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Green Corrosion Inhibition of API 5L Grade B Steel Using Myrmecodia Pendans and Piper Crocatum Extracts in 3.5% NaCl

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Abstract: Method to prevent the corrosion during pipeline hydrotest using seawater is generally by the addition of inorganic inhibitor containing corrosion inhibitor agent, oxygen scavenger and biocide, so that require to find out the alternative eco-friendly materials with better performance. The main objective of this study is to investigate the efficiency of the use of mixture of extract of *Myrmecodia pendans* and *Piper crocatum* as an alternative of eco-friendly inhibitor for reducing the use of inorganic inhibitors for corrosion protection of steel material API 5L Grade B in 3.5% NaCl. The corrosion inhibition ability of natural ingredient extraction are investigated by using tafel polarization test and EIS and verified by weight loss test. The content of the active compounds in natural ingredient extraction along with adsorption compound on metal surfaces and inhibition mechanism are investigated by EIS, FTIR and adsorption isotherm model. In the mixed green inhibitor concentration of 2 ml *Myrmecodia pendans* and 1 ml *Piper crocatum* is resulted in approximately 73.66% inhibitor efficiency while concentration of 1 ml chemical cocktail and 2 ml green inhibitor are significantly reduce the corrosion rate from 0.42 mm/year to be 0.03 mm/year with approximately 93.15% inhibitor efficiency. The green inhibitor affected the cathodic as well as the anodic polarization curves which were known as mixed corrosion inhibitor type. The adsorption of compounds contained in the *Myrmecodia pendans* and *Piper crocatum* on a metal surface are occur spontaneously follows the Langmuir adsorption isotherm. The findings of this study demonstrate that the use of a mixed green inhibitors delivers high corrosion protection efficiency and markedly decreases dependence on synthetic inhibitors.

Keywords: Green Corrosion Inhibitor; Mixed Inhibitor; *Myrmecodia pendans*; *Piper crocatum*; Polarization

Citation: Kusumawardani, R., Budiono, A., Soedarsono, J. W., Pratesa, Y. (2025). Green Corrosion Inhibition of API 5L Grade B Steel Using Myrmecodia Pendans and Piper Crocatum Extracts in 3.5% NaCl. Recent in Engineering Science and Technology 3(03), 25–39. Retrieved from https://www.mbi-journals.com/index.php/riestech/article/view/112

Academic Editor: Noor Hidayati

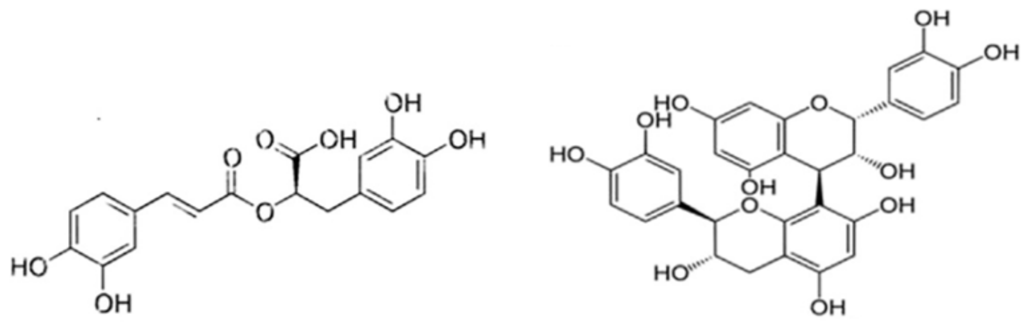
Received: 24 May 2025
Accepted: 12 June 2025
Published: 31 July 2025

1. Introduction

Oil and gas industry faces many corrosion problems at various stages, including exploration of oil wells, transport fluid from the well or the processing, storage and refinery operations in the onshore and offshore[1]. In oil and gas pipelines system, initial corrosion can be triggered by seawater during pre-commissioning and hydrotest where the seawater are used for pressure testing. In addition to the corrosion due to the environment with salt (NaCl) and dissolved oxygen, anaerobic conditions (without oxygen) can trigger the activation of the types of bacteria such as Sulphate Reducing Bacteria (SRB) which can initiate other corrosion processes i.e Microbial Induced Corrosion (MIC) that is local corrosion with a relatively high corrosion rate[2]. Among the various methods to avoid or prevent damage or degradation of the metal surface, corrosion inhibitor is one of the best methods for corrosion protection and one of the most useful in oil and gas industry[3]. Currently, this method are still survive caused low cost and practical method[3,4]. Treated seawater with anorganik inhibitor commonly used during pre-commisioning process of subsea pipelines which chemical inhibitor basically are toxic and difficult to decompose by environmental so that it is essential to develop alternative corrosion inhibitors as known as green inhibitor which are environmentally acceptable, economical and renewable[6]. Several study of green corrosion inhibitor development based on natural product such us *Myrmecodia pendans*[6][7][8], Green tea and *Piper Betle*[9], Purple Sweet Potato[10], *Pluchea indica* (L.)[11], and other natural plants.

