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Dried Clove Leaf as Corrosion Inhibitor for Medium Carbon Steel in Acidic Media

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Abstract

Medium carbon steel is a widely used steel variant known for its susceptibility to mechanical property degradation due to corrosion. In order to decrease the corrosion rate of medium carbon steel, various protective measures are employed such as the addition of inhibitors. Dried Clove Leaf (DCL) extract was extracted and applied as an inhibitor for medium carbon steel AISI 1040 in different acidic environments. Fourier-transform infrared spectroscopy (FTIR) was conducted to analyze the compounds present in the clove leaf extract. Subsequently, corrosion rate and inhibitor efficiency were assessed to demonstrate the effectiveness of the clove leaf inhibitor. The parameters under this research included varying inhibitor concentrations for 0%, 5%, 10%, 15%, and acidic media using HCl and H_2SO_4. The successful extraction of DCL was confirmed by the presence of a C=C bond in the FTIR results, occurring at wavenumbers ranging from 1638 to 1514 cm^{-1}, indicative of the presence of benzene rings corresponding to eugenol (a phenolic component). The inhibitor exhibited remarkable efficiency, reaching its peak at 96.51% when used with HCl media at a DCL concentration of 15%. This high efficiency is notably reflected in the significant reduction of the corrosion rate from 352.96 mpy to 12.31 mpy in the presence of HCl media.

Keywords: *Medium Carbon Steel, Dried Clove Leaf, Inhibitor, Corrosion Rate, Efficiency*

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INTRODUCTION

Carbon steel for every industrial application is never spared from corrosion process, such as in the gas piping system, hull, and construction [1]–[3]. The corrosion process causes a decrease in the mechanical properties of steel which can cause losses in economic and safety aspects [4]. Medium carbon steel is one of the widely used steel that shows the lowering of the mechanical properties due to corrosion. Corrosion has been proven to reduce the impact strength by 39.8% in medium carbon steel in seawater media [5]. In order to decelerate the corrosion rate of medium carbon steel, several methods are taken to protect the metal, such as coating and inhibitor addition.

The corrosion inhibitor is a chemical compound that is added to the environment or electrolyte media and then able to decrease the corrosion attack in the metal [6]. Based on the basic substances, inhibitors consist of organic and inorganic compounds, additionally, dissolve in a liquid environment. The inorganic inhibitors such as chrome, arsenate, and tungstate, are mostly expensive and not environmentally friendly. This causes the use of inorganic inhibitors to be minimized by some industrial sectors. The organic inhibitor is rapidly developed, especially using a natural extract that is safe for the environment, biodegradable, and easy to obtain [7]. This organic inhibitor mostly can be extracted from marine invertebrates such as shrimp and crabs [8]. Additionally, it can be obtained from plant parts such as leaf, seed, etc. [7], [9].

The clove plant is one of the spice plants, the most important part commercially, around 80-90% is the flower which is used in the cigarette industry [10]. Meanwhile, the leaves have not been utilized optimally and left to dry, then considered as a waste. Besides, the clove leaf has the essential oil content of 1 – 4% and phenolic component [11], [12]. This phenolic component in clove leaf is from eugenol and has high antioxidant activity which can prevent oxidation [13]. The presence of the phenolic component in the plant is potentially used as green corrosion inhibitor due to the ability of preventing oxidation process. A similar phenolic component is also found in the guava leaf which the previous study has already reported, the 400-ppm guava leaf extract gave 53.03% of inhibition efficiency in steel alloy using NaCl medium [14]. Other plants that have phenolic content and have been proved as the corrosion inhibitor is tobacco leaf. Setiawan et al reported in their research that inhibition efficiency of 700mg/L tobacco leaf extract reached 71.71% for carbon steel ini HCl medium [4]. The application of clove leaf extract as a corrosion inhibitor in the previous study also showed similar results in lowering the corrosion rate [15], but it was only concerned in the corrosion behavior of API 5L grade B in NaCl media. There is still limited research about the clove leaf extract for inhibiting corrosion in carbon steel using acidic media.

