. Meanwhile, organic inhibitors are a livestock alternative, the most appropriate solution because apart from being non-toxic, organic materials are readily available in nature, are easy to renew, and do not damage the environment (Rumiyanti et al., 2019).

Cacao leaves contain bioactive compounds in the form of phenolic compounds that have a role as antioxidants, the amount of which varies depending on the age of the leaves and the age of the plant (Supriyanto et al., 2014). One of the organic inhibitors is a cacao leaf extract because *cacao* leaf extract contains phenolic compounds, including catechins, epicatechins, proanthocyanidins, phenolic acids, tannins, and other flavonoids (Jusmiati, 2015).

2. Research methods

Tools were used in this final project is a beaker, measuring cup, flask, sample bottle, spatula, drop pipette, funnel, vernier calipers, *rotary vacuum evaporator,* steel cutting tools, *and X-Ray Diffraction* (XRD). Those tools are used to generate specific peaks and identify the crystalline phase in the material by determining the parameters of the lattice structure and particle size. *Scanning electron microscopy* (SEM) is equipped *with Energy Dispersive Spectroscopy* (EDS). This tools are used to determine the particle size and elemental composition contained in the sample, and *Fourier Transform InfraRed* (FTIR) this tool is used for qualitative analysis of functional groups in chemical compounds contained in the sample. In comparison, the materials used in this final project are sandpaper 400 great, 800 great, 2000 great, blender, cacao leaf extract, steel St 37, NaCl 3%, ethanol 96%, distilled water, and acetone.

2.1. Making Inhibitor Solution from Cacao Leaves

The essential ingredients of cacao leaf extract are dried at room temperature for 25 days to remove the moisture content. then mashed with a blender to facilitate the extraction process. The extraction process was carried out by the maceration method. Namely, the cacao leaves are put into a bottle containing 96% ethanol for 24 hours. The result of the maceration was filtered so that the filtrate was obtained. The filtrate from the maceration was evaporated using a vacuum rotary evaporator at a speed of 200 rpm at a temperature of 50 degrees Celcius to produce a concentrated extract.

2.2. Steel Sample Preparation

Steel sample preparation was carried out by cutting 18 pieces of St 37 steel with a size of 5 mm × 5mm × 5 mm. After that, the steel surface was cleaned and smoothed using sandpaper 400 great, 800 great, and 2000 great to remove dirt and scratches during cutting. Then the steel is put in acetone to clean the dirt that sticks to the steel. Steel samples are weighed first to find out the initial period before making corrosion.

2.3. Preparation of Corrosive Medium Solution NaCl 3%

To get a 3% NaCl solution, the NaCl was diluted using the addition of distilled water. Dilution is done by adding 3 milliliters of NaCl solution and diluting with 97 milliliters of distilled water into a beaker.

2.4. Manufacture of Inhibitor Solution

To get an inhibitor with concentration of 3%, 5% dan 7%, the first thing to do is adding 3 milliliters of cacao leaf extract inhibitor solution dissolved with 97 milliliters of distilled water unto a beaker then, get an inhibitor solution with a concentration of 5% this was done by adding 5 ml of cacao leaf extract inhibitor solution and dissolved with 95 ml of distilled water into a beaker and to get a solution of inhibitor with a concentration of 7% this is done by adding 7 ml of inhibitor solution of cacao leaf extract and diluted with 93 ml of distilled water into a beaker.

2.5. Testing

In this stage, 18 stell samples were immersed in an inhibitor of cacao leaf extract with concentrations 0%, 3%, 5%, and 7% in a 3% NaCl corrosive medium with an immersion time of 3 days dan six days. After that, the sample that has been soaked in a corrosive medium with an inhibitor was then allowed to dry or wipe with a tissue. After the sample was dried the sample was weighed to determine the final period. Then the corrosion rate was calculated using the weight loss method according to the following equation:

$$CR = \frac{k\,W}{A\,t\,D}$$

where CR is the Corrosion rate (mm/year), k is the corrosion rate constant (87,6), W is the mass difference (mg), t is soaking time (year), A is surface area (mm^2), and D is carbon steel density (7,85 mg/mm^3).