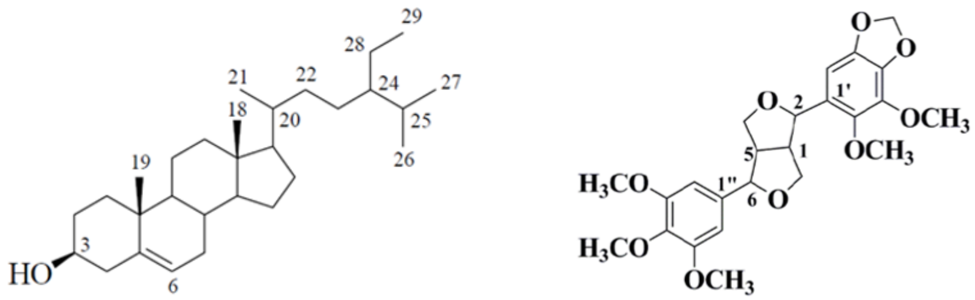
Most studies focus on using a single natural product as a corrosion inhibitor to control corrosion [6][10][11]. However, this approach may not achieve the expected technical and economic efficiency. Using a mixture of natural products can be an alternative to improve the efficiency of green inhibitors through synergistic effects [12][13]. Additionally, combining natural and chemical products can reduce the use of chemical inhibitors [15]. In general, the protection mechanism is ions or molecules adsorption on the surface of the metal which can create barriers inhibitor (film forming) to inhibit the electrochemical reactions (anodic and cathodic) so as to inhibit the corrosion process[16].

Myrmecodia pendans contains several antioxidant compounds such as saponins, tannins, Phenolic, flavonoids, alkaloids, Triterpenoid, steroids and glycosides[17] which phenolic compounds be regarded as a powerful antioxidant for their ability to donate hydrogen or electrons and form the basis of stable transition[15]. The chemical structure of the main antioxidant phenolic constituents in the myrmecodia pendans is shown in Fig. 1. In the process of corrosion inhibition, flavonoid compounds able to inhibit with the ability of flavonoids to be heterocyclic compounds[11]. In *Piper crocatum* plants, showed positive results contain phenolic compounds, flavonoids, terpenoids and steroid compounds[18]. In betel leaf essential oil contains a variety of bioactive phenolic compounds present in significant quantities and have to antimicrobial properties[19]. Cytotoxic chemical structure of the terpenoids and steroids constituents in Piper crocatum is shown in Fig. 2. In general, inhibitor derived from the extract of organic compounds will work to inhibit corrosion by forming a hydrophobic layer on the metal surface[20]. Hydrophobic layer formed by adsorption of molecules contained in the inhibitor with antioxidant compounds. Antioxidant compounds contained in the *Myrmecodia pendans* and *Piper crocatum* are predicted to inhibit the corrosion process and metal surface with adsorption mechanism that will form the inhibition layer. In other research that uses Pyridine-based inhibitors in CO_2 environments showed R_{ct} increases (up to 1760 Ω·cm^2) and C_{dl} reductions, attributed to N-heteroatom adsorption, indicating a thicker protective layer[21].



(**a**) (**b**)

Figure 1. The chemical structure of the main antioxidant phenolic constituents of *Myrmecodia pendans* (a) rosmarinic acid and (b) procyanidin B1[18]



(**a**) (**b**)

Figure 2. Cytotoxic chemical structure of the terpenoids and steroids constituents of *Piper crocatum* (a) β-sitosterol dan (b). 2-(5′,6′-dimethoxy-3′,4′-methylene dioxyphenyl)-6-(3″,4″,5″-trimethoxyphenyl)-3,7-dioxabicyclo[3,3,0] octane[22]

2. Materials and Experiment Methods

2.1. Sample Preparation

The specimen used was carbon steel API 5L Grade B standard taken from part of offshore topside piping wellhead platform. The size of 15 mm x 15 mm x 6.4 mm specimen was formed from 152,4 mm diameter steel pipe with ±30 mm length and 40 schedule pipe thickness (± 7.1 mm thick) for mounting of linear polarization and EIS tests while size of 30 mm x 20 mm x 6.4 mm are used for weight loss test. The sample surface is polished with 1000 grit silicon carbide paper to get a smooth surface and flat. The chemical composition of carbon steel material samples are presented in Table 1.