Dried Clove Leaf (DCL) was extracted and applied to be the inhibitor for medium carbon steel AISI 1040 in various acidic media. The Fourier-transform infrared spectroscopy (FTIR) was carried out to characterize the compounds in the clove leaf extract. Then the corrosion rate and inhibitor efficiency were analyzed to prove the efficacy of the clove leaf inhibitor. The parameters analyzed are related to the variation of inhibitor concentration (0%, 5%, 10%, 15%) and the type of acidic media (HCl and H_2SO_4).

METHODS AND ANALYSIS

The medium carbon steel used in this research is AISI 1040 with dimensions of 30x30x3 mm for 24 specimens. Each specimen was drilled in the top center with a diameter of 3 mm which functions as a specimen hanger (see Figure 1). The acidic media for the soaking process of the corrosion test were HCl and H_2SO_4 with a percentage of 3% for each acid, corresponding to the total immersion solution needed of 5088 ml.

The corrosion inhibitor was extracted from the Dried Clove Leaf (DCL). A big boiler filled with water was prepared, then the dried clove leaves were put inside it. The next step was to tightly close the boiler which is equipped with some locking bolts to prevent leakage. Then light the fire in the furnace. The results of steam distillation went through several stages, a cooling process in a cooling pool, then separation of the water and oil

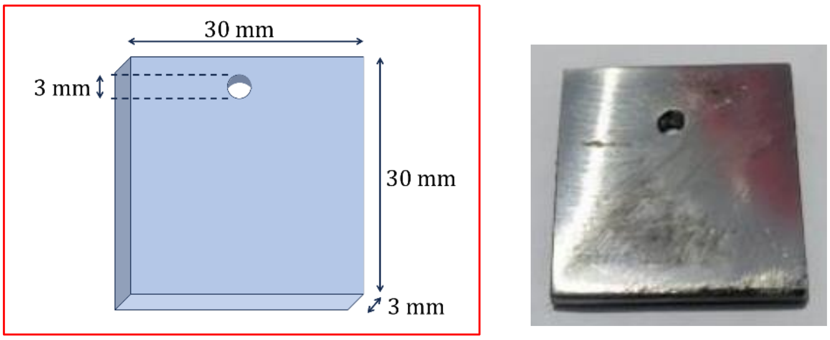

Figure 1. Specimen dimension

Figure 2. Dried clove leaf extraction process

from the distillation process around 2 – 4 hours. The clove leaf extract result was a purplish liquid. This process is illustrated in Figure 2. The inhibitor concentration is varied in 0%, 5%, 10%, and 15% calculated based on the total volume of the immersion solution.

After the extraction process, the clove leaf extract was characterized using Fourier-Transform Infrared Spectroscopy (FTIR) with spreading on NaCl method for the FTIR sample. This characterization was aimed to analyze the functional groups and identify the bonding type.

The corrosion rate calculation was obtained by measuring the surface area, the initial and final weight of the specimens. The corrosion experiment was carried out using weight loss method, the specimens were soaked for 7 days, then the corrosion rate was calculated with the following formula [16].

$$Corrosion\ Rate\ (mpy) = \frac{K \cdot W}{D \cdot A \cdot T} \quad (1)$$

Where, K is constant factor (3.45×10^6), W is weight loss (gram), D is specimen density (gram/cm^3), A is soaked specimen surface area (cm^2), and T is exposure time (hour).

The inhibitor efficiency was calculated to obtain the efficacy of inhibitor. The Inhibitor Efficiency (IE) was calculated using equation 2 [17].

$$Inhibitor\ Efficiency\ (\%) = \frac{(CR_{uninhibited} - CR_{inhibited})}{CR_{uninhibited}} \times 100 \quad (2)$$

Where, $CR_{uninhibited}$ is corrosion rate without inhibitor and $CR_{inhibited}$ is corrosion rate with the application of inhibitor.

