RJC

RASĀYAN *J. Chem.*
Vol. 18 | No. 2 |1125-1129| April - June | 2025
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

AN INVESTIGATION INTO THE INHIBITORY EFFECT OF AGAVE AMERICANA EXTRACT ON MILD STEEL CORROSION IN HCL MEDIUM

S. Sulochana[1,✉], J. Sathiyabama[2], A. Sahaya Raja[2], L. Jayalakshmi[1], and R. Shanmuga Selvan[2]

[1]Research Scholar, PG and Research Department of Chemistry, Thanthai Periyar Government Arts and Science College (Autonomous), Affiliated to Bharathidasan University, Tiruchirappalli, Tamil Nadu, India

[2]PG and Research Department of Chemistry, G.T.N. Arts College (Autonomous), Dindigul-624005

[1]Associate Professor, Sethu Institute of Technology, Puloor, Kariapatti-626115

✉Corresponding author: shreekisanth@gmail.com

ABSTRACT

The corrosion inhibition effect of the ethanol extract of Agave Americana was investigated for carbon steel corrosion in HCl solution with different concentrations. The inhibition mechanism is discussed considering the thermodynamics of adsorption and kinetics of electrochemical reactions. Inhibition efficiency increases with temperature, while the activation energy for the corrosion rate decreases with the addition of Agave Americana. SEM and AFM studies confirmed the formation of a protective film on the surface of the carbon steel.

Keywords: Agave Americana, Carbon Steel, Corrosion, Inhibition, SEM and AFM.

RASĀYAN*J. Chem.*, Vol. 18, No.2, 2025

INTRODUCTION

Due to the easily accessible materials, cheap cost, straightforward process that can be carried out in any laboratory, and use of non-toxic reagents, the synthesis of metal nanoparticles using plant leaf extract has drawn the interest of numerous researchers in recent years.[1] Nanotechnology is essential to modern research. Biomedical science, pharmaceuticals, electronics, healthcare, food and feed, chemical industry, energy science, cosmetics, environmental health, mechanics, and space sectors are just a few of the businesses that can benefit from nanotechnology.[2] The copper nanoparticles are made by two processes: electrochemical reduction[4] and vapor deposition.[3](e) production at room temperature using starch and hydrazine hydrate[7], (d) reduction of copper metal salt chemically[6], and (c) thermal breakdown [5] In recent years, microbes have been used to create copper nanoparticles.[8] In many different domains, copper nanoparticles function as antibacterial agents. Copper is particularly toxic to bacteria and other microbes. The Cu nanoparticles were prepared using a variety of plant extracts, such as Hibiscus Rosasinensis[9], Ocimum santanum leaf extract[10], Syzygium aromaticum (Cloves)[11], lemon fruit extract[12], Vitis vinifira extract[13], Eucalyptus[14], Cassia alata, Centellaasiatica, and Malva sylvestris.[17]In the present study, we used an extract from Agave Americana, a plant in the Asparagaceae family, to create copper nanoparticles. We also investigated and described the corrosion inhibition characteristics of the copper nanoparticles.

Fig.-1: Agave Americana Plant from Dindigul Region

http://doi.org/10.31788/RJC.2025.1829131

EXPERIMENTAL

Preparation of Agave Americana Extract

A. Americana leaves were collected from the region of Dindigul. The fresh leaves were soaked in water to remove all residues (debris and damaged portions) and rounded into small pieces using a mortar. Five grams of grounded fresh leaves were extracted in 50 mL of H_2O (1/10: w/v). The sample was placed in the chamber using a silica crucible specially made for the Soxhlet apparatus. The heating plate was set up to 85 °C and kept for 18 hrs to take water extract of Agave Americana. Kept at room temperature in a tight plastic container. This extract was used as a corrosion inhibitor in the present study. The major constituent of the ethanol extract is Kammogein.

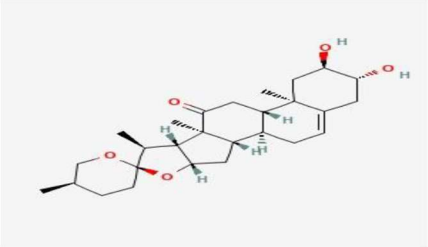

Fig.-2: Structure of Kammogein

Preparation of the Carbon Steel Specimen

Carbon steel specimens of dimensions 1.0 cm × 4.0 cm × 0.2 cm (surface area 10 cm^2)and a density of 7.87 g/cm^3 were polished to a mirror finish and degreased with acetone and used for the weight loss method and surface examination studies. A carbon steel rod encapsulated in Teflon with an exposed cross-section of 1cm^2 area was used as the working electrode in potentiodynamic polarization and AC impedance studies. The surface of the electrode was polished to a mirror finish and degreased with acetone.

