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Investigation of Corrosion Inhibition of Carbon Steel by Using Natural Iraqi Plum Tree Gum in a Saline Medium

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Abstract

In response to the growing interest in green chemistry and the adoption of environmentally friendly and cost-effective compounds in industrial and agricultural applications, this study focuses on exploring the potential of natural compounds. Specifically, the research investigates the corrosion inhibitory properties of Iraqi plum tree gum. The natural gum is characterized using Fourier transform infrared spectroscopy to identify its functional groups and atomic force microscopy (AFM) for further analysis. The electrochemical polarization technique was used to study corrosion measurements for carbon steel (C.S) in saline solution and in the presence of the inhibitor (Plum Tree Gum) in different concentration solutions. The findings revealed a positive correlation between the concentration of plum tree gum and the efficiency of the inhibitor, indicating that higher concentrations of the gum result in increased inhibitory effectiveness.

Keywords: Plum Tree Gum, Corrosion, carbon steel, green chemistry, electrochemical polarization technique.

التحقيق في تثبيط تآكل الفولاذ الكربوني باستخدام الصمغ الطبيعي لاشجار البرقوق العراقية في وسط ملحي

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الخلاصة

استجابة للاهتمام المتزايد بالكيمياء الخضراء واعتماد مركبات صديقة للبيئة وفعالة من حيث التكلفة في التطبيقات الصناعية والزراعية ، تركز هذه الدراسة على استكشاف إمكانات المركبات الطبيعية. على وجه التحديد ، يدرس البحث الخصائص المثبطة للتآكل لصمغ شجرة البرقوق العراقي. تم استخدام صمغ شجرة البرقوق العراقي الطبيعي كمثبط للتآكل ،تم فحص المثبط باستخدام مطيافية الأشعة تحت الحمراء لتحديد

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المجموعة الوظيفية في المركب باستخدم مجهر القوة الذرية (AFM) . و تم استخدام تقنية الاستقطاب الكهروكيميائي لدراسة قياسات التآكل لصلب الكربون (C.S) في محلول ملحي وبوجود المثبط (Plum Tree Gum) في محاليل مختلفة التركيز. أظهرت النتائج وجود علاقة ارتباط طردية بين تركيز صمغ شجرة البرقوق وكفاءة المثبط ، مما يشير إلى أن التراكيز العالية للصمغ تؤدي إلى زيادة الفعالية التثبيطية.

Introduction

Corrosion, a complex phenomenon that encompasses both surface damage and mental deterioration in aggressive environments [1], involves intricate interactions of metals with their surroundings. Through chemical or electrochemical oxidation processes, metals release electrons to their environment, leading to changes in their valence from zero to positive numbers. These environments, such as gases, liquids, and soil-liquid hybrids, act as electrolytes, facilitating electron transport [2]. In various fields where metals are extensively used, corrosion poses significant challenges, prompting substantial investments in mitigating measures and materials. Among these methods, the incorporation of corrosion inhibitors [3] stands out. These chemical agents adsorb onto metal or alloy surfaces, forming protective coatings that isolate the surface from environmental reactions or diminish the attack of corrosive ions [2]. As researchers sought alternative materials, green chemistry emerged as a widely embraced approach, harnessing the potential of natural substances derived from various plant components, like roots, seeds, leaves, and stems. Additionally, incidental products resulting from plant diseases, such as glues from environmentally friendly, non-toxic trees, have gained attention and recyclability [4-17]. A numerous of natural products, ranging from honey and Lawsonia inermis to Opuntia extract, henna, guar gum, jojoba oil, apricot gum, Gum arabic, and others, have been explored in this domain. There is a lot of studies being done to control corrosion using different techniques, such as the use of natural materials and green chemistry. In this article, we delve deeper into the potential of these eco-friendly solutions and explore the effectiveness of Iraqi plum tree gum as a promising corrosion inhibitor, presenting a comprehensive analysis of its properties and implications for various applications. The bulk of effective corrosive inhibitors are heteroatom-containing compounds, such as those with oxygen, sulfur, or nitrogen atoms[18] . Gum's efficacy as an inhibitor depends on the chemical makeup and film-forming properties of the alloy [19]. Because of how effective it is in preventing corrosion, nitrogen-containing varieties of plum tree gum are commonly employed. These compounds were chosen because they: a) enormous molecular size b) contain extensive connections in the form of aromatic rings; and c) comprise functional polar groups (such as -C=O, C=N). In this investigation, carbon steel was exposed to the gum of the Iraqi plum tree as a corrosion inhibitor in a saline media made up of sodium chloride.