RESULTS AND DISCUSSIONS

FTIR Characterization

The FTIR result of DCL in Figure 3 indicates several major peaks. These peaks were observed by comparing them to the Spectroscopic Data Handbook and similar research about clove leaf extract [18]–[20]. A broad peak showed at 3520 cm^{-1} wavenumbers indicating strong –OH groups. The wavenumbers around 2935 – 2846 cm^{-1} denote the aliphatic C–H. The aromatic bonding C=C that indicates the presence of the benzene rings is found in sharp intensity at 1638 – 1514 cm^{-1} wavenumbers. Handayani et al said the 900 – 650 cm^{-1} wavenumbers strengthened the presence of the characteristic absorption bands for C=C [19]. The appearance of the aromatic C=C in the FTIR result exhibits the existence of eugenol which has the main characteristic of the benzene ring in its chemical structure.

Corrosion Rate

The weight loss method was used to obtain the corrosion rate. The specimens were weighed before and after the 7-day soaking process. Then the required data was calculated using the formula previously explained and the corrosion rate results were showed in Table 1. Each variable was carried out using 3 samples, so then the average was calculated from the corrosion rate of the 3-sample. The specimens without inhibitor shows the highest corrosion rate with the value of 352.96 mpy in HCl medium and 435.04 mpy in H_2SO_4 medium. The corrosion rate in H_2SO_4 media consistently shows higher results than the corrosion rate in HCl media, this is likely caused by the acidity level (see Figure 4).

The addition of DCL inhibitor extremely decreases the corrosion rate starting at 5% DCL addition. Th e lowest corrosion rate is 12.31 mpy with 15% inhibitor concentration

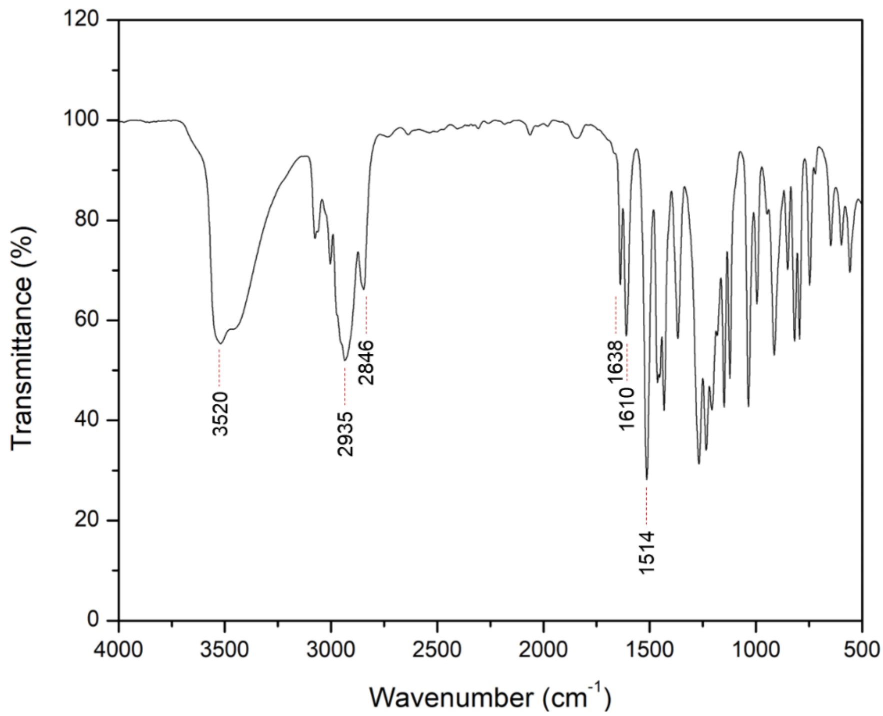

Figure 3. FTIR result of dried clove leaf extract

Table 1. Corrosion rate results of medium carbon steel using clove leaf inhibitor