Table 1. The chemical composition of API 5L Gr. B carbon steel material samples

	C (%)	**Si (%)**	**S (%)**	**P (%)**	**Mn (%)**	**Cr (%)**	**Mo (%)**
API 5L Grade B	0.203	0.352	0.005	0.016	0.887	0.124	0.026
	Ni (%)	**Ti (%)**	**Cu (%)**	**Nb (%)**	**V (%)**	**Al (%)**	**Fe (%)**
	0.104	0.003	0.165	≤0.002	≤0.002	0.042	Balance

The laboratory tests were conducted to determine and investigate the corrosion behavior of carbon steel material API 5L Grade B samples that immersed in 3.5 % NaCl solution. Laboratory testing was performed without and with the addition of green inhibitors and the use of single and mixed inhibitor with a chemical inhibitor mixture at room temperature and atmospheric pressure.

2.2. Fourier Transform Infrared (FTIR)

Fourier transform infrared (FTIR) test was performed to characterize the functional groups of active compounds from green inhibitor extracts. Linear polarization test was carried out to obtain the corrosion potential and current density data as the basis to calculate the effectiveness of natural ingredients extract as an green inhibitor and verified by weight loss test. While the mechanism of inhibition was investigated by electrochemical impedance spectroscopy (EIS) testing and calculation of the adsorption isotherm models. The flow diagram of the overall experiment process from preparation until conclusion and reporting are as shown in Fig. 3.

2.3. Inhibitor Extract

Based on Pradityana study[6], the most effective of *Myrmecodia pendans* inhibitors are at 500 ppm concentration so that in this study, the similar concentration was adopted. The results of extract natural inhibitor will be diluted with 1:10 ratio to facilitate mixing[23]. Mixed and single extract natural inhibitor will be added into 3.5% NaCl solution as green inhibitor at 200 ml volume with 1.5% v/v concentration therefore obtained 1.5ml/1000ml (1500 ppmv) concentration with assumption that 1.5 ml will produce 0.5 grams of dry weight inhibitor which is equivalent to 0.5gr/1000ml (500 ppmw).

2.4. Corrosion Test

Linier polarization testing is carried using three electrode circuit (conventional three-electrode cell assembly) that is graphite as the counter electrode (CE), Ag/AgCl as reference electrode, and samples of carbon steel API 5L Grade B as working electrode in 3.5% NaCl solution. The 200 ml cell system equipped with copper cables mounting on carbon steel sample as working electrode. Polarization tests are carried out on cathodic potential range of -0.3 mV to the anodic potential of +0.2 mV (vs Ag/AgCl) with potential corrosion in the scan rate of 0.1 mV/s. Measurements were performed for single or mixed green inhibitor as well as mixed with a chemical inhibitor cocktail type.

The mechanism of corrosion occurred on the sample steel material API 5L Grade B are investigated by electrochemical impedance spectroscopy (EIS) testing. A basic method of EIS testing are based on response of the circuit to the AC voltage as a function of frequency. Electrochemical impedance measurements is performed on potensiostatic condition using the same potentiostat instrument for linier polarization testing. Sinusoidal wave voltage (AC) with the low amplitude of 10 mV is superimposed on the open circuit corrosion stable potential. Value of real impedance (Z ') and the imaginary impedance (Z'') are measured at various frequencies in the range of 10 MHz to 0.1 Hz. Nyquist plot of the real impedance (Z') value and the imaginary impedance (Z'') value will be generated from EIS testing.

Weight loss testing was conducted to verify the linear polarization and eis testing. Duration of immersion was conducted for 32 days and 10 hours with adjustments to the actual conditions in the field as a subsea pipeline hydrotest fluid. Samples for weight loss testing were made with a hole for a tying rope with a diameter of 3 mm. After immersion the samples was weighed and the average weight loss value was calculated.

