# Synthesis of Extract from Waste Banana Peels, Coating of the Extract on Copper by Drop Casting, and Examination of Corrosion Behavior of Coated Copper Substrates in Saline Water

Pranjal Dixit[1], Anuj Kumar Sharma[1*], Siddharth Yadav[1], Gopal Ji[2*], Rabesh Kumar Singh[3] Prakhar Dixit[4]

[1]Centre for Adavanced Studies Lucknow, Sector - 11, Jankipuram vistar, Lucknow - 226031, Uttar Pradesh, India
[2]Department of Mechanical Engineering, Graphic Era (Deemed to be University), Dehradun - 248002, Uttarakhand, India
[3]Madan Mohan Malaviya University of Technology, Deoria Road, Singhariya, Kunraghat, Gorakhpur – 273010, Uttar Pradesh, India
[4]Indian Institute of Technology Tirupati, Venkatagiri Road, Yerpedu Post, Tirupati District, Andhra Pradesh – 517619, India

*Corresponding author: anujksharma@cas.res.in, gopalji.me@geu.ac.in

**Abstract**

Corrosion prevention of metals by coating them with protective materials is a good strategy of corrosion control. However, the use of cost-effective organic materials for this purpose has been preferred over inorganic materials. This work reports a similar cost-effective organic material (waste banana peel) for corrosion prevention of copper (Cu) in saline water (3.5% NaCl). The ethanol extract of waste banana peels (EEWBP) has been prepared and characterized by UV-visible and FTIR spectroscopy (UVS and FS). The EEWBP has been deposited on Cu in layers (1-5) by drop casting (DC). The corrosion behaviors of bare and coated Cu strips have been examined by monitoring their open circuit potential (OCP), impedance by electrochemical impedance spectroscopy (EIS), and polarization properties by Tafel polarization tests (TPT). The results have shown that the corrosion resistance of the coated Cu strip increases with the number of layers. The maximum corrosion prevention of 96% has been observed for 4 layers of EEWBP coated Cu. The increase in the corrosion prevention may correspond to increase in surface coverage with the number of layers. The overall study demonstrates that the EEWBP can be used as a green, low-cost,


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and effective coating material for Cu in saline water corrosion barrier for copper.

**Keyword:** Corrosion; Copper; Banana Peels; Layers; Drop Casting; EIS.

## 1. Introduction

Copper (Cu) shows high electrical conductivity, good thermal stability, anti-microbial and anti-corrosive properties [1]. Due to above-mentioned virtues, Cu has been used in many engineering applications like air-conditioners, electric wiring, home utensils, and water purifiers [2]. One of the major concerns in ensuring smooth functioning of Cu-based articles is corrosion. Corrosion can damage the articles heavily and eliminate their functional virtues [3-4]. Hence, it is necessary to protect Cu in these environments, especially chloride containing [5].

One of the most effective strategies to restrict metal's corrosion is covering them with layers of protective materials [6]. However, the main focus of selecting protective material has been shifted to organic materials instead of inorganic materials due to strict environmental policies.

In organic materials, waste of natural organic materials (WNOM) can also be utilized for corrosion prevention purpose because they contain high amount of nutrients, flavonoids, phenols, tannins, alkaloids, and similar organic molecules [7, 8]. WNOMs may be the result of unemployment in agro-industries and deliberate ignorance of individuals due to bad appearance (or test). These WNOMs are generated in high amount and spread over lands in open. Such an ignorant and deliberate disposal of WNOMs can pollute the soils and spread various diseases [9]. Hence, it is a wise idea to use them as coating materials in corrosion prevention applications. Further, there are number of ways of coating metals; however, drop casting has been selected in this work for its simplicity, rapid nature, easy principle, and low-cost requirements [10, 11]. Some of similar WNOMs have already been reported as coating materials for corrosion prevention of metals like watermelon seeds [12], waste spinach leaves [13], lady finger caps

[14], capsicum pedicles [15], and sponge gourd peels [16]. These facts motivated us to use banana peels in this work.

Banana belongs to Musaceae family and highly consumed in the world for its health benefits. However, individuals and industries use only its pulp and discard peels. In this way, banana peel becomes WNOMs. On the other banana peel is reported to be richer in nutritional values than pulp [17]. Also, peels are found rich in bioactive compounds like flavonoids (catechin and gallo-catechin), polysaccharides, and alkaloids [17]. Due to above mentioned benefits, banana peels have already been used as corrosion inhibitors for metals [17-19]. However, they are never used as coating material. Hence, we are motivated to use banana peels as coating material in this work.

The present work is aimed at the synthesis of EEWBP, coating on Cu by drop casting in layers, and testing corrosion behaviors of bare and coated Cu in saline water. The saline water has been selected to mimic sea-side conditions (chloride rich) [20]. The EEWBP has been characterized by UVS and FS, which shows richness of EEWBP in biomolecules. The corrosion tests employed for the investigation was OCP, EIS, and TPT. The corrosion prevention property of EEWBP is found to be enhanced with the number of layers. However, it was saturated beyond 4 layers (96%).

## 2. Experimental Details

### 2.1. Preparation and Characterization of EEWBP

The bananas were purchased from the local fruit seller in Lucknow and peeled off carefully. The collected peels were rinsed with water and dried in an electric oven for 3 hours at 50º C. The peels were crushed in a kitchen grinder and powdered. An amount equal to 5gm was weighed (Figure 1a), soaked in 100 mili litre of ethanol (MERCK, AR grade), and stirred for 24 hours at 400 RPM on a magnetic stirrer (Figure 1b). After a rigorous stirring process, the solution of powdered peels and ethanol was filtered through a glass funnel with the help of a whatman filter paper. The residues on the paper were dried and weighed. The prepared EEWBP concentration was 30 mg $mL^{-1}$.

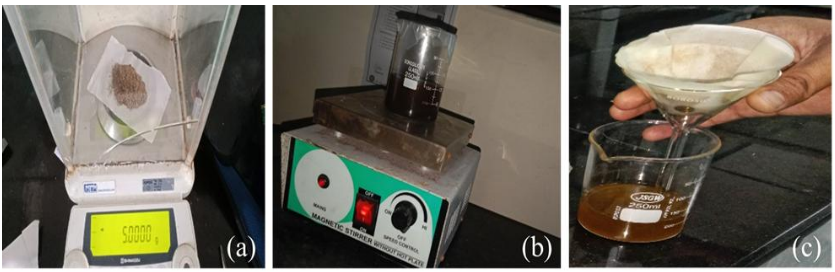

**Figure 1.** (a) Weighing of dried banana peel powder, (b) ethanolic extraction under 24-hour magnetic stirring