No	Acidic Media	Inhibitor Concentration (%)	Corrosion Rate (mpy)
1	HCl	0	352.96
		5	20.52
		10	16.41
		15	12.31
2	H_2SO_4	0	435.04
		5	53.35
		10	65.46
		15	53.35

in HCl media. Moreover, in H2SO4 media, the corrosion rate also diminishes from 435.04 mpy to 53.35 mpy for 15% DCL inhibitor addition. This tremendous decrease attributed to an effective blanketing of inhibitors at the steel surface [21]. Although there is a slight increase of the corrosion rate in the 10% DCL that may be attributed to the uneven distribution of the inhibitor on the sample surface. The higher concentration of DCL inhibitor leads to a lower corrosion rate. This is due to the reduction of the exposed surface area of the steel as a result of an increase in the number of inhibitor molecules added. This result is in line with the previous researches done by Ji et al. and Nnanna et al. [21], [22].

Inhibitor Efficiency

The inhibitor efficiency was calculated to observe the inhibitor efficacy. The efficiency was obtained from the uninhibited and inhibited specimen's corrosion rate. The results are displayed in Figure 5. The inhibitor efficiency is inversely proportional to the corrosion rate. The lower the corrosion rate due to the inhibitor addition, the higher the efficiency.

The greatest efficiency is achieved by 15% DCL concentration addition with a value of 96.51% in HCl media. In H_2SO_4 media, the highest inhibitor efficiency obtained is 87.74%. The larger number of DCL concentration additions increases the inhibitor efficiency. The result shows that the DCL inhibitor addition is more effective in HCl media