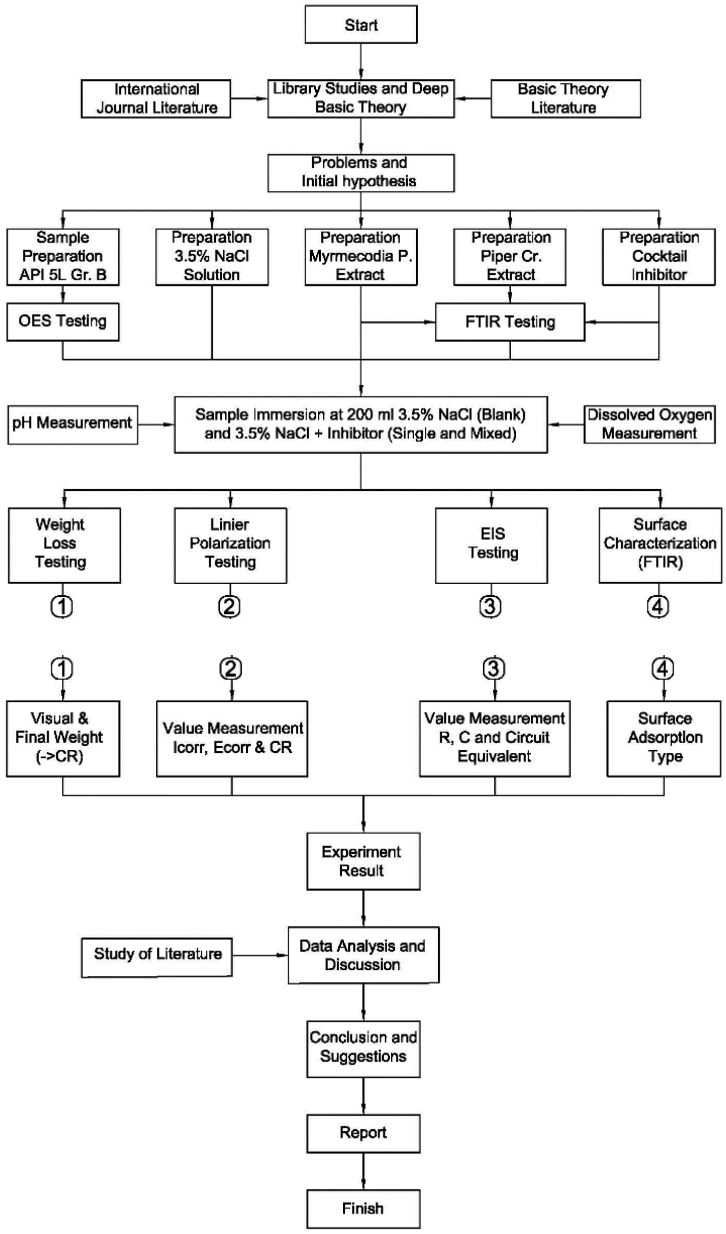


Figure 3. Experimental flow diagram

3. Results and Discussion

3.1. Inhibitor Solution

3.1.1. Fourier Transform Infrared (FTIR)

From the pH measurement results on 3.5% NaCl solution can be observed that the use of green inhibitor would increase the level of acidity with pH values decreased. Refer to pourbaix diagram on iron can be observed that the acidity reduction of the environment will shift the stability curve towards corrosive region (uniform corrosion) which will increase the possibility of corrosion[24], however this behaviour can be compensated by inhibitor effects from green inhibitor extracts with increase polarization resistance on steel surfaces and reduce the corrosion rate as shown in Fig.5-7 and Table 2.

Refer to interpretation result of FTIR testing for green inhibitor and carbon steel samples on a 3.5% solution, there are identified some top of wavenumber which showing the absorption spectrum of functional groups that detected adsorbed on the metal surface where peak wavenumbers are identified similar between two types of this natural inhibitor as well as functional group of chemical inhibitor cocktail as shown in Fig.4. *Myrmecodia pendans* and *Piper crocatum* extracts contain phenolic-type hydroxyl groups[17] that are able to form hydrogen bonds with water (O-H stretch) which helps the adsorption process on metal surfaces. In *Piper crocatum* extract, there are oily alkene hydrocarbon groups (nonpolar) so that the solubility of red betel in a 3.5% NaCl solution is lower than that of *Myrmecodia pendans* so that it has a repellent (hydrophobic) property on metal surfaces with C-H stretch groups. Nonpolar alkene groups (e.g., C=C and C-H stretches) form a hydrophobic layer on metal surfaces, limiting direct contact with water and chloride ions[25][26]. These two characteristics synergize in the process of inhibiting metal surfaces by forming a protective layer/film forming (barrier). This barrier inhibits electrochemical corrosion by repelling polar electrolytes like NaCl[27]. This aligns with studies on plant extracts like *Azadirachta indica* and *Psidium guajava*, where similar functional groups improved inhibition efficiency[28].