2. Experimental and material

2.1 Material

Natural Iraqi Plum tree gum was harvested in Babylon city farms. Electrochemical measurements were measured by advanced potentiostat winking MLab-200(2007) with all accessories and three electrodes cell. FT-IR spectra were measured using SHIMADZU FT-IR- 8400 Charles Fourier Transform Infrared Spectrophotometer, as KBr disk. AFM spectra were measured by AA3000/220V Angstrom Advanced Inc. USA at Baghdad University College of science.

2.2 Carbon steel alloy

In this captivating experimental study, circular iron-carbon alloy samples with a diameter of 1 cm underwent meticulous preparation before their performance in the static stress polarization device. Their metal surfaces were thoroughly cleansed, with the removal of oxide layers and impurities achieved through immersion in concentrated hydrochloric acid, followed by rinsing with regular water and distilled water. The samples then underwent transformative smoothing and polishing processes, encountering various grids mesh silicon carbide sheets with different levels of smoothness, ranging from grit mesh 80 to grit mesh 2000. Their surfaces radiated with anticipation and readiness for the challenges that lay ahead. A wet smoothing method was used to prevent the metal from overheating, as well as to prevent the grains from sticking to the smoothing paper on the metal surface. Table 1 contains the components of the metal alloy.

Table 1: The components of the metal alloy.

Metal	C%	Si%	Mn%	S%	P%	Cu%	Ni%	Cr%	Fe%
Carbon Steel	0.36-0.42	0.15-0.30	1.00-1.40	0.05	0.05	0.50	0.20	0.20	96.88-97.49

3. Preparing of gum samples

Once the samples were gathered from the field, an initial purification process delicately liberated them from any lingering impurities. Subsequently, they underwent a meticulous sequence of washing, drying, and grinding, transforming them into refined forms. Finally, an appropriate weight was taken from them as required in the work.

3.1 Preparing of sample solutions

The sample solution is prepared by dissolving a certain weight (25, 50, 100, 250, 500) mg of the gum in a little distilled water. The solution is transferred to a 1-liter volumetric flask and 35 gm (for prepare 3.5% saline water) of sodium chloride salt is added to it after dissolving it in distilled water, and the volume is completed with distilled water to the mark in the volumetric flask.

3.2 Electrochemical measurements

A Host computer, Mat lab (Germany, 2000), thermostat, potentiostat, magnetic stirrer and galvanostat are all components of the potentiostat configuration. The Pyrex cell has a capacity of 1 L and is made up of interior and external bowls. Three electrodes make up the electrochemical corrosion cell [20]. To calculate the potential of it in relation to the electrode reference, carbon steel is employed as the working electrode. Platinum, with a length of 10 cm, is utilized as the auxiliary electrode, and silver-silver chloride (Ag/AgCl, 3.0 M KCl), serves as the reference electrode. To get a steady-state open circuit potential (Eocp), the electrode of working was immersed in the solution of test for 15 minutes. Then, a potential range of (200) mV were carried out in electrochemical measurements. All experiments were conducted utilizing a cooling-heating system to maintain a temperature at 298 K.

4. Results and Discussion

4.1 Polarization Curves

The data in Table 2 and Figures 1-3 were used to estimate the corrosion parameters. The anodic and cathodic Tafel extrapolation in the absence and presence of the inhibitors molecules in NaCl solution yielded the corrosion potential (E_{corr}) and corrosion current density (i_{corr}). Additionally, using the Figures, the Tafel slopes of cathodic (βc) and anodic (βa) were determined. Table 2 displays the resulting data of the corrosion potential E_{corr} (mV), current density of corrosion i_{corr} (A/cm^2), Tafel slopes of cathodic and anodic βc and βa (mV/Dec), weight loss WL (g/m^2.d), penetration loss PL (mm/y), and protection efficiency PE%. The information in Table 2 demonstrates that as concentration of the inhibitors increased, the corrosion current density (i_{corr}) generally decreased. Tafel plot evidence suggests that the protection serves as anodic protection since Ecorr for C.S in the presence of the inhibitors shifts to a higher (noble) position in comparison to blank solution. In addition, both the anodic and cathodic Tafel curves were shifted to lower current densities by the inhibitor, demonstrating that plum tree gum performances as a mixed corrosion inhibitor. The inhibition efficiency (%IE) was computed using the given equation [21]:

