Original Research Article

Sterilized Chicken Feather as Eco-friendly Corrosion Inhibitor for Mild Steel in a Water-Based Drilling Mud – Gravimetric and FTIR assessment

ABSTRACT

This research evaluated the corrosion performance of mild steel in sterilized and unsterilized alkaline mud corroding systems using chicken feather powder (CFP) obtained through the usual hydrolysis and acid neutralization protocol. Insightfully, gravimetric analysis revealed that bacterial infestation of the unsterilized environment caused its corrosion performance to be lower at 10.3% while the sterilized counterpart stood at 49 % at 92 days of exposure to the environments respectively. The functional groups, C=N, O=C=O, H-C=O etc, revealed by FTIR to be present in the protein saturated feather were overwhelmed by microbial activities rendering them inactive to perform as inhibitors.

Keywords: Chicken feather, mild steel, weight loss, FTIR, Corrosion inhibitor.

1. INTRODUCTION

A great amount of the failures and losses of facilities in industries, most especially the oil and gas industry are due to corrosion processes (Harsimran et al., 2021). Chemical inhibitors have become effective in controlling economic wastage brought about by the effect of corrosion on metals which have manifested on their inabilities to support designed load requirement. These chemical inhibitors have negative environmental and social consequences; however, in view of protecting our environment and reducing cost, the use of green inhibitors have become inevitably recommended as substitutes for these chemical inhibitors.

Plant extracts have been classified as green corrosion inhibitors (Oki et al., 2019). They are biodegradable and contain no heavy metals or other harmful compounds. Many research groups have recorded successes in the use of plant extracts to mitigate the corrosion of metals in acidic and alkaline media (Olawale et al., 2018; Adekunle et al., 2020, Oki et al., 2020; Odusote et al., 2020; Edoziuno et al., 2020). Aluminum corrosion in hydrochloric acid solutions was reduced by *Delonix regia* extracts (Abiola et al., 2017), and the impact of *Opuntia* extract on aluminum has also been studied. On mild steel, an ethanolic extract of African bush pepper *(Piper guinensis)* was used to reduce the rate of corrosion (Yerinmearede et al., 2020). The leaf extract of *Plukenetia conophora* was used to inhibit corrosion of Al-Zn-Cu alloy in two different acidic media. The study observed a direct proportion of the concentration of the leaves' extract and the inhibition efficiency to increase. Hence, the extract showed good corrosion inhibition characteristics due to the extracts' adhesion on the surface of the substrates (Odusote et al., 2020). Almond leaves extract was evaluated to inhibit corrosion rate on aluminium. The corrosion rate was ameliorated when the substrate was immersed in the HCl medium (Olawale et al., 2018). Adekunle et al. (2020) investigated and compared the inhibition effects of extracts from two different leaves of *Cascabela thevetia* and *Jatropha curcas* on mild steel in H_2SO_4 solution. Both extracts showed good corrosion inhibition and were recommended for utilization to replace toxic chemical inhibitor used in industries. Apart from the fact that these plant extracts are feedstock for microorganisms, plant scientists are of the view that if plant materials are continuously used as corrosion inhibitors, the various plants will slowly become extinct. More so, plants and its wastes have been researched on for renewable energy utilization (Adeleke et al., 2022, Balogun et al., 2022). Hence, making the utilization of plant materials as not sustainable for corrosion inhibition.

Valorization of chicken feather has received major interests in recent times because of disposal of this patently obnoxious environmental pollutant. (Akintola et al. 2019).

Anadebe et al. (2019) and Stefania et al. (2019) have used Chicken feathers and amino acids as corrosion inhibitors respectively.

In the current research, rice husk which forms about 25% of wastes from paddy milling was valorized for use as a corrosion inhibitor for Al 6061 in hydrochloric acid. Ikubanni P. et al. (2024)

As far as we know, much work has not been done on the use of chicken feather as corrosion inhibitor. This research work is aimed at analyzing the inhibitive performance of hydrolyzed chicken feather (an agricultural waste) towards the corrosion of mild steel and standard corrosion coupons in corrosive environment. Therefore, the use of these waste materials fills the space of plant slowly going to extinction.