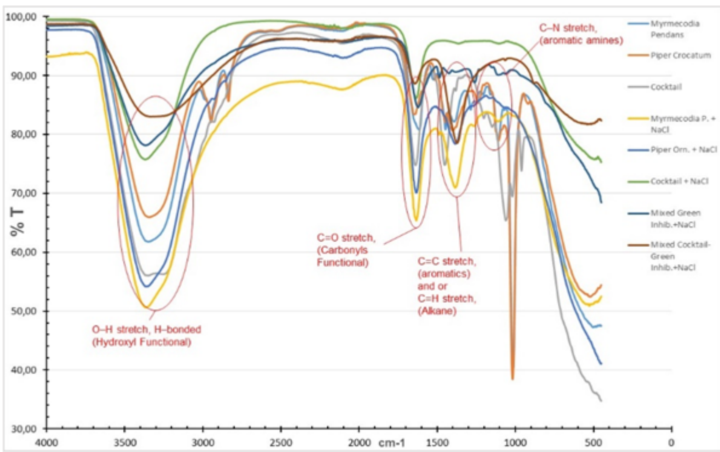


Figure 4. Graph of FTIR result for all variation inhibitor (Extract Inhbitor + Sample and Mixed Inhibitor + Sample)

3.2. Corrosion Test

3.2.1. Potentyodinamic Polarization (PDP)

From the linier polarization result in 3.5% NaCl solution without addition of inhibitor and with addition of a chemical inhibitor and natural extracts will obtain polarization curve as shown in Fig. 5, while the addition of mixed inhibitor of *Myrmecodia pendans* and *Piper crocatum* on some variation of mixing ratio will obtain polarization curve as shown in Fig. 6. In addition of cocktail inhibitor and green inhibitor on some variation of mixing ratio will obtain polarization curve as shown in Fig. 7. The electrochemical parameters of the linier polarization test such as the corrosion current density (i_{corr}), corrosion potential (E_{corr}), Tafel slope (β_a & β_c), and the corrosion rate (CR) based on post processing results of Fig. 5-7 are as shown in Table 2.

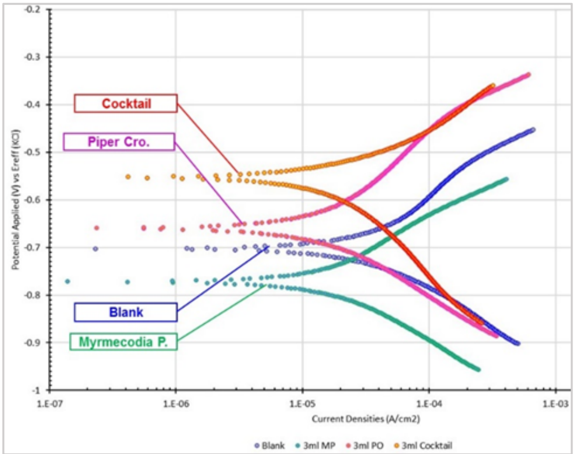


Figure 5. Polarization curve for 3.5% NaCl solution without inhibitor and with pure cocktail inhibitor and green inhibitor

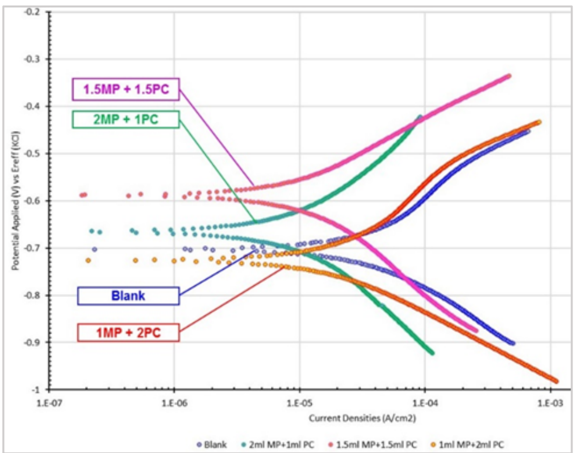


Figure 6. Polarization curve for 3.5% NaCl solution with mixed inhibitor *Myrmecodia pendans* and *Piper crocatum* at various mixed ratio

The results of polarization measurements as shown in Fig. 5-7 and Table 2 indicate that there was an effect of inhibition by natural inhibitors *Myrmecodia pendans* and *Piper* *crocatum* as well as cocktails inhibitor along with the mixture on low carbon steel corrosion in 3.5% NaCl environmental. The reduction of corrosion rate is characterized by impairment of current densities from 36.13 μA.cm^{-2} (CR = 0.42 mm/year) to the value of 13.59 μA.cm^{-2} (CR = 0.16 mm/year) with addition of *Myrmecodia P.* inhibitor. The current densities to be 9.52 μA.cm^{-2} (CR = 0.11 mm/year) in addition of mixed green inhibitor and 2.47 μA.cm^{-2} (CR = 0.03 mm/year) in the addition of mixed green inhibitor and a cocktail inhibitor. The maximum efficiency of 93.15% is achieved by mixed cocktail and green inhibitor with mixing ratio of 1 ml cocktail and 2 ml of green inhibitor. It is characterized by increasing polarization resistance from Rp = 578.65 Ω in the blanks without inhibitor to R_p = 5535.20 Ω on mixed green and chocktail inhibitor. Both anodic (βa) and cathodic (βc) Tafel slopes shifted, confirming mixed inhibition type. For example, βa increased from 173.86 mV/dec (blank) to 243.86 mV/dec with mixed inhibitors[29]. Efficiency and increased polarization resistance can be affected by compounds of both natural materials extracts and cocktail inhibitor were approximately equal to so that complementarity each other as shown by functional groups of FTIR results in Fig. 3.