2.6. Characterization

At this stage, the soaked sample was then characterized. The first is a sample in the community to determine the tannin content in the cacao leaf extract by carrying out a phytochemical test. Then the sample was characterized using Scanning Electron Microscopy (SEM) equipment and Energy Dispersive Spectroscopy (EDS) to determine the surface structure of the sample and see the chemical elements present in the sample. The samples that were characterized were seen from the steel soaked with cacao leaf extract with the specified concentration and the samples using radiator cooling water to see if the steel was attacked by corrosion, X-Ray Diffraction (XRD) which aims to determine the phase formed in the sample. The sample used for XRD characterization is the sample that has the highest corrosion rate value and the sample without inhibitor and Fourier Transform InfraRed (FTIR), which aims to analyze the functional groups qualitatively in a chemical compound contained in the sample. The sample used in the FTIR characterization was cacao leaf extract.

3. Results and Discussion

3.1. Phytochemical Test Results and FTIR Analysis

The phytochemical test on cacao leaf extract showed positive results containing tannins, alkaloids, and flavonoids. Tannins belong to the polyphenol group, divided into two groups: hydrolyzed tannins and condensed tannins. The easily hydrolyzable tannins are polymers of gallic acid and ellagic acid, which are esters linked to a sugar molecule. So, according to Patra dan Saxena (2010), condensed tannins are polymers of flavonoid compounds with carbon-carbon bonds in the form of catechins and gallcatechins. The result of the phytochemical test also showed that the cacao leaf extract was positive for tannin, which was evidenced by the color of the solution changing to blackish green. These results indicate that the tannins in the cacao leaf extract are nonpolar condensed tannins.

This is reinforced by the FTIR result shown in **Figure 1.**

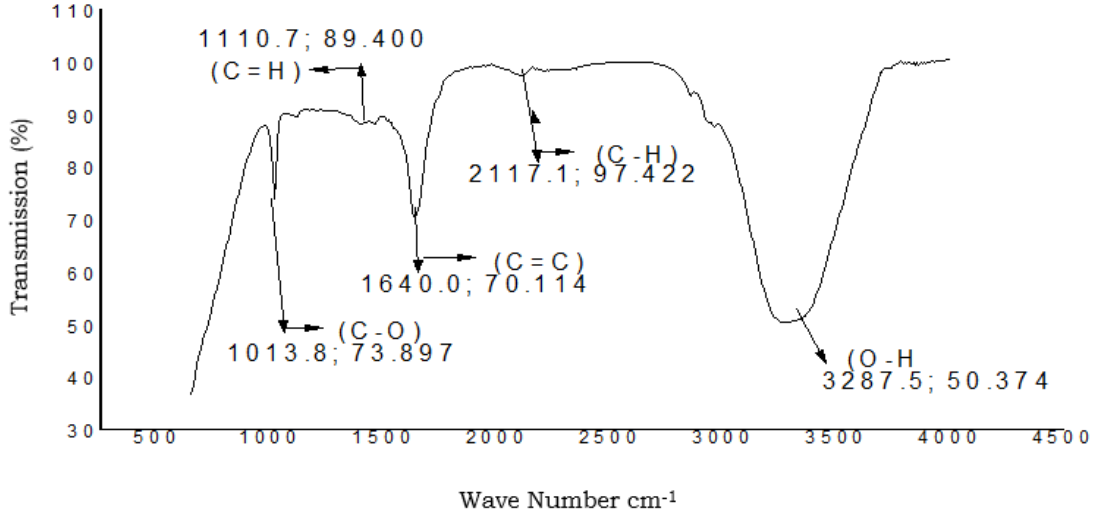

Figure 1. analysis results of cacao leaf extract

The results of the FTIR characterization (Fourier Transform Infrared) shown in Figure 1 show that the groups in the cacao leaf extract consist of O-H hydroxyl alkane, CH phenyl C-O (C=H), and alkane C=C. The absorption peak indicates the C-O groups at the wavenumber 1013,8 cm^{-1}. Alkane group C-H (phenyl) shown by absorption peak at wavenumber 2117,1 cm^{-1}. The absorption peak indicates the alkane group C=C at wavenumber 1640,0 cm^{-1}. The absorption peak indicates the C=H alkane group at wavenumber 1110,7 cm^{-1}. The absorption peak indicates the O-H (hydroxyl) group at wavenumber 3287,5 cm^{-1}. According to the results of research conducted by Sudiarti et al. (2018), there is an alkane group C-H which is nonpolar and hydrophobic so that it can repel water, and the C-O groups which can be adsorbed on the steel surface or a victim of tannins have the potential to be developed because of its ability to absorb metals (Irianty, 2017). Based on the results of the FTIR analysis of cacao leaf extract, (Figure 1) it is similar to the results of the analysis conducted by Christina and Florentina (2017) which stated that the positive content of tannins contained functional groups O-H, C-H, and C=H.