2. Materials and Methods

2.1 Test Environment

The corrosive medium employed in this investigation was mud, which pH ranged from 8.0 to 9.0, i.e. alkaline in nature. 22 g of bentonite clay was weighed separately into sixteen different labeled containers. 350 ml of distilled water was added to each of the weighed clay. Additives (barite (5 g); soda ash (0.2 g); NaCl (0.335 g)) were added to all the samples before the addition of different concentration of inhibitors.

2.2 Preparation of Hydrolyzed Chicken Feather

Feathers were washed using deionized water, after which it was dried. The dried feathers were thereafter cut into smaller pieces and then ground with the aid of mechanical blender. This material with 1 mm diameter was termed as powdered feather. Hydrolysis and neutralization followed using the protocol established by Taskin et al. (2016).

Functional groups in the hydrolyzed chicken feather were determined with a Shimadzu Fourier transform infrared (FTIR) spectrophotometer. Readings were obtained between 4000 and 400 cm^{-1}.

In addition, the corrosion product from specimens immersed in inhibited drilling mud was further analyzed with FTIR to ascertain the mode and extent of interaction between the inhibitor and the mild steel substrate.

2.3 Weight loss measurements

Rectangular specimens of mild steel employed in this study with dimensions of 78 mm x 25 mm and 9 mm were abraded with hand files and grit emery sheets of various grades. The mild steel specimens were rinsed with distilled water, degreased with acetone and methanol, dried at room temperature and weighed.

The conventional weight loss measurement involved weighing the test samples before immersion into corrosive environment and re-weighed after duration of pre-determined exposure periods. The same sample is re-immersed for the next duration of test period. The test period in this work was 92 days at 7 days interval. The weight loss experiment was conducted in accordance to ASTM G 1-03 standard. From the weight loss data, determination of the corrosion rate and the inhibitor efficiency was estimated.

Corrosion rate and inhibitor efficiency were evaluated with Equations (1) and (2), respectively:

$$mpy = 22300 \times \left(\frac{W}{A\rho T}\right) \quad (1)$$

Where mpy is corrosion rate (milli-inches per year penetration), A is area of specimen (in^2), ρ is metal density of specimen (g/cm^3), W is Weight Loss (g), T is time of exposure in corrosive environment (days).

$$IE\ (\%) = \frac{CR_{cont} - CR_{inh}}{CR_{cont}} \times 100 \quad (2)$$

Where IE (%) is the percentage inhibition efficiency, CR_{cont} is the corrosion rate of sample in the control experiment, and CR_{inh} is the corrosion rate of sample in the presence of inhibitor.

3. RESULTS AND DISCUSSION

The FTIR spectra for the sample of hydrolyzed chicken feather and that of the corrosion product are displayed in Figures 1 and 2, respectively. Also, Table 1 describes the various functional groups identifiable from the spectra.