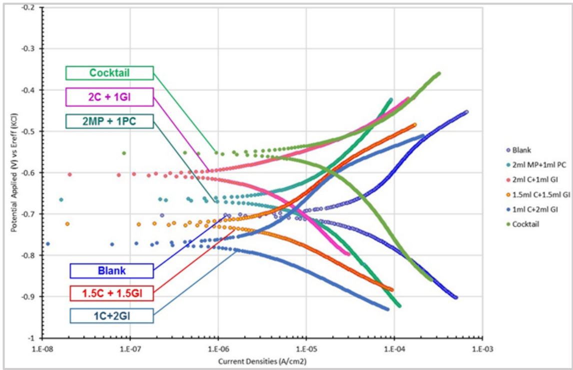


Figure 7. Polarization curve for 3.5% NaCl solution with mixed cocktail inhibitor and green inhibitor (*Myrmecodia pendans* and *Piper crocatum*) at various mixed ratio.

Table 2. The electrochemical parameters of the linier polarization on 3.5% NaCl solution with addition of inhibitor and mixed at various mixing ratio

No	Inhibitor Type and Concentration (%v/v)	E_{corr} (mV)	I_{corr} (μA. cm^{-2})	Rp (Ω)	$β_a$ (mV. dec^{-1})	$β_b$ (mV. dec^{-1})	C_R (mm /year)	Efficiency η (%)
Group 1- Without Inhibitor and With Pure Chemical and Green Inhibitor								
1	3.5% NaCl (Blank)	-702.75	36.13	578.65	173.86	244.98	0.42	0
2	3 ml MP	-769.35	13.59	1149.00	161.12	143.02	0.16	62.39
3	3 ml PC	-665.01	15.09	1880.30	167.43	156.12	0.18	58.24
4	3 ml Cocktail	-559.03	15.54	1080.80	128.03	225.62	0.18	57.00

Group 2 – Mixed Inhibitor Between *Myrmecodia pendans* and *Piper crocatum* at Various Ratio								
1	2 ml MP + 1 ml PC	-659.68	9.52	2501.80	243.86	220.46	0.11	73.66
2	1.5 ml MP + 1.5 ml PC	-569.35	10.34	2440.20	234.33	146.32	0.12	71.37
3	1 ml MP + 2 ml PC	-724.76	13.08	1412.00	129.55	150.12	0.16	63.80
Group 3 – Mixed Inhibitor Between Cocktail and Green Inhibitor at Various Ratio								
1	2 ml C + 1 ml GI	-629.63	4.11	3960.00	131.40	198.63	0.05	88.64
2	1.5 ml C + 1.5 ml GI	-725.04	3.48	4162.50	114.76	167.74	0.04	90.38
3	1 ml C + 2 ml GI	-776.03	2.47	5535.20	185.11	102.03	0.03	93.15

3.2.2. Electrochemical Impedance Spectroscopy (EIS)

Electrochemical impedance spectroscopy (EIS) testing was conducted to identify the mechanism of inhibition on Sodium chloride corrosion (sea water corrosion) and surface phenomena that occur at the interface metal / electrolyte due to the effect of inhbitor addition. The EIS test results are displayed in the Nyquist plots on 3.5% NaCl solution without inhibitor addition and with addition of a pure chemical and natural extracts inhibitor as shown in Fig. 8 while the addition of mixed inhibitor of *Myrmecodia pendans* and *Piper crocatum*. Extract on various mixing ratio will generate Nyquist plot as shown in Fig. 9. In addition of mixed cocktail inhibitor and green inhibitor on various mixing ratio will generate Nyquist plot as shown in Fig.10.

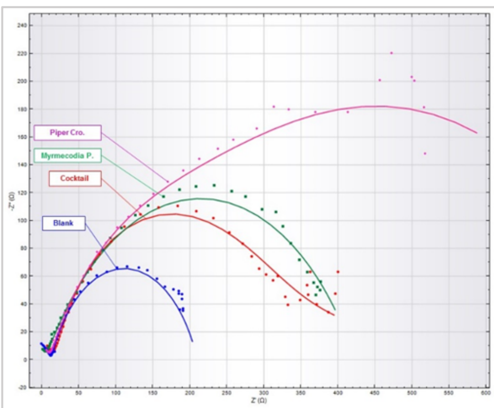


Figure 8. Nyquist plot of 3.5% NaCl solution without inhibitor and with pure cocktail inhibitor and green inhibitor