3.2. Corrosion Rate Calculation Results with the Weight Loss Method

St37 steel samples showed a change in the mass of each sample. These changes were triggered due to the influence of the concentration of the inhibitor given and the immersion time. The greater the concentration of the inhibitor given, the smaller the mass change that occurs, while the smaller the inhibitor concentration, the greater the mass change that occurs. Based on the research results, it can be seen that the lowest mass loss occurred in the sample within six days with a concentration of 5% cacao leaf extract inhibitor.

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Table 1. Research Data of St37 steel in corrosive medium NaCl 3%

Sample	P (mm)	L (mm)	T (mm)	Surface Area (mm^2)	Initial mass (g)	Final mass (g)	mass difference (g)
3-0	5.1	4.9	5	132.71	0.753	0.747	0.006
3-3	5.2	4.9	5	143.63	0.441	0.436	0.005
3-5	5.5	4.9	5	139.49	0.580	0.576	0.004
3-7	5.0	4.7	5	140.37	0.734	0.729	0.005
6-0	5.6	5	5	144.59	0.797	0.792	0.005
6-3	5.2	4.7	5	142.45	0.594	0.591	0.003
6-5	5.4	4.6	5	134.61	0.635	0.633	0.002
6-7	5.3	4.9	5	136.67	0.666	0.664	0.002

The effect of soaking time has a different impact where. The longer the immersion time in cacao leaf extract. the corrosion rate decreases. The immersion time of 6 days causes the entire steel surface to be coated with tannin compounds. Calculating the corrosion rate can be done using the weight loss method according to the mass difference value in Table 1.

Table 2. The relationship between corrosion rate and the addition of inhibitor concentration

Sample	Corrosion rate (mm/year)
3-0	0.0699
3-3	0.0538
3-5	0.0443
3-7	0.0551
6-0	0.0267
6-3	0.0162
6-5	0.0114
6-7	0.0113

Based on table 2. The results of the calculation of the corrosion rate of St37 steel in a 3% NaCl corrosive medium indicate that the addition of inhibitor volume resulted in a decrease in the corrosion rate at each immersion time. At six days of immersion, the corrosion rate was lower than that of 3 days of immersion. The highest corrosion rate value was shown in 3 days of the sample with an inhibitor concentration of 0%, getting the highest corrosion rate of 0.0699 mm/year. At the beginning of the reaction, the inhibitor adsorption event on the surface was more dominant, so it took place more quickly. With increasing inhibitor concentration, the corrosion rate decreased. Materials that do not use inhibitors tend to have the highest corrosion rates due to the absence of a protective coating on the surface. In the 6-day sample with 7% inhibitor concentration, the lowest corrosion rate value was 0.0113 mm/year. as a comparison. Calculations were carried out on steel samples with the manufacturer's inhibitor immersion medium (air coolant). The corrosion rate value was 0.0219 mm/year.

From the data, it was found that 7% cacao leaf extract was superior in preventing corrosion rate compared to radiator water inhibitor products. Each sample decreased due to the presence of tannin compounds in the cacao leaf extract. Where the tannin compounds have been adsorbed on the iron surface, according to Ali et al. (2014), this adsorption will be a barrier that separates the iron surface from the corrosive medium. There is a decrease in the corrosion rate from the initial concentration until after adding the inhibitor because the adsorption of the inhibitor on the carbon steel has reached a saturation state. The inhibitor no longer protects the carbon steel surface because it is more attracted to the medium, so it is solvated in the medium.

The addition of inhibitor volume and immersion time affects the efficiency of the inhibitor. The efficiency of the cacao leaf extract inhibitor is shown in Table 3. Based on Table 3.