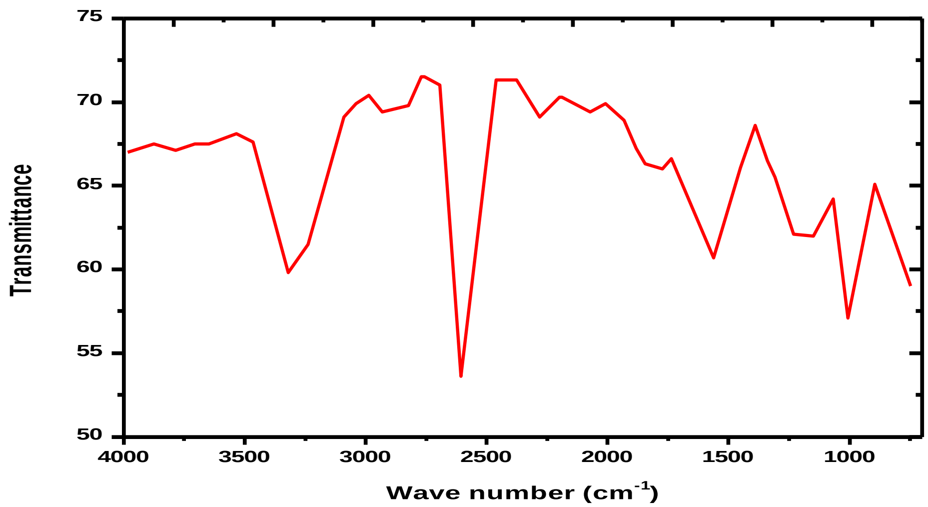

Fig. 1: FTIR spectrum of hydrolyzed chicken feather powder

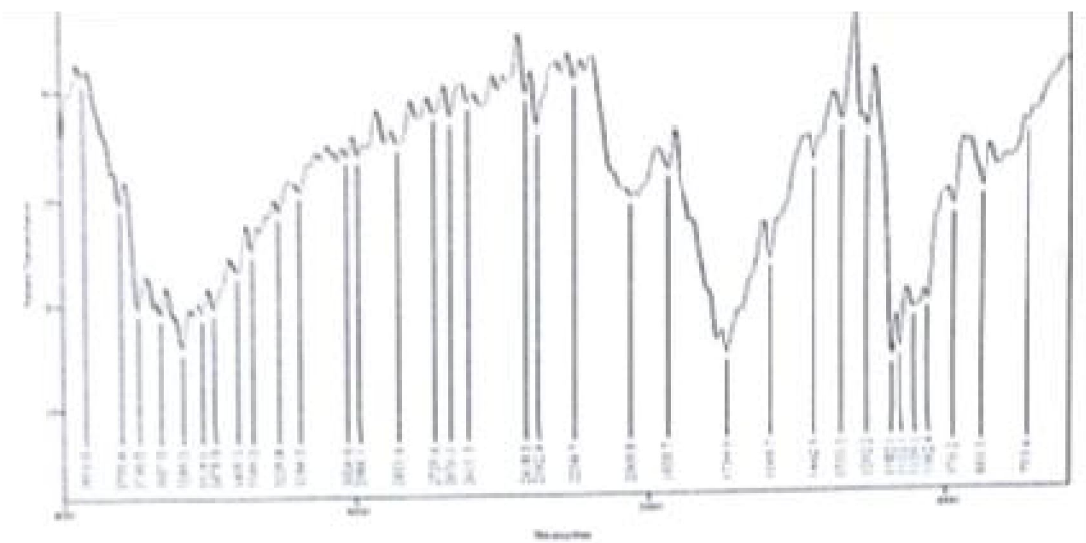

Fig. 2: FTIR spectrum of the corrosion product of specimens immersed in drilling mud with inhibitor

There are several peaks in the hydrolyzed chicken feather (HCF) and one peak was missing in the corrosion product. However, some new peaks appeared in the corrosion products which were missing in the HCF. These were suppressed in one manner or the other in the hydrolyzed extract but never the less became prominent in the corrosion products as a result of interaction with the metal, resulting in formation of stronger bonds

Table 1: The various functional groups identifiable from chicken feather.

S/N	Peaks from FTIR spectra, (cm^{-1})		Possible Groups
	HCF	Corrosion product	
1	3320.3	3349 and 3518.1	OH_{str} intermolecular bonded (phenol)
2	3041.7	3024.6 and 3259.8	C-H_{str} Alkene
	2988.1	2988.1	C-H_{str} Alkene
3	2823.1 and 2771.0	2729.6	C-H_{str}Aldehyde
4	---------------	2254.7	C≡N Nitriles
5	---------------	2382.4	O=C=O Carbon dioxide
6	---------------	2063.8	C≡C Acetylenes
7	1774.4	--------	C=O_{str}Vinyl
8	1736.0	1734.9	C=O_{str} Aldehyde
9	1559.9 and 1230.1	1558.7	N-O_{str}Aliphatic
10	---------------	1351.0	-NO_2 Nitro
11	1149.8	1152.1	C-O_{str}Alcohol
12	1006.1	1062.4	C-H Alkene out of plane