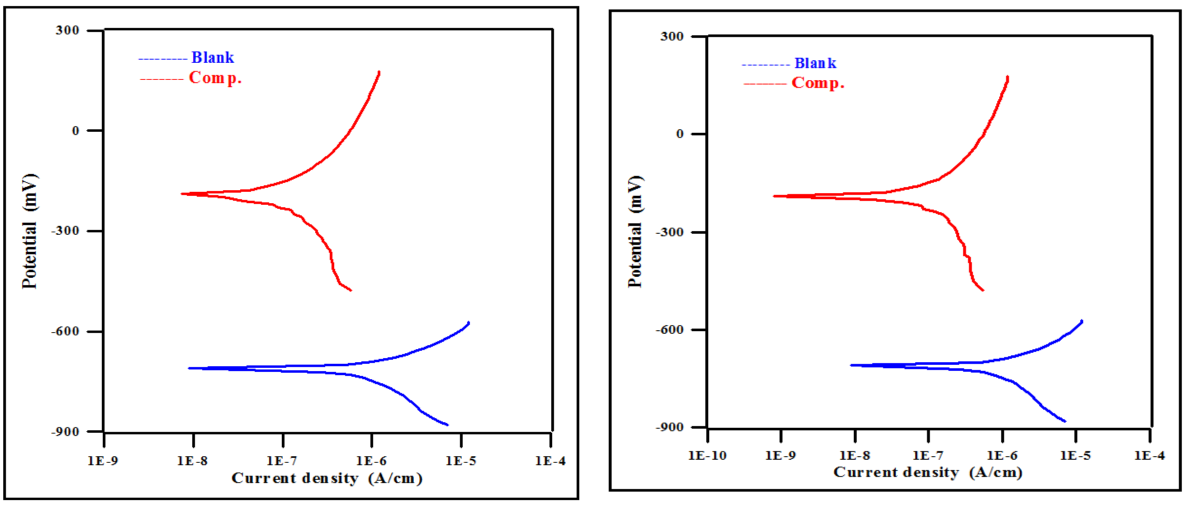
$$\%\mathbf{IE} = \frac{(\mathrm{icorr})o-(\mathrm{icorr})}{(\mathrm{icorr})o} * 100 \quad (1)$$

Where $(icorr)_o$ is the corrosion current density without inhibitors and (icorr) is the corrosion current density.

In the captivating world of corrosion inhibition, the enigmatic corrosion current density (icorr) intertwines with the presence of inhibitors, where the gum takes on a formidable role. Its potency lies in the allure of carbonyl and imide groups, complemented by a captivating array of heterogeneous rings. As the gum's mystique deepens with the charm of oxygen and nitrogen, intricate metal complexes, especially with iron, delicately drape the alloy's surface, providing steadfast protection against corrosive forces [1,4,21]. A mesmerizing revelation awaits in Table 2, where the gum's inhibition efficiency astoundingly reaches 94% even at a mere 25 ppm concentration, exemplifying its profound safeguarding prowess for carbon steel in saline environments. As concentration escalates, the inhibitor's grandeur remains unwavering, defying all odds and weaving an unbroken thread of mastery over the corrosion inhibition mechanism.