Table 3. Effect of inhibitor volume and immersion time on inhibitor efficiency

Sample	Inhibitor Efficiency (%)
3-0	0
3-3	23.03
3-5	36.62
3-7	21.17
6-0	0
6-3	39.32
6-5	57.30
6-7	57.67

Giving inhibitors will reduce the corrosion rate and can increase the inhibition value. It is evident from the results obtained in this study that the corrosion rate decreases, and the inhibition value increases according to the concentration of the inhibitor used. The results obtained are the same as those of research conducted by Malfinora et al. (2014), that the ability to inhibit is measured by its efficiency. The efficiency value depends on the concentration

of the inhibitor used. The highest inhibition efficiency of cacao leaf extract obtained from this study was found in the sample of St 37 steel with an immersion time of 6 days at a concentration of 7% extract with an efficiency reaching 57.67%. So it can be ascertained that the corrosion inhibitor is the main factor that can affect the corrosion rate. There is a significant difference in the reduction in weight loss in each sample. The research results are the same as those of Mulyati (2019), which proves that tannin compounds can prevent corrosion.

Corrosion inhibitors from cacao leaf extract contained tannins because phytochemical tests had been carried out, which showed positive results. According to Hermawan (2007), Inhibitors play a critical role in inhibiting corrosion because the tannins contained in cacao leaf extract bind to iron to form complex compounds that form protection that can protect steel from corrosion. Tannins in this study act as anodic inhibitors. Inhibitors tend to stick with Fe, a barrier inhibiting corrosion. The variation of soaking time was carried out to determine the optimum efficiency of the cacao leaf extract, which was influenced by the soaking time.

Complex compounds that will block the attack of corrosive ions on metal surfaces. In addition, the complex compounds contained in it will block the attack of corrosive ions on the metal surface to the optimum limit of inhibitors (Widharto, 1999). Tannin compounds in the cacao extract can form complex compounds with Fe on the metal surface, causing the corrosion reaction rate to decrease. Inhibitors can inhibit the corrosion rate because the inhibitor has adhesive power on the surface of the material so that the inhibitor can coat the material and slow down the material's surface that reacts directly with the soaking solution (Purnomo, 2015).

3.3. XRD Characterization Results

XRD test is used to determine the phase formed from St37 steel. There were two samples analyzed by XRD in this study: steel samples with six days of immersion time with 0% inhibitor concentration and samples with three days of immersion time with 5% inhibitor concentration. The XRD test was carried out with a wavelength of Å. Following are the results of the XRD analysis diffractogram shown in Figure 3.