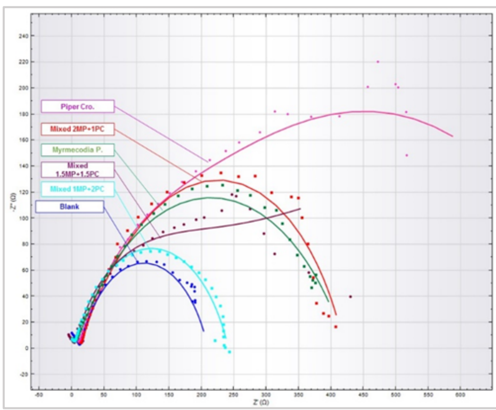


Figure 9. Nyquist plot of 3.5% NaCl solution with mixed inhibitor *Myrmecodia pendans* and *Piper crocatum* on various mixing ratio

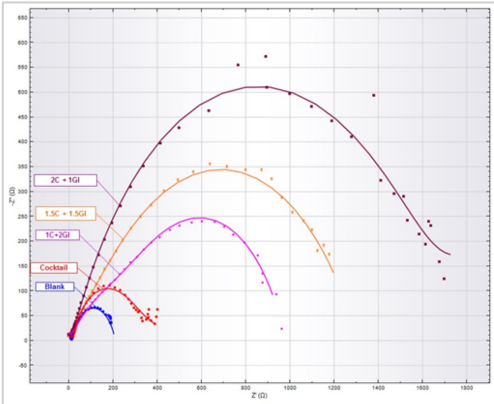


Figure 10. Nyquist plot of 3.5% NaCl solution with mixed cocktail inhibitor dan green inhibitor (*Myrmecodia pendans and Piper crocatum*) on various mixing ratio

Table 3. Parameters of EIS on 3.5% NaCl solution without and with addition of inhibitor on various mixing ratio

No	Inhibitor Type and Concentration (%v/v)	R_{ct} (Ω.cm²)	C_{dl} (μ.Fcm^{-2})	Efficiency η (%)
Group 1- Without Inhibitor and With Pure Chemical and Green Inhibitor				
1	3.5% NaCl (Blank)	200.95	2498.50	-
2	3 ml MP	427.25	848.91	52.97
3	3 ml PC	775.23	2777.10	74.08
4	3 ml Cocktail	333.43	221.80	39.73
Group 2 – Mixed Inhibitor Between *Myrmecodia pendans* and *Piper crocatum* at Various Mixing Ratio				
1	2 ml MP + 1 ml PC (Mixed GI #1)	422.05	913.68	52.39
2	1.5 ml MP + 1.5 ml PC (Mixed GI #2)	317.9	923.99	36.79
3	1 ml MP + 2 ml PC (Mixed GI #3)	239.00	430.75	15.92
Group 3 – Mixed Inhibitor Between Cocktail and Green Inhibitor at Various Mixing Ratio				
1	2 ml C + 1 ml GI (Mixed #1)	1760.10	74.00	88.58
2	1.5 ml C + 1.5 ml G1 (Mixed #2)	1149.40	885.84	82.52
3	1 ml C + 2 ml GI (Mixed #3)	1543.00	731.50	86.98

The parameters of impedance and polarization resistance (R_{ct}), double layer capacitance (C_{dl}) and inhibition efficiency (EI%) results from EIS testing without addition of inhibitor and with addition of inhibitors can be given as shown in Table 3. EIS measurements as shown in Fig. 8-10 and Table 3 shows that with addition of inhibitor, the overall impedance have experienced a significant improvement that can be attributed to Warburg impedance however capacitive impedance due to control mechanism of charge transfer can be attributed to the overall impedance. C_{dl} decreased from 2498.5 μF/cm² (blank) to 731.5 μF/cm², suggesting a thicker protective layer[30]. From the measurement data results, the corrosion rate and efficiency shown better results with the use of mixed inhibitor. The corrosion rate is significantly decreased and efficiency is increased in the use of mixed inhibitors between green inhibitor and cocktail inhibitor.

3.2.3. Weight Loss

The laboratory test have been verified by weight loss test as shown in Table 4. After 32 days, the corrosion rate decreased from 0.2676 mm/year (blank) to 0.0661 mm/year (75.3% efficiency) with mixed inhibitors. Weight loss results correlated with EIS and polarization, confirming inhibitor stability over time. The same result with palm oil leaves extract achieved 83.7% efficiency in NaCl via weight loss[31]. From the experiment result, a mixture of extract of *Myrmecodia pendans* and *Piper crocatum* are effective for use as an alternative environment friendly corrosion inhibitor for corrosion protection of API 5L steel material in NaCl environment.