Identified functional groups of hydrolyzed chicken feather are for: phenol, alcohol, aliphatic, aldehyde and amines. Most of these functional groups appeared in the corrosion products but with shifts in wave numbers. For example, OH functional groups that are at 3320.3cm^{-1} in HCF shifted to 3519.8cm^{-1} in corrosion products. C-H aldehyde shifted from 2771.0 cm^{-1} (HCF) to 2729.6 cm^{-1} (corrosion product), whereas C=O shifted from 1736 cm^{-1} (HCF) to 1734.9cm^{-1} (corrosion product). New peaks appear at frequencies of 1351.0, 2063, 2254.7, 2382.4 cm^{-1} in the corrosion product that represent NO_2 (Nitro), C≡C (Acetylenes), C≡N (Nitriles), and O=C=O (carbon dioxide), respectively; which were absent in the HCF. Also, a peak at 1774.4 cm^{-1} (C=O_{str}Vinyl) present HCF which does not appear in the corrosion product may indicate that such functional group was consumed during hydrolyzation reactions. These results indicate that there had been interactions and formation of chemical bonds between the mild steel surface and the hydrolyzed chicken feather. The notable peaks in the HCF varied in value after interactions with the substrate obtained from the corrosion product. This implied that lone pairs of electrons have been transferred between the substrate's surface and the HCF (Akintola et al., 2019). Partially suppressed functional groups in the HCF showed prominent adsorption with electron-rich centres of the Fe mild steel substate. Hence, this is an indication of shorter bond lengths with stronger bonds considering the peaks.

3.1 Corrosion Rate and Inhibition Efficiency

From experimental observations, it was revealed that the efficiency of the hydrolyzed chicken feather as corrosion inhibitor was minimal. Moreover, in some isolated cases, increase in the rate of corrosion of test specimen was observed over a long exposure period. The system was infested by microbes. This goes to ascertain the proposition of Oki et al. (2017) that biodegradable inhibitors may not be adequate or sustainable as corrosion inhibitor because of their biodegradability. These inhibitors should be mixed with eco-friendly inorganic inhibitors and/or safe organics to enhance their performances.

Thus, on addition of 0.5 ml formalin to the corroding system, there was marked improvement in the efficiency of the inhibitor at a concentration of 0.3g. Efficiency obtained after 92 days of exposure without formalin was 10.03% as against approximately 49% on addition of formalin to the corroding system in the current investigation. The result from the calculations of corrosion rates and inhibitor efficiencies from equations 1 and 2 are shown in table 2 and 3, respectively.

Table 2: Mild steel samples in different concentrations

Inhibitor concentration(g)	Corrosion rate (mpy)	Inhibitor Efficiency (%)
Blank	1.724388	
0.3	1.551364	10.03
0.5	2.671302	----
0.8	2.686446	-----

Table 3: Mild steel samples in different concentrations of inhibitor with formalin

Inhibitor concentration(g)	Corrosion rate (mpy)	Inhibitor Efficiency (%)
Blank	1.455963	
0.3	0.747405	48.67
0.5	1.361074	6.52
0.8	1.387046	4.73

4. CONCLUSION

The primary goal of this study is to examine the corrosion inhibition efficiency of hydrolyzed chicken feather. The experimental results from the study gave the following outcomes:

- Chicken feather powder at concentrations above certain level became easily infested with microbes which enhanced corrosion rate of mild steel.
- The introduction of formalin as sterilizer, helped to mitigate the adverse effect of bacteria on the corrosion rate of mild steel in the corroding system.
- The corrosion inhibition effect of hydrolyzed chicken feather was enhanced on addition of formalin to the corroding system.
- The FTIR result actually indicate proper interactions between the inhibitor and the metal surface.

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