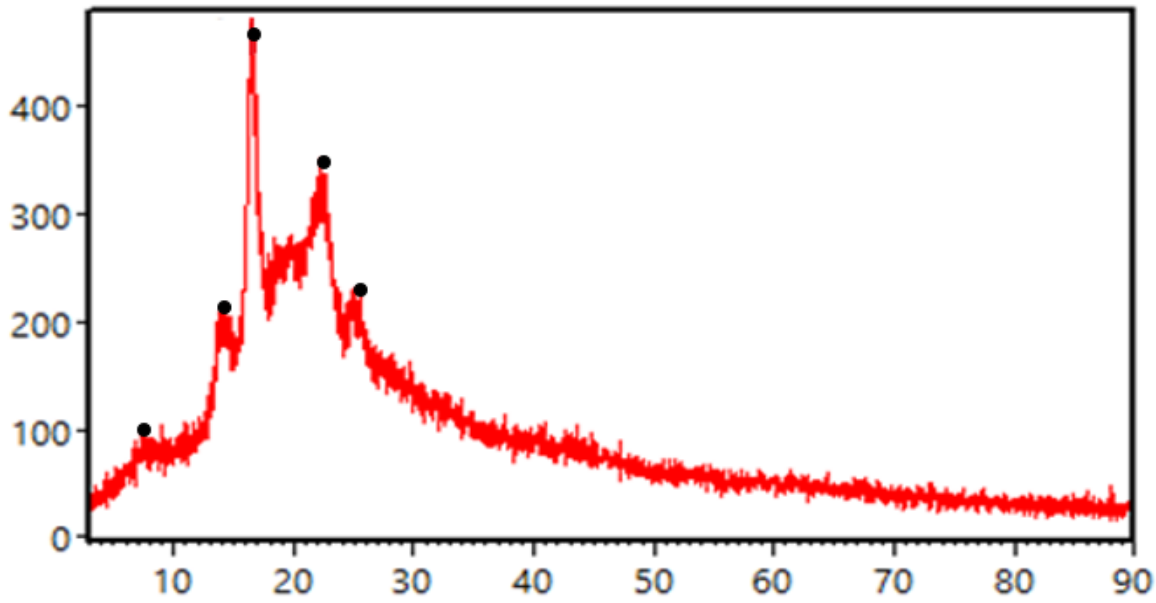


Figure 3. XRD Characterization Diffractogram 3 days 5%

Figure 3 is a graph of XRD analysis of samples 3-5 processed using High Score Plus (HSP) software. Sharp peaks show that there is a crystalline phase. After samples, 3-5 were XRD tested and analyzed, a phase was formed, namely the Hematite phase with the formula Fe2O3 with a Rhombohedral crystal structure which is the highest peak value on the graph. So that the highest intensity value is at 2θ = 25.266°. Furthermore, the data will be matched by comparing the parameters 2θ and d (Å) from the XRD test results with standard data from the High Score Plus software.

Table 4. XRD Results Comparison 3-5

No	Research Data		Standard Data		High Score Plus	Compound
	2θ (°)	d (Å)	2θ (°)	d (Å)		
1	7,44	11,87	7,29	12,11	0,24	*Iron*
2	14,10	6,27	13,76	6,43	0,16	*Iron*
3	16,47	5,37	16,43	5,39	0,02	*Iron*
4	22,60	3,93	22,4	3,96	0,03	*Iron*
5	25,5	3,49	25,2	3,52	0,03	*Iron*

Based on research data compared to standard ICDD data 00-033-0664, it can be compared the values of 2θ and d (Å) in samples 3-5 shown in Table 4. The results show the five highest peaks, according to Figure 3. Judging

from the five samples, there is a difference from the value of d (Å). The first peak has a difference in the d (Å) value of 0.24. The second peak has a difference in the value of d (Å) of 0.16, the third peak has a difference in the value of d (Å) of 0.02 while at the fourth peak has a difference in the value of d (Å) of 0.03, and the fifth peak has a difference in the value of d (Å) of 0.03.

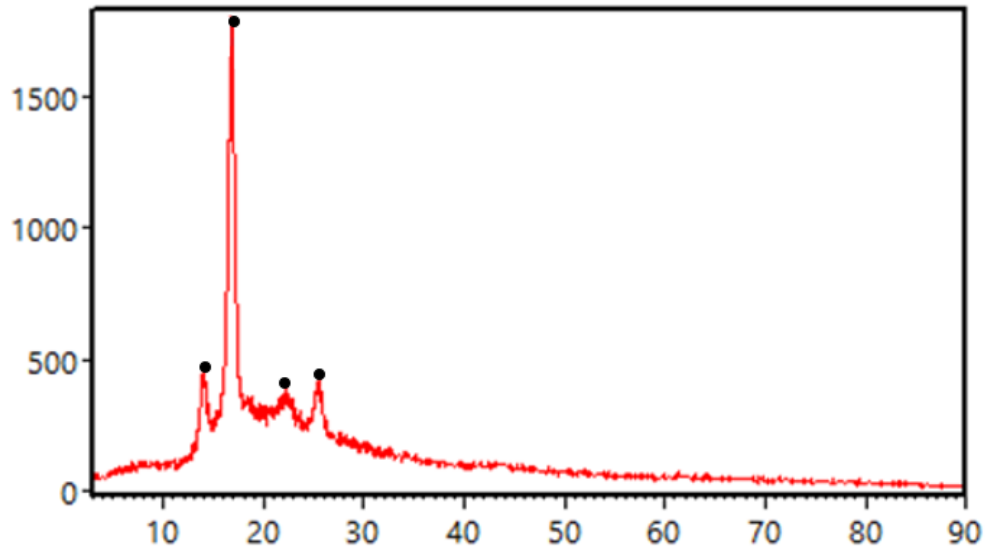


Figure 4. XRD Characterization Diffractogram 6-0

Figure 4 is a sample XRD analysis graph of 6-0, which was processed using High Score Plus software. Based on the picture above, there are sharp peaks that are shown in the symbol. The peaks indicate the presence of a crystal phase. Based on the results of the search match analysis or matching the sample data 6-0, there is a phase formed, namely the Hematite phase with the formula Fe2O3 with a Rhombohedral crystal structure which is the highest peak value on the graph, so that the highest intensity value is at 2θ = 22.41°.