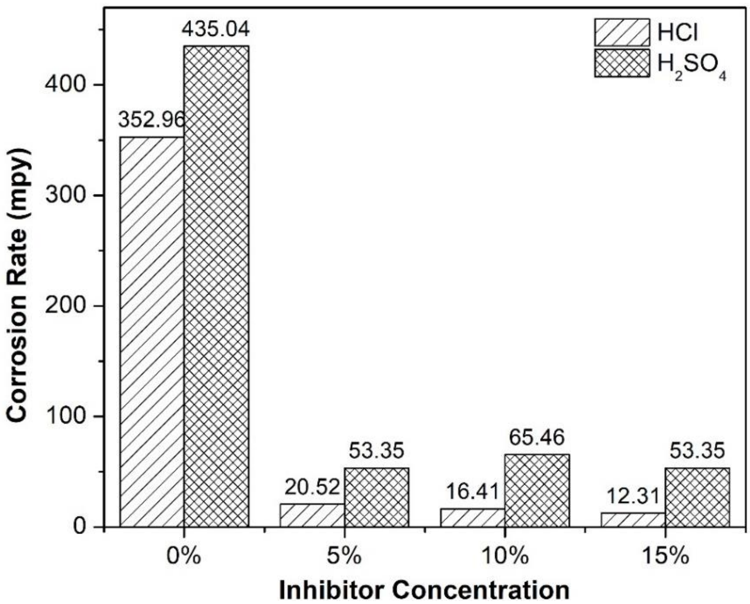

Figure 4. Corrosion rate results

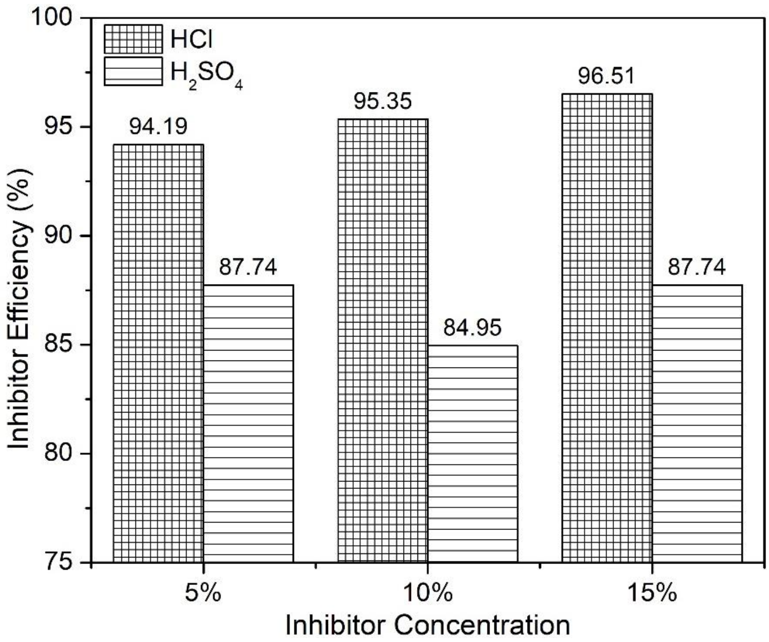

Figure 5. Inhibitor efficiency results

than H_2SO_4. This higher effectiveness of inhibitor addition to HCl media compared to H_2SO_4 media is similar to the previous studies [21], [22].

CONCLUSIONS

The results of this research prove that DLC extract has efficacy in inhibiting the corrosion process on medium carbon steel AISI 1040. The DCL was successfully extracted as evidenced by the appearance of a C=C bond at 1638 – 1514 cm^{-1} wavenumbers in the FTIR results which indicates the presence of the benzene rings corresponding to eugenol (phenolic component). The efficacy was measured in the inhibitor efficiency which reached the highest efficiency at 96.51% using HCl media with a DCL concentration of 15%. Meanwhile, this high efficiency is relevant to the dropping of corrosion rate from 352.96 mpy to 12.31 mpy with HCl media.

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DECLARATION OF CONFLICTING INTERESTS

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REFERENCES

[1] A. Hartadi, A. A. Rosidah, and S. Suheni, "Analisis Laju Korosi dan Sisa Umur Pakai Pada Sistem Perpipaan Stasiun Penerima Gas Bumi," Pros. Semin. Nas. Sains Dan