Determination of Surface Area of the Specimens

The length, breadth, and thickness of carbon steel specimens were determined with the help of a Vernier caliper with a least count of 0.01mm, and the surface areas of the specimens were calculated.

Weighing the Specimens Before and After Corrosion

The weights of the specimens before and after immersion were determined using a digital balance model AUY220 SHIMADZU.

RESULTS AND DISCUSSION

High-Performance Liquid Chromatography (HPLC)

The retention time for the isolated kammogenin and gentrogenin was identical to the main peak of the standard reference, as shown in Figure. From the HPLC, the peak shows in the retaliation time 3.501 is assigned for gentrogenin and 4.963 is assigned for kammogenin both structures are confirmed by using FTIR. Kammogein IUPAC name (1R,2S,4S,5'R,6R,7S,8R,9S,12S,13R,15R,16R)-15,16-dihydroxy-5',7,9,13-tetramethylspiro[5-oxapentacyclo[10.8.0.02,9.04,8.013,18]icos-18-ene-6,2'-oxane]-10-one molecular formula C27H40O5.

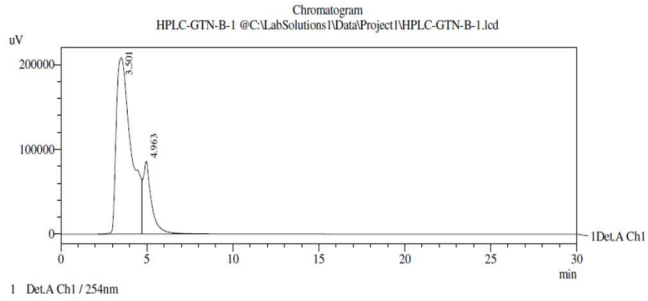

Fig.-3: HPLC for *Agave Americana* Water Extracts

Table-1: HPLC Assigned Peaks for *Agave Americana* Water Extracts

Peak#	Ret. Time	Area	Height	Area %	Height %
1	3.501	12521643	208044	81.368	70.807
2	4.963	2867289	85776	18.632	29.193
Total		15388932	293820	100.000	100.000

Fourier Transform Infrared (FTIR)

Fourier-transform infrared spectroscopy is a useful technique to differentiate various samples based on their chemical constituents (functional groups) and to determine the properties of materials. Raw fiber, NFC prepared from the Agave fibers, and commercial MCC were analyzed, and the FTIR spectra are shown in Fig.-4. The main peaks corresponding to cellulose are shown in Table-2. The confirmation of cellulose was obtained from the peaks at 3329 cm^{-1} to 3330 cm^{-1}, which corresponded to OH stretching. These OH-stretching peaks were in agreement with the previous peak values at 3300 cm^{-1} and 3400 cm^{-1}. Peak shifts of C-H symmetrical stretching were in the range of 2886 cm-1 to 2900 cm^{-1}. The FTIR peaks of C=O stretching vibrations were in the range of 1731 cm^{-1} to 1734 cm^{-1}, which confirms functional groups of pectin, hemicellulose, lignin, carboxylic groups of ferulic and p-coumaric acid, and ester groups of acetyl and uronic acid.

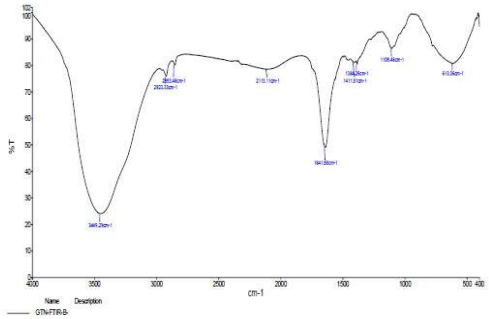

Fig.-4: FTIR of Extract

Water can be found in cellulose due to the strong interaction between them. The apparent spectral peaks at 1601 cm-1 to 1653 cm^{-1} corresponded to the OH bending of absorbed water. The peak values of C-O-C pyranose ring stretching were in the range of 1019 cm^{-1} to 1031 cm^{-1} in raw fiber, NFC, and MCC samples. These peaks' increase was due to the band intensity and crystallinity of samples. The small peaks at 663 cm^{-1} to 664 cm^{-1} in raw fiber, NFC, and MCC samples were attributed to C-OH out-of-plane bending. The present FTIR results indicated that the process conditions were successful in eliminating some of the lignin and hemicellulose during the delignification process.