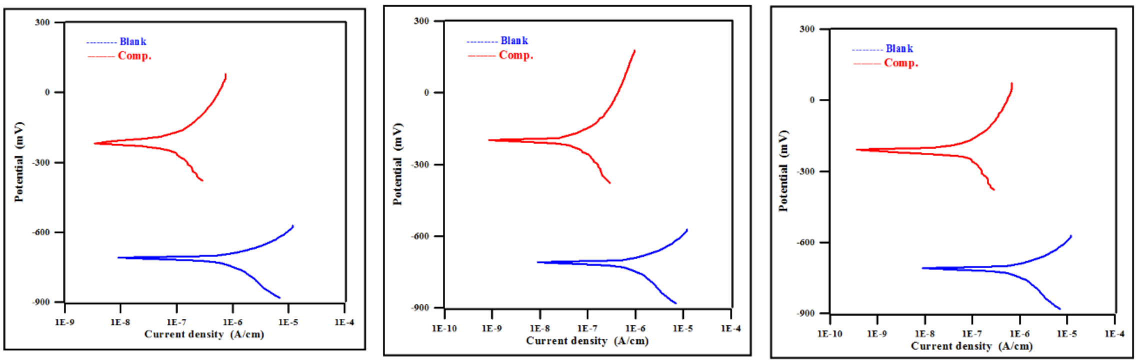
Table 2: Corrosion parameters for (C.S) solutions including blanks and inhibitors at 298 K

Inhibitor conc. (ppm)	-Ecorr (mV)	icorr (A/cm^2) *10^{-6}	-βc (mV/Dec)	βa (mV/Dec)	WL (g/m^2.d)	PL (mm /y)	inhibition efficiency IE%
blank	-711.1	674.35	-157.1	79.3	169	7.83	-
25	-194.0	38.51	-108.7	106.9	9.63	.0447	94
50	-186.7	28.16	-82.2	72.9	7.04	.0327	95
100	-218.4	21.72	-73.1	73.9	5.43	.0252	96
250	-200.6	17.47	-66.7	66.3	4.37	.0203	97
500	-211.0	13.77	-55.4	56.7	3.44	.0160	97



a b

Figure 1: a) Polarization curves of corrosion of blank and inhibitor (25 ppm) in 3.5% NaCl solution at different temperatures. b) Polarization curves of corrosion of blank and inhibitor (50 ppm) in 3.5% NaCl solution.



a **b** **c**

Figure 2: a) Polarization curves for corrosion of blank and inhibitor (100 ppm) in 3.5% NaCl solution.b) Polarization curves for corrosion of blank and inhibitor (250 ppm) in 3.5% NaCl solution. c) Polarization curves for corrosion of blank and inhibitor (500 ppm) in 3.5% NaCl solution.

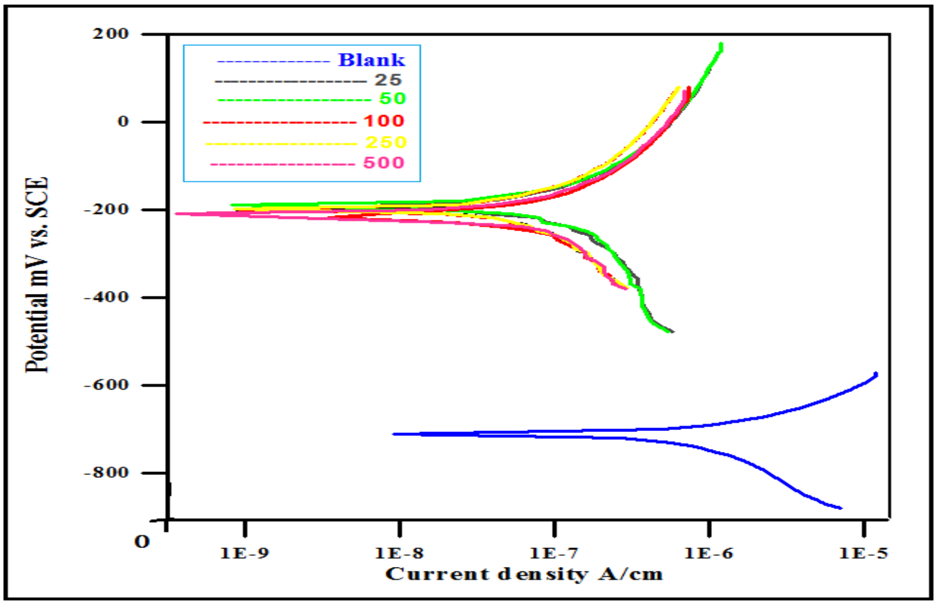


Figure 3: Polarization curves for corrosion of blank and all inhibitor concentrations in 3.5% NaCl.