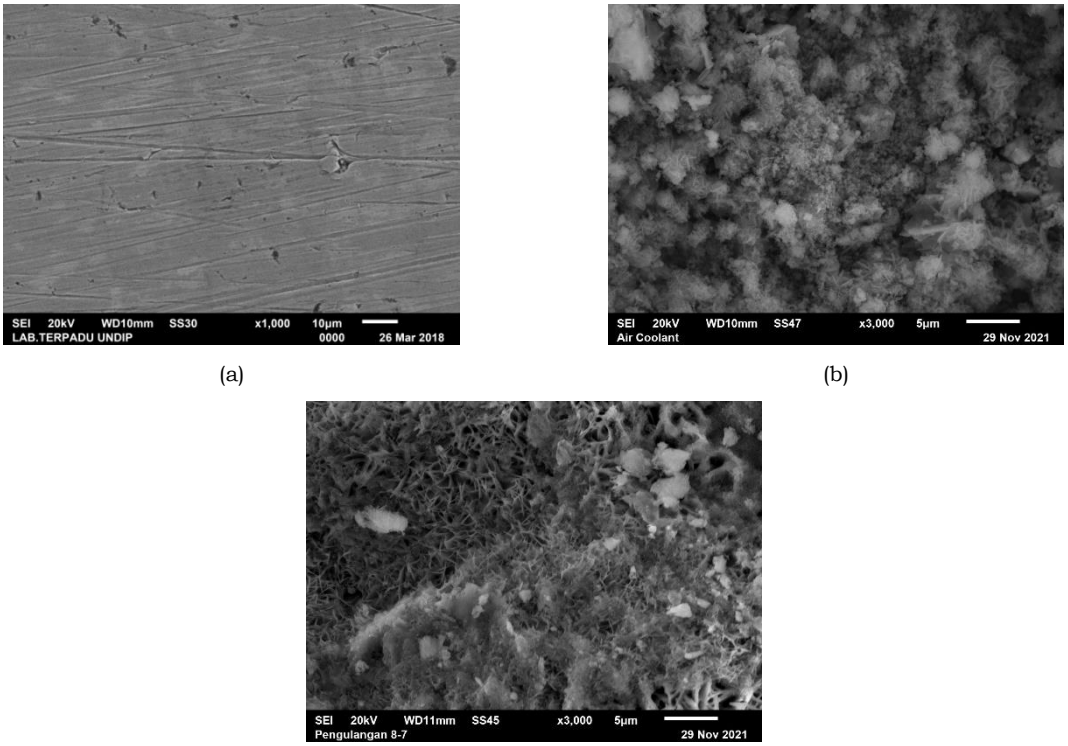
Table 5. XRD Result Comparison 6-0

No	Research Data		Standard Data		High Score Plus	Compound
	2θ (°)	d (Å)	2θ (°)	d (Å)		
1	13.92	6.354	13.88	6.379	0.025	*Iron*
2	16.76	5.282	16.76	5.289	0.007	*Iron*
3	22.31	3.981	16.43	4.000	0.019	*Iron*
4	25.42	3.502	22.41	3.504	0.002	*Iron*

Based on the research data compared to standard ICDD data 00-033-0664, it can be compared the values of 2θ and d (Å) in the 6-0 sample as shown in Table 4.4. the results show the four highest peaks following Figure 4. Judging from the four samples, there is a difference in the value of d (Å), the first peak has a difference in the value of d (Å) of 0.025, the second peak has a difference in the value of d (Å) of 0.007, the third peak has the difference in the value of d (Å) is 0.019 and at the fourth peak has a difference in the value of d (Å) of 0.002. The Fe peak produced in sample 8-0 decreased. Because the sample was in a corrosive environment and without being protected by an inhibitor, the sample was easily corroded.

3.4. SEM and EDS Characterization Results

Scanning Electron Microscopy (SEM) analysis was carried out to see the corroded surface, SEM analysis aimed to determine the microstructure on the sample surface. In addition to SEM analysis, EDS analysis was also carried out to determine the composition of elements or compounds in the sample. SEM analysis was performed on two samples of St37 steel, which had been soaked in a solution of 7% cacao leaf extract for six days and 3% NaCl, then a coolant water solution soaked for three days with a volume of 200 ml each. This test was carried out on coolant water samples and 6-day samples with a concentration of 7%. This characterization can be viewed with magnifications of 1000x, 3000x, 5000x, and 10000x. 1000x magnification will be shown in Figure 4.4, while some other magnifications, such as 3000x, 5000x, and 10000x will be shown in the Appendix. The image results from this characterization differ from the electron signal, which causes the image to look dark-bright. The results of the SEM analysis are shown in Figure 5. The difference between secondary and backscattered electron signals, where the second signal results in the topography of the object being analyzed with a higher surface being lighter in color than the lower surface, while backscattered electrons give a difference in the molecular weight of the atoms that make up the surface. So it can be seen that atoms with higher molecular weights will have a brighter color than atoms with lower molecular weights (Putri et al., 2012).