Table 4. Data and analysis of weight loss test result for 778 hours (32 days 10 hours)

No	Description of Sample	Surface Area (cm^2)	Weight Before Immersion (gram)	Weight After Immersion (gram)	C_R (mm/year)	Efficiency η (%)
Group 1- Without Inhibitor and With Pure Chemical and Green Inhibitor						
1	3.5% NaCl (Blank)	16.9462	26.5424	26.2258	0.2676	-
2	3 ml MP	16.6641	26.1157	26.0258	0.0773	71.12
3	3 ml PC	14.1838	20.8232	20.7558	0.0681	74.57
4	3 ml Cocktail	16.0851	22.5272	22.4615	0.0585	78.14
Group 2 – Mixed Inhibitor Between *Myrmecodia pendans* and *Piper crocatum* at Various Ratio						
1	2 ml MP + 1 ml PC	13.0446	18.3399	18.2841	0.0613	77.10
2	1.5 ml MP + 1.5 ml PC	14.7224	22.6386	22.5736	0.0632	76.37
3	1 ml MP + 2 ml PC	13.9873	20.4600	20.3930	0.0686	74.36
Group 3 – Mixed Inhibitor Between Cocktail and Green Inhibitor at Various Mixing Ratio						
1	2 ml C + 1 ml GI	17.5872	27.3906	27.2855	0.0856	68.01
2	1.5 ml C + 1.5 ml GI	14.3430	21.1877	21.1096	0.0780	70.85
3	1 ml C + 2 ml GI	15.5796	23.3890	23.3171	0.0661	75.30

3.3. Adsorption Isotherm

In Table 5 shows the calculation of adsorption isotherm model Langmuir and four adsorption isotherm models of Temkin, Frumkin, Bockris-Swinkels, and virial Parson[29]. The modeling of adsorption isotherm mode Langmuir are generate the greatest average value of correlation coefficient (degree of conformity), with a value ≥ 0.95. Langmuir isotherm models is assume that organic molecules adsorbed as a monolayer on a metal surface without any interaction with other organic molecules adsorbed[32] and the organic molecules adsorbed on only one site[33]. The same result with Chitosan-Schiff base inhibitors followed Langmuir adsorption (R^2 = 0.99) on steel in NaCl[34]. Therefore, the inhibitor molecule from mixed inhibitor of chemical and natural inhibitor of *Myrmecodia pendans* and *Piper crocatum* can be predicted to adsorption on metal surfaces by forming a single inhibition layer (monolayer).

Table 5. Correlation coefficient value (R^2) for the fifth adsorption isotherm mode

No	Inhibitor Type and Concentration (%v/v)	Degree of Conformity Value, Correlation Coefficient (R^2)				
		Langmuir Isoterm	Temkin Isoterm	Frumkin Isoterm	Bockris-Swinkels Isoterm	Virial Parson Isoterm
1	Mixed Green Inhibitor	0.9899	0.7523	0.9111	0.9111	0.7523
2	Mixture of Green Inhibitor and Chemical Coctail Inhibitor	0.9748	0.3227	0.8521	0.5387	0.3227
Average Value (R^2)		0.9824	0.5375	0.8816	0.7249	0.5375

4. Conclusions

In this study, mixture of *Myrmecodia pendans* and *Piper crocatum* as green inhibitor on chemical cocktails inhibitor has been aligns with the study objective's by confirming that the green inhibitor is effevtice as a corrosion inhibitor. Analysis of the findings of several tests resulted in the following conclusions:

1. Functional groups of phenolic and flavonoid compounds are dominate the composition of *Myrmecodia pendans* and phenolic compounds in *Piper crocatum* extract as an antioxidant compounds that contribute to inhibit corrosion of the carbon steel material.
2. Corrosion inhibitor from a mixture of *Myrmecodia pendans* and *Piper crocatum* extract are works as mixed corrosion inhibitor type which reduce the cathodic and anodic current density in the 3.5% NaCl environment. This mixed corrosion inhibitors can

reduce the corrosion rate of 0.42 mm/year to 0.03 mm/year with an efficiency of 93.15% based on linear polarization testing and 86.98% based on EIS testing.

3. Addition of corrosion inhibitor will be physically adsorbed on the metal surface following Langmuir isotherm mode. The formation of inhibition layer on the metal surface will be dominant to control the transfer charge or diffusion so that it will inhibit the corrosion process which be affected by the mixing ratio.

Addition of green inhibitor on chemical inhibitor of cocktail type will increase the efficiency of corrosion protection of steel materials based on test measurement which it is significantly increase the efficiency of a pure chemical inhibitors with added green inhibitor.

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