Teknol. Terap., no. 0, Art. no. 0, Dec. 2022, Accessed: Oct. 04, 2023. [Online]. Available: http://ejurnal.itats.ac.id/sntekpan/article/view/3464
[2] N. Ngatmin, H. Purwanto, and I. Riwayati, "ANALISIS LAJU KOROSI PADA PLAT BAJA LAMBUNG KAPAL DENGAN UMPAN ANODA KORBAN ALUMINIUM," J. Ilm. Momentum, vol. 15, no. 2, Art. no. 2, Oct. 2019, doi: 10.36499/jim.v15i2.3085.
[3] F. F. F. F, "Korosi pada Beton Bertulang dan Pencegahannya," SMARTek, vol. 5, no. 3, Art. no. 3, Apr. 2012.
[4] A. Setiawan, N. E. Mayangsari, and D. Dermawan, "Pemanfaatan Ekstrak Daun Tembakau sebagai Inhibitor Korosi pada Logam Baja Karbon dan Aluminium," CHEESA Chem. Eng. Res. Artic., vol. 1, no. 2, p. 82, Dec. 2018, doi: 10.25273/cheesa.v1i2.3432.
[5] C. Z. Sibarani, L. M. Marpaung, S. Sebayang, and et al., "ANALISA KOROSI BAJA KARBON SEDANG DI LINGKUNGAN AIR LAUT," J. Teknol. Mesin UDA, vol. 3, no. 2, Art. no. 2, Dec. 2022.
[6] M. F. Sidiq, "ANALISA KOROSI DAN PENGENDALIANNYA," J. FOUNDRY, vol. 3, no. 1, Art. no. 1, 2013.
[7] N. L. Indrayani, "STUDI PENGARUH EKSTRAK ECENG GONDOK SEBAGAI INHIBITOR KOROSI UNTUK PIPA BAJA SS400 PADA LINGKUNGAN AIR," J. Ilm. Tek. MESIN, vol. 4, no. 2, pp. 47–56, Agustus 2016.
[8] M. Erna, E. Emriadi, A. Alif, and et al., "Sintesis dan Aplikasi Karboksimetil Kitosan sebagai Inhibitor Korosi pada Baja Karbon dalam Air," J. Nat. Indones., vol. 12, no. 1, p. 87, Nov. 2012, doi: 10.31258/jnat.12.1.87-92.
[9] A. D. S. Anjani, Ihsan, and Rahmaniah, "Pengaruh Inhibitor Alami Dari Biji Nangka Terhadap Laju Korosi Baja Karbon Tinggi," JFT J. Fis. Dan Ter., vol. 10, no. 1, Art. no. 1, Jun. 2023, doi: 10.24252/jft.v10i1.28548.
[10] N. Nurdjannah, B. Besar, P. Dan, and et al., "Diversifikasi Penggunaan Cengkeh. Perspektif. 3 (2): 61-70," 2004.
[11] N. Nuryoto, J. Jayanudin, and R. Hartono, "Karakterisasi Minyak Atsiri dari Limbah Daun Cengkeh," Pros. Semin. Nas. Tek. Kim. "Kejuangan" 2011, Feb. 2011, Accessed: Oct. 04, 2023. [Online]. Available: http://repository.upnyk.ac.id/336/
[12] J. Rorong, "UJI AKTIVITAS ANTIOKSIDAN DARI DAUN CENGKEH (Eugenia Carryophyllus) DENGAN METODE DPPH," Chem. Prog., vol. 1, no. 2, Art. no. 2, Dec. 2019, doi: 10.35799/cp.1.2.2008.4961.
[13] A. Mu'nisa, T. Wresdiyati, N. Kusumorini, and W. Manalu, "Aktivitas Antioksidan Ekstrak Daun Cengkeh," vol. 13, no. 3, 2012.
[14] A. Ngatin, A. F. Wulandari, A. D. Saffanah, and et al., "Pemanfaatan Ekstrak Daun Jambu Biji Sebagai Inhibitur Korosi Baja Paduan dalam Medium Larutan NaCl," Fluida, vol. 15, no. 2, Art. no. 2, Nov. 2022, doi: 10.35313/fluida.v15i2.3923.
[15] I. Amalia, "Pengaruh variasi konsentrasi ekstrak daun jambu biji (psidium guajava) dan daun cengkeh (syizigium aromaticum) sebagai inhibitor organik pada api 5 L grade b di lingkungan Nacl 3, 5% pH 4," 2016.
[16] M. G. Fontana, Corrosion engineering, 3. ed., International ed. in McGraw-Hill series in materials science and engineering. New York: McGraw-Hill, 1987.
[17] G. M. Al-Senani, S. I. Al-Saeedi, and R. Almufarij, "Green corrosion inhibitors for carbon steel by green leafy vegetables extracts in 1 M HCl," Orient. J. Chem., vol. 31, no. 4, pp. 2077–2086, Dec. 2015.
[18] B. D. Mistry, A Handbook of spectroscopic data chemistry (UV, IR, PMR, 13CNMR and mass spectroscopy), 1st ed. Jaipur: Oxford Book Co., 2009.
[19] D. S. Handayani, T. Kusumaningsih, and M. Yuli, "Synthesis of co-poly(eugenol sulfonate)-DVB from eugenol as a major component of Syzygium aromaticum oils," Biofarmasi J. Nat. Prod. Biochem., vol. 2, no. 2, pp. 53–57, Aug. 2004, doi:

10.13057/biofar/f020202.
[20] M. Tuganyita, S. Gugule, and I. D. K. Anom, "Pemisahan dan identifikasi komponen-komponen utama minyak atsiri dari daun cengkeh segar dan kering (syzygium aromaticum)," Fuller. J. Chem., vol. 4, no. 2, p. 44, Aug. 2019, doi: 10.37033/fjc.v4i2.71.
[21] G. Ji, P. Dwivedi, S. Sundaram, and et al., "Inhibitive Effect of Chlorophytum borivilianum Root Extract on Mild Steel Corrosion in HCl and H2SO4 Solutions," ACS Publications. Accessed: Oct. 06, 2023. [Online]. Available: https://pubs.acs.org/doi/epdf/10.1021/ie4008387
[22] L. A. Nnanna, V. U. Obasi, O. C. Nwadiuko, and et al., "Inhibition by Newbouldia leavis Leaf Extract of the Corrosion of Aluminium in HCl and H2SO4 Solutions," 2012.