(a) (b)

(c)

Figure 5. The results of SEM characterization with 1000x magnification: (a) Raw sample, (b) manufacturer inhibitor sample, (c) 6-7 sample.

Based on the results of the analysis in Figure 5a, it can be seen that there are fine lines on the sample. These lines are the influence of grinding and sanding the sample. Raw steel is not soaked using inhibitors so that no grains or lumps indicate corrosion is formed. Because the steel has not shown a corrosion reaction, there has been no influence from any environment, such as water, air, acid, salt, base, or other corrosion substances. Figure 5b shows a large, evenly distributed lump. In clumps, black holes are seen, which are not evenly distributed. The black hole is the surface part attacked by corrosion, resulting in a darker surface area than the other surface areas. The hole is the main factor causing metal corrosion because the hole is the entrance of oxygen, so the electrons in the metal react with oxygen, so the sample will lack electrons and corrode (Vlack, 1994). Figure 5c shows cracks with holes that are almost evenly distributed. In Figure 5c, there are cracks and holes caused by corrosion in the sample. The SEM results of the two samples concluded that the sample with the inhibitor of cracks and holes was less so that the corrosion rate would be lower. Surfaces with cracks occur because the metal surface lacks Cr, Mn, and Si elements, so the strength of the steel becomes weak and susceptible to corrosion (Widharto, 1999). With that, oxygen will efficiently react with the metal's electrons and cause corrosion of the steel surface (Piere, 2008).

Sample of St 37 steel in 6 days immersion with the addition of 7% inhibitor and manufacturer's inhibitor. EDS characterization aims to determine the elements in the sample. The EDS test uses an SE (secondary electron) detector, which aims to determine the elements present in the sample.

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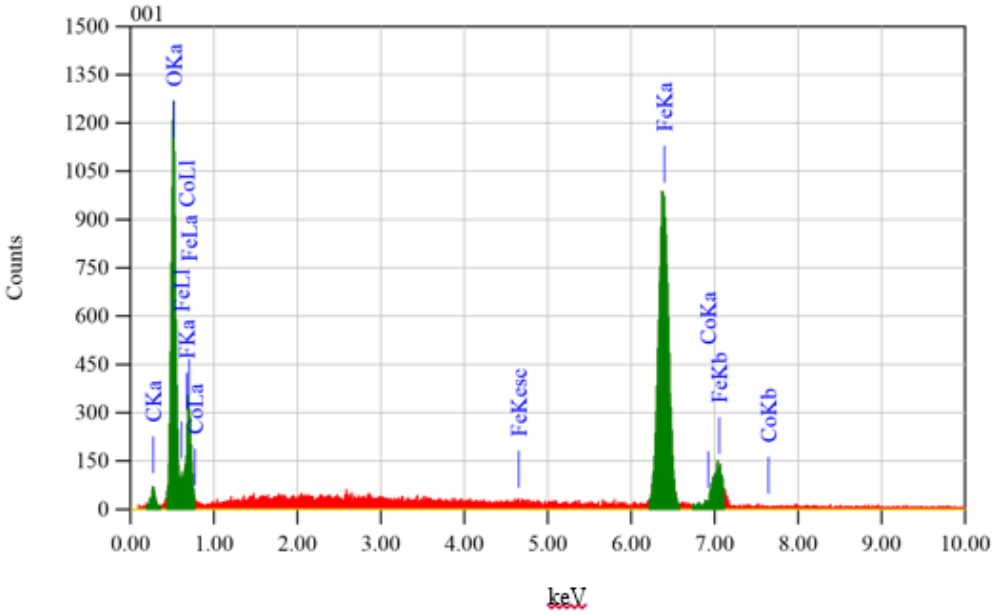

Figure 6. Results of EDS sample 6 days with the addition of 7% inhibitor

The comparison of elements and compounds in each sample can be shown in Table 6.