Table-2: FTIR Assignment for Prepared Sample

Observed Values (Frq cm-1)	Reported Values (Frq cm-1)	Assignment
613.36	663	C-OH out-of-plane bending.
1105.46	1031	C-O-C pyranose ring stretching
1641.58	1653	OH bending of absorbed water
2853.46	2886	C-H symmetrical stretching
3449.29	3330	OH stretching peaks

Atomic Force Microscopy (AFM)

Figure-5 and 6 show the 3D topography images and surface profiles of untreated carbon steel X65 before and after contacting the solution. Before immersion, the roughness of the surface shown from the profile curve was ~ 600 nm. The surface morphology and profile measurements on the carbon-steel surface were used as "blank" values for analyzing the adsorption of inhibitor molecules. After immersion in an uninhibited aqueous solution, the steel surface shows a rough texture, indicating metal dissolution due to corrosion. The maximum roughness of the surface indicated by the surface profile curve after 6h immersion was 481 nm. The time-dependent topography and corresponding profile change of the steel surface immersed in the aqueous solution with 150 ppm vimidazolinium are presented in Fig.-5 and Fig.-

6. After 6 h immersion of 461nm in the inhibited solution, the steel surface shows only some minor roughening, indicating minimal metal dissolution due to the protection of the surface by the inhibitor. The maximum roughness of the surface indicated by the profilometry after 6 h immersion was 4 nm. It is evident from a comparison with Fig.-5 and Fig.-6 that the corroded surface is quite different when comparing the unprotected to the protected surface. The difference can be ascribed to the Methyl stearate compound in the test solution spontaneously forms a film on the steel surface.

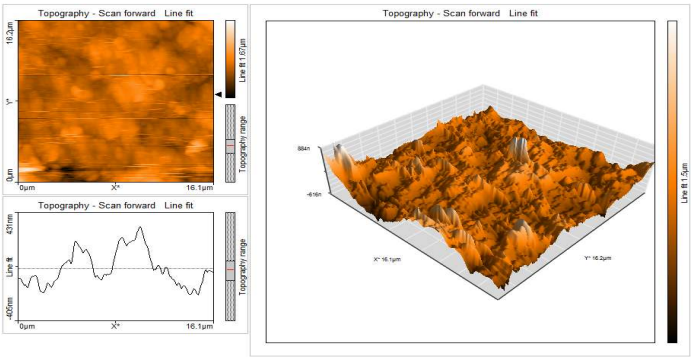

Fig.-5: AFM of Inhibit Steel

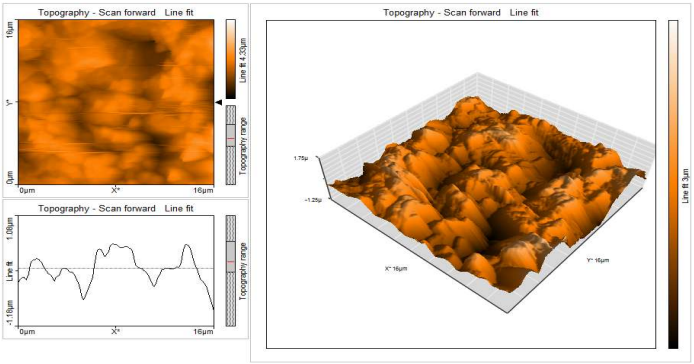

Fig.-6: AFM of Polished Steel After Inhibited

CONCLUSION

An aqueous solution of Agave Americana extract was prepared. The mild steel immersed in the prepared solution with different ppm was studied. The corrosion rate and inhibition efficiency of the Agave Americana extract were calculated. Excellent inhibitive property is shown by Agave Americana in 25 ppm and 50 ppm. It is evident from the SEM that the metal surface of mild steel is smoothed to a very large extent in the presence of the collective inhibitor system. The AC impedance spectra and polarization studies reveal that in the presence of the inhibitor system, the corrosion resistance of mild steel increases. Thus, the system of 8 ml of Agave Americana extract in a bore well water medium is the best system for corrosion protection.