4.2 Fourier Transform Infrared (FTIR) Spectroscopy

Figure (4) shows the FTIR chart for the natural plum tree gum, this Figure appeared mains absorption bands at 1066, 1620, 1645, 2927, 3377 cm^{-1} due to the main groups' presence in gum are stretching vibrations of C-O bond, stretching vibration of C=O of the group of carboxylate, stretching vibration of C-H and stretching vibration of O-H groups respectively.

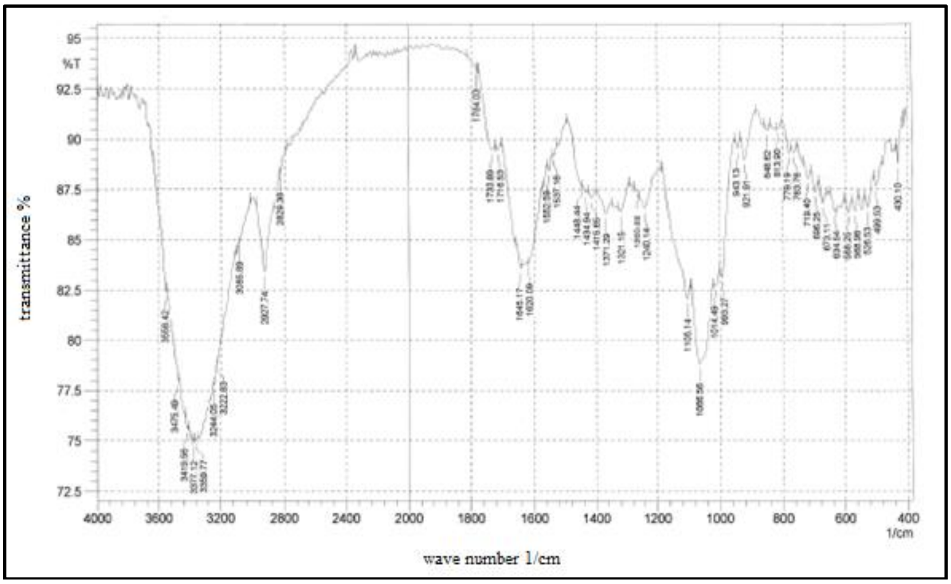


Figure 4: FTIR chart of natural Iraqi Plum tree gum

4.3 Atomic force microscope

Figure (5) A, B shows two-dimensional as well as a three-dimensional image of the surface of carbon steel without inhibitor and with gum inhibitor with the atomic force device.