Table 6. Comparison of elements contained in each sample

element	Percentage (%)	
	St37 Steel 6-7	Manufacturer inhibitor
C	4,70	9,75
O	36,87	21,98
F	0,74	-
Fe	64,71	57,90
Co	1,22	0,59
Si	-	3,18

The results obtained from the EDS test in Table 6 on steel samples with an immersion time of 6 days in a 7% inhibitor concentration show that the element with the most significant percentage is Fe, which is 64.71% because the main element of steel is Fe. O is obtained at 36.87 %, indicating that there has been corrosion in the sample due to oxygen entering the St37 steel metal. In addition, trace elements were detected in the steel, namely C (Carbon) at 4.70%, F (Flour) at 0.74%, and Co (Carbon monoxide) at 1.22%.

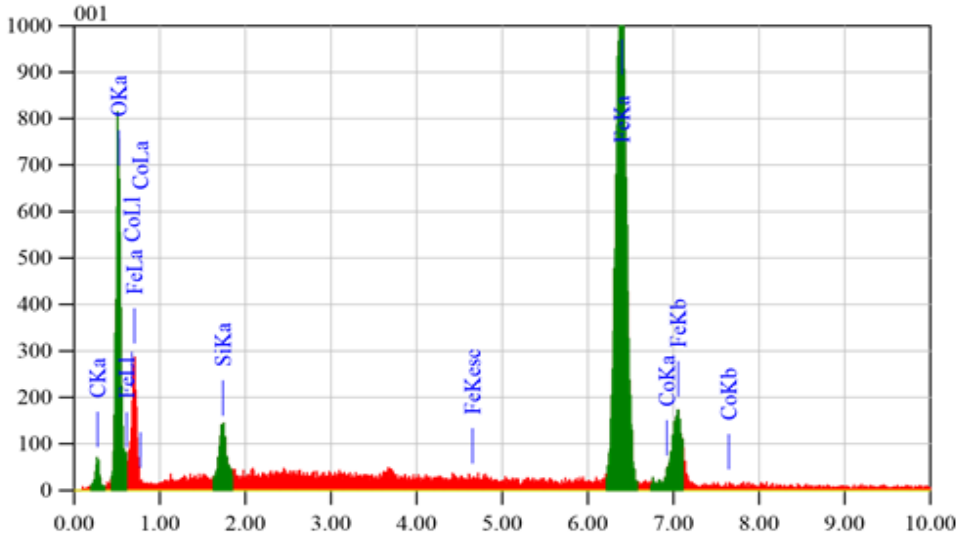

Figure 7. Manufacturer's sample inhibitor EDS results

In the EDS test on air coolant, the element with the most significant percentage was Fe, as much as 57.90%, then O, as much as 21.98%. Other impurity elements were also detected in the steel in small amounts, namely C (Carbon), as much as 9.75%, and CO (Carbon monoxide), as much as 0.59%. And Si (Silicon), as much as 3.18%. Air coolant was used as a comparison for the inhibitor of cacao leaf extract. From the two samples of Fe, the steel sample with an immersion time of 6 days in an inhibitor concentration of 7% is greater than the Fe air coolant. Because the longer the steel is immersed in the corrosive medium, the lower the FeO content in the sample. It can be concluded that the greater the concentration of cacao leaf extract inhibitor used, the corrosion rate will decrease, and the inhibition will increase. From the three results of characterization and calculation of the corrosion rate, it was found that the inhibitor of cacao leaf extract was effective in inhibiting the corrosion rate on St37 carbon steel. From the two mediums, the inhibitor of cacao leaf extract was more effective in the NaCl medium.

4. Conclusion

From the research that has been done, it is concluded that the inhibitor of cacao leaf extract is proven to be effective in inhibiting corrosion because the higher the concentration used, the lower the corrosion rate. Based on the results of SEM and EDS analysis, it is proven that the steel samples have been corroded, as evidenced by the presence of lumps and holes caused by corrosion so that the structure changes. It is also seen in the results of EDS with a reduced amount of FeO. Based on the results of XRD analysis, the peak formed in samples 3-5 has a Hematite phase with the formula Fe2O3, and there is a Rhombohedral crystal structure which is the highest peak value on the graph, so the highest intensity value is at 2θ = 25.266°, while in sample 6-0 the phase is formed the same as the phase in 3-5, namely the Hematite phase and there is a Rhombohedral crystal structure with the highest intensity value being at 2θ = 22.41°.

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