ACKNOWLEDGMENTS

We thank the authorities of our institutions for providing the basic facilities of this research.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

S. Sulochana https://orcid.org/0009-0007-4432-0558
J. Sathiyabama https://orcid.org/0000-0002-3083-2436
A. Sahaya Raja https://orcid.org/0000-0002-2076-6084

L. Jayalakshmi https://orcid.org/0000-0002-9180-2062
R. Shanmuga Selvan https://orcid.org/0000-0003-3006-0883

REFERENCES

1. Rajkumar Kandhasamy, Krishnaveni Vasudevan, *International Journal of Innovative Research in Science, Engineering and Technology*, **4(3)**, 848(2015), https://doi.org/10.15680/IJIRSET.2015.0403006
2. Ganesh Khadka, Kateel G. Shetty, Thirunavukkarasu Annamalai, Yuk-Ching Tse-Dinh, Krish Jayachandran, *Letters in Applied Microbiology*, **77(3)**, ovae025(2024), https://doi.org/10.1093/lambio/ovae025
3. Binayak Raj Pandey, Angela Shrestha, Nisha Sharma, Bhupal Govinda Shrestha, *Nepal Journal of Biotechnology*, **7(1)**, 30(2019), https://doi.org/10.3126/njb.v7i1.26948
4. Tewodros Shegute, Yared Wasihun, *Journal of Experimental Pharmacology*, **12**, 447(2020), https://doi.org/10.2147/JEP.S258605
5. Karen Alejandra Olán-Jiménez, Rosa Isela Cruz-Rodríguez, Beatriz del Carmen Couder-García, Nadia Jacobo-Herrera, Nancy Ruiz-Lau1,Maritza del Carmen Hernández-Cruz and Víctor Manuel Ruíz-Valdiviezo, *Scientia Pharmaceutica*, **92(3)**, 41(2024), https://doi.org/10.3390/scipharm92030041
6. Tewodros Shegute, Yared Wasihun, *Journal of Experimental Pharmacology*, **12**, 447(2020), https://doi.org/10.2147/JEP.S258605
7. Yesmi Patricia Ahumada-Santos, Julio Montes-Avila, Magdalena de Jesús Uribe-Beltrán, , Sylvia Páz Díaz-Camacho, Gabriela López-Angulo, Rito Vega-Aviña, José Ángel López-Valenzuela, José Basilio Heredia, Francisco Delgado-Vargas, *Industrial Crops and Products*, **49**, 143(2013), https://doi.org/10.1016/j.indcrop.2013.04.050
8. Julio Cesar López-Romero, Jesús Fernando Ayala-Zavala, Etna Aida Peña-Ramos, Javier Hernández, Humberto González-Ríos, *Journal of Food Science and Technology*, **55(11)**, 4413(2018), https://doi.org/10.1007/s13197-018-3351-3
9. Ambreen Aleem, Shahla Shahnaz, Sana Javaid, Waseem Ashraf, Muhammad Fawad Rasool, Tanveer Ahmad, Abdullah F.Alotaibi, Khalid S. Albeshri, Faleh Alqahtani, *Saudi Pharmaceutical Journal*, **30(10)**,1373(2022), https://doi.org/10.1016/j.jsps.2022.06.003
10. Daniel Anokwah, Evelyn Asante-Kwatia, Abraham Y. Mensah, Cynthia Amaning Danquah, Benjamin K. Harley, Isaac Kingsley Amponsah and Lukas, *International Journal of Phytomedicine and Phytotherapy*, **7**, 28(2021), https://doi.org/10.1186/s40816-021-00266-4
11. Jasmeen Sidana, Bikram Singh, Om P. Sharma, *Phytochemistry*,**130**, 22(2016), https://doi.org/10.1016/j.phytochem.2016.06.010
12. Carlos Alberto Lecona-Guzmán, Sheila Reyes-Zambrano, Felipe Alonso Barredo-Pool, Miguel Abud-Archila, Joaquín Adolfo Montes-Molina, Reiner Rincón-Rosales, and Federico Antonio Gutierrez-Miceli, *HortScience*, **52(7)**, 996(2017), https://doi.org/10.21273/HORTSCI10498-16
13. Athmani Sameh, Abderrahmane Sihem, Benachour Fadila and Gülfeza Kardas, *Materials Research Express*, **6(1)**, 016504(2019), https://doi.org/10.1088/2053-1591/aae32c
14. Benachour Fadila, Abderrahmane Sihem, A. Sameh, Gülfeza Kardaş, *Materials Research Express,* **6(4)**, 046419(2019), https://doi.org/10.1088/2053-1591%2Faafcd7
15. Alexander M. Jones, Yadi Zhou, Michael A. Held, Sarah C. Davis, *Frontiers in Plant Science*, **11(11)**, 654(2020), https://doi.org/10.3389/fpls.2020.00654

[RJC-9131/2024]