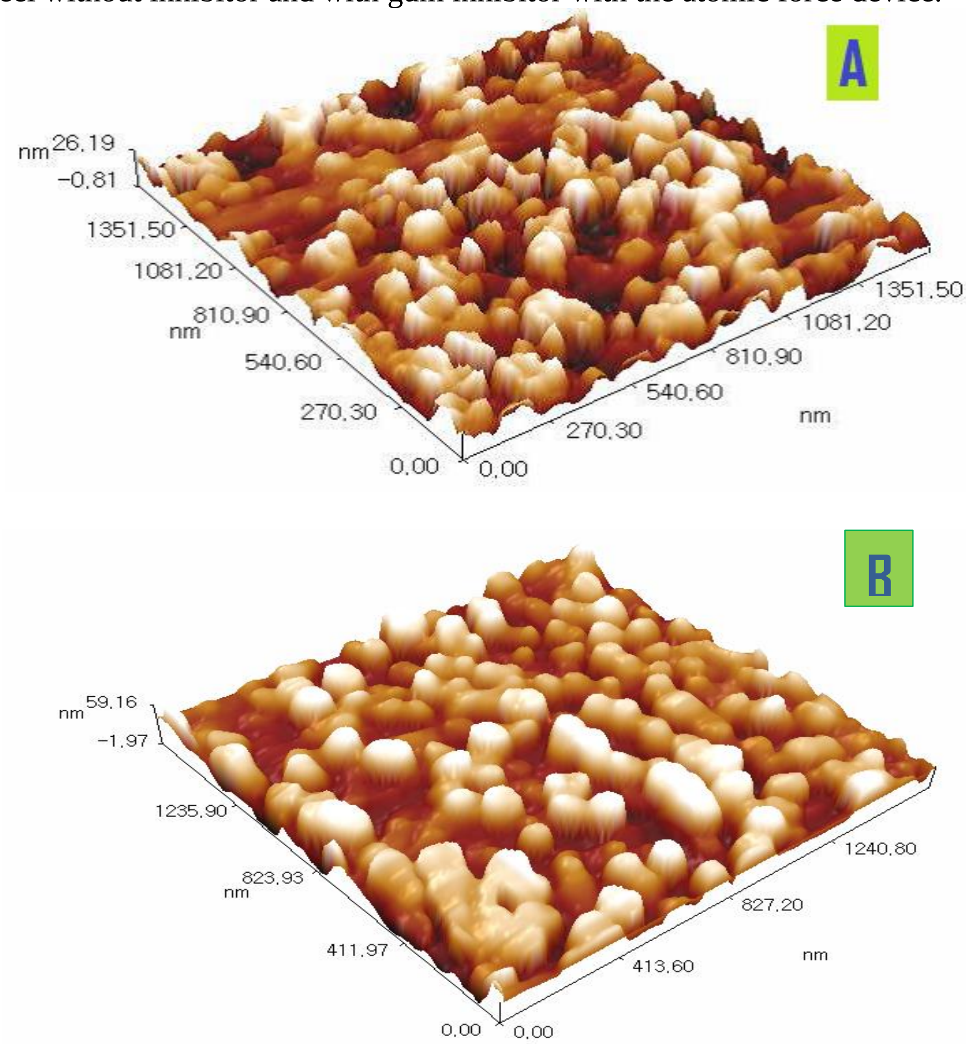


Figure 5: Image of the surface of gum with the atomic force device.

Table 3:

Avg. Diameter:93.00 nm %10=>Diameter:60.00 nm <=50% Diameter:95.00 nm <=90% Diameter:115.00 nm								
Diameter (nm)<	**Volume (%)**	**Accumulation (%)**	**Diameter (nm)<**	**Volume (%)**	**Accumulation (%)**	**Diameter (nm)<**	**Volume (%)**	**Accumulation (%)**
35.00	0.62	0.62	75.00	6.17	19.75			
45.00	0.62	1.23	80.00	6.79	26.54	110.00	14.20	80.86
50.00	2.47	3.70	85.00	4.32	30.86	115.00	6.79	87.65
55.00	1.23	4.94	90.00	7.41	38.27	120.00	5.56	93.21
60.00	0.62	5.56	95.00	9.26	47.53	125.00	6.17	99.38
65.00	5.56	11.11	100.00	10.49	58.02	130.00	0.62	100.00
70.00	2.47	13.58	105.00	8.64	66.67			

The images depicted in Figure 5 served to strengthen the findings derived from the electrochemical polarization technique. Notably, the surface morphology in the absence of gum, observed in 3.5% NaCl (Figure-5-A), displayed a notably rough terrain, characterized by deep valleys. However, a fascinating transformation unfolded with the introduction of gum as an inhibitor. The roughness seemed to adopt a gentler demeanor, hinting at the formation of intricate complexes between iron cations and heteroatoms (e.g., N and O) that artfully adorned the alloy's surface (Figure 5-B). As shown in Table 3, gum has a variety of molecular sizes, which makes it a potential inhibitor [22].

Conclusions

In this study, Iraqi plum tree gum was utilized as a green corrosion inhibitor, and the results showed that as the concentration of gum increased, the corrosion current density of carbon steel decreased. The highest level of inhibition efficiency, reaching 97%, was observed at higher concentrations of the gum. The gum exhibited high inhibitor efficiency due to the presence of specific chemical groups, such as carbonyl and imide groups, along with heterogeneous rings, oxygen, and nitrogen. These compounds formed a complex with iron metal, which adsorbed on the alloy's surface, providing protection against corrosive environments.

“This article does not contain any studies involving animals performed by any of the authors.”
“Conflict of Interest: The authors declare that they have no conflicts of interest.

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