



Article Info

Received: 13th March 2024Revised: 18th July 2024Accepted: 26th July 2024

Department of Chemistry, Sokoto State University, Birnin Kebbi Road, Sokoto, Nigeria

*Corresponding author's email:

abdulrashidgarba2012@gmail.comCite this: *CaJoST*, 2024, 2, 170-174

Corrosion Inhibition of Mild Steel using Bee Pollen as inhibitor in acidic medium

Abdulrashid A. Garba, Sirajo Muhammad and Shamshudeen A. Ahmad

The inhibitive action of bee pollen on corrosion of mild steel in two different acid media (HCl and H₂SO₄) was investigated using weight loss gravimetric method. By obtaining the mild steel, which were cut and sized into 2-2 cm² coupons, the coupons were grouped into three groups A, B and C. The weight of the coupons was measured before and after immersion into acid solutions. Effect of inhibitor, time and temperature on different acid concentration was also investigated. Scanning electron microscope (SEM) and Fourier-transform infrared spectroscopy (FTIR) were employed to analyse the inhibition of bee pollen on mild steel. The study reveals that the percentage inhibition efficiency (%IE) is enhanced with decreased in corrosion rate as well as increase in volume of bee pollen. High inhibition efficiency of 90.9% was attained.

Keywords: Corrosion; Mild steel; HCl; H₂SO₄; coupons; SEM.

1. Introduction

Corrosion is the primary means by which metals deteriorate. Corrosion introduces itself into many parts of our lives [1]. The great majority of us have personal feeling for the importance of corrosion. Far too many have cringed at the emergence of rust holes in the body panels of relatively new automobiles [2]. The outdoor rusting of steel, household and garden appliances is a common fact of life. All have seen the strains on cooking utensils from hot foods or experienced the metallic taste in acid foods stored too long on open cans. That these effects are caused by corrosion is well known [6]. However, corrosion is just as common in other material classes such as ceramics, plastics and rubber. Since, practically all environments are corrosive to some degree and are major contributing causes of material failure and also are a large economic cost to the society [1]. Bee products were identified as efficient green inhibitors of corrosion in aluminum and its alloys. The anticorrosive properties of natural honey applied to Al-Mg-Si alloy in seawater. The SEM analysis confirmed the presence of a thin layer of corrosion inhibitor on the surface of the protected alloy, which in effect decreased the overall rate of corrosion. Similar studies were reported by [7]. Application of corrosion inhibitors is regarded as very practical and most economical way to mitigate corrosion. These inhibitors reduce the corrosion rate by adsorption behavior at metal/

solution interface. Presence of hetero atoms (N, S, P and O), unsaturated bonds and planarity are major requirements of the inhibitors to protect the metal surface from corrosion [8]. Ionic liquids get their significance due to the presence of both organic and inorganic (anisotropy) functional groups in their structures which assist adsorption on to metal surfaces [3]. This research is aimed at investigating the corrosion behaviour of mild steel in hydrochloric acid and Sulphuric Acid (HCl and H₂SO₄) Using Bee Pollen as inhibitors. In this research, we also assessed anti-corrosive properties of bee pollen extract (BPE) towards mild steel in an acidic environment. Bee pollen (BP), which is a natural product from beehives, has a complex composition with known antioxidant properties. FTIR and SEM was used to characterized Bee pollen, the bee pollen contains complex components such as phenolic and aromatic compounds, which are known to provide excellent corrosion inhibition and have been used in green corrosion inhibitors in the past [15].

2. Materials and Methods

2.1 Sample collection

Mild steel was purchased from Sokoto state market (KARA MARKET).

2.2 Sample pre-treatment

The metal was first cut into 2-2 cm² coupons and pretreated by polishing with emery paper, and cleaning with clean cloth. The coupons were named A, B and C and washed first with tap water, then distilled water, and finally washed with acetone in order to degrease them. The coupon was then completely air dried, and weighed on an analytical balance separately. The weight of the Coupons was noted, and they were dipped into test solutions of H₂SO₄ and HCl separately. At 30 minutes interval, the Coupon was removed from the test solutions and first washed with tap water. This was followed by washing in distilled water, cleaning with fine cloth, washing again with distilled water, and further washing with acetone. The Coupons were finally weighed on an analytical balance, and the differences in weights at each interval were noted [21].

2.3 Scanning Electron Microscope (SEM)

SEM was used to investigate the inhibition of bee pollen on the corroded site caused by acid. The Morphology of the Coupons was determined by SEM recorded using LEICA stereo scan - 440 interfaced with Phoenix proxy EDX. Images were recorded at 10kV. Each of the sample coupons was placed on the carbon tape mounted on the SEM stub [17].

2.4 Fourier transform infrared spectroscopy

The FT-IR spectroscopic analysis of Bee Pollen was carried out at a Centre for advance science Laboratory Complex (Caslac), Usmanu Danfodiyo University, Sokoto using Agilent technologies FT-IR spectrometer. The spectrum was obtained in the range of 1000-3500 cm⁻¹ at a resolution of 4cm⁻¹. A sample was drop on a thin film positioned in the standard sample

compartment of the FT-IR and the spectral data was obtained [16].

2.5 Weight loss measurement (chemical method)

Weight loss measurement was performed by weighing the Coupons before and after immersion in a 100 ml of 0.2 M of H₂SO₄ and HCl acid solution in absence and presence of inhibitor. The same procedure was repeated for different volume (0.2 ml, 0.4 ml and 0.6 ml) of Bee Pollen at temperature (305K) of the test solution. Replicate experiments were carried out in each case and the mean values of the weight loss was recorded. The corrosion rate (CR) was determined using the equation below:

$$CR = \frac{\Delta w}{A \times t} \dots\dots\dots 2.0 \quad [19]$$

Where CR is corrosion rate, t is time taken (hours), Δw is change in weight, A is coupon area

The percentage inhibition efficiency (%IE) was calculated using the equation below:

$$\%IE = \frac{(V_o - V_1)}{V_o} \times 100 \dots\dots\dots 2.7 \quad [20]$$

Where V_o = is corrosion rate without inhibitor

V₁ = corrosion rate with the addition of inhibitor

3. Results and Discussion

In order to notice the inhibition behavior of bee pollen and to obtain preliminary information about how it can influence the mild steel, the corrosion rate, inhibition efficiency and surface coverage were recorded in the tables below with different coupons weight on mild steel in acid solutions without and with bee pollen concentrations used in experimental studies. Figs. 1,2,3 and four shows the SEM Images and FTIR analysis on the mild steel coupons respectively.

Table1: Corrosion Rate, Inhibition Efficiency and Surface coverage of Coupons A1, A2 and A3 at Temperature (318K) and Time (60hr)

Solution	Coupons	BPV. (ml)	R _{cor} (gcm ² /m)	IE (%)	Θ
H ₂ SO ₄	A ₁	0.2	1.91	42.3	0.42
	A ₂	0.4	0.72	78.3	0.78
	A ₃	0.6	0.30	90.9	0.91
HCl	A ₁	0.2	1.72	39.8	0.39
	A ₂	0.4	0.88	64.9	0.64
	A ₃	0.6	0.28	71.4	0.71

Table 2: Corrosion Rate, Inhibition Efficiency and Surface coverage of Copouns B1, B2 and B3 at Temperature (305k) and Time (60hrs)

Solution	Coupon	BPV. (ml)	R _{corr} (gcm ² /m)	IE (%)	θ
H ₂ SO ₄	B ₁	0.2	0.30	67.9	0.679
	B ₂	0.4	0.20	70.8	0.708
	B ₃	0.6	0.10	77.7	0.777
HCl	B ₁	0.2	1.25	70.8	0.708
	B ₂	0.4	1.20	73.8	0.738
	B ₃	0.6	0.12	76.8	0.768

Table 3: Corrosion Rate, Inhibition Efficiency and Surface coverage of Coupons C1, C2 and C3 at Temperature (305k) and Time (60hrs)

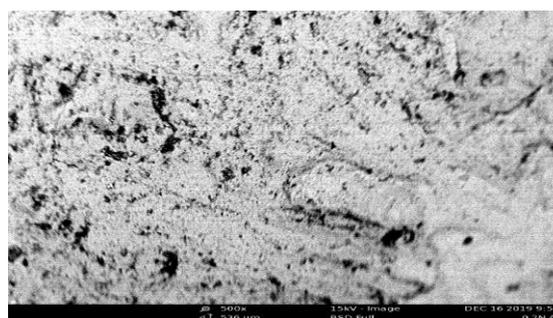
Solution	Coupons	BP conc. (ml)	R _{cor} (gcm ² /m)	IE (%)	θ
H ₂ SO ₄	C ₁	0.2	0.30	67.9	0.679
	C ₂	0.4	0.20	70.8	0.708
	C ₃	0.6	0.10	81.4	0.814
HCl	C ₁	0.2	4.30	73.1	0.731
	C ₂	0.4	4.10	76.6	0.766
	C ₃	0.6	2.30	78.4	0.784

Where PBV, R_{corr}, IE and θ are pollen bee volume, corrosion rate, inhibition efficiency and surface coverage respectively.

From the results presented in Table 1, 2 and 3, it can be seen that corrosion rate is decreasing by increasing the volume of bee pollen added in mixture solution of acid containing the coupons, maximum inhibition efficiency values of 78.4%, 76.8% and 76.5% in HCl and 90.9%, 81.4% and 77.7% in H₂SO₄ solutions were obtained as the highest inhibition efficiency for 0.6ml bee pollen added in acid solution. In acid solution without Bee Pollen, on the coupons surface, a protective layer based on corrosion products is formed, which provides a partial anticorrosive protection

The presence of bee pollen can be

attributed to its adsorption on the metal surface blocking thus the active sites where acid can attack to cause corrosion[18]..

**Fig 1:** SEM image of coupon A₃

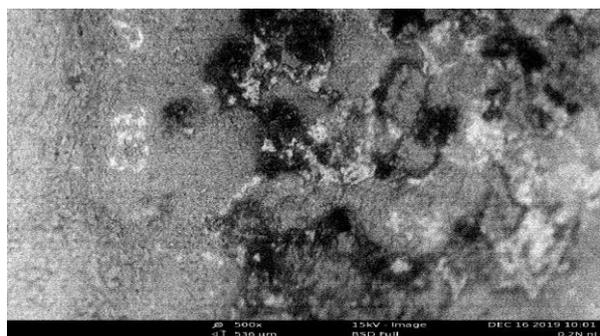


Fig 2: SEM image of coupon B₃

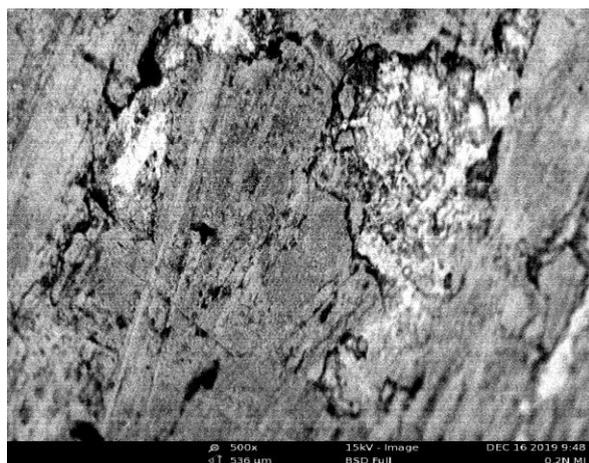


Fig 3: SEM micrograph for Coupon C₃

Fig 1 shows the SEM image of coupon A after 60hr immersion in 0.2M H₂SO₄ in the absence and presence of 0.6ml of bee pollen. Smooth line grooves are visible due to the mechanical polishing and grinding of mild steel coupons. Corrosion is much reduced in the inhibited coupon A. Highly corroded particles are noticed in Fig 2 with covering on the entire surface due to the corrosive action of HCl with metal surface. Fig 3 shows that the H₂SO₄ content are high due to the formation of corrosion product with the metal.

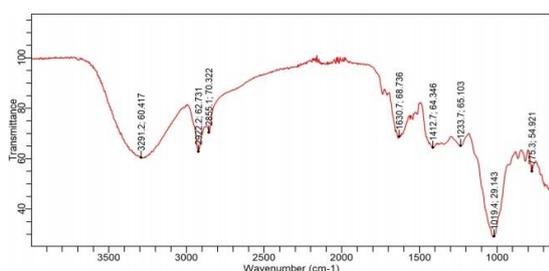


Fig. 4: Bee Pollen FTIR Spectrum

A characteristic FTIR- spectrum of bee pollen is presented in Fig. 4 above. A typical FTIR-

spectrum of bee pollen is characterized by the broad absorption observed in the spectral range from 3500 to 3000 cm⁻¹ with an absorption maximum at 3291 cm⁻¹, which can be assigned to both N–H stretching vibrations of the protein structure [11,12], and O–H stretching vibrations of carbohydrates (primarily glucose, fructose, and sucrose) and water. Two IR absorptions, the medium intensity absorption band observed at 2922 cm⁻¹ and the weaker one at 2855 cm⁻¹, correspond to C–H stretching (aliphatic C–H groups) and can be described as non-specific IR signals given that they may be related to the molecular vibrations of numerous bee pollen constituents, such as lipids, fatty acids, carbohydrates, cellulose, and other long-chain structures [14,19].

4. Conclusion

The inhibitive efficiency of Bee Pollen was determined through various electrochemical and non-electrochemical techniques on mild steel in 0.2 M HCl and H₂SO₄. It was observed that Bee Pollen exhibit better inhibition for mild steel corrosion in 0.2 M HCl and H₂SO₄. Furthermore, inhibition efficiency increased with increasing in the volume of inhibitor, and maximum efficiency of 90.9% was attained at 0.6 ml of bee pollen.

Conflict of interest

The authors herein declare that there is no conflict of interest of any sort as regards the publishing of this manuscript

Acknowledgements

The authors would like to use this opportunity to appreciate Sokoto State University for lab facilities to carry out this research and TETFund institution-based research for financial fund to carry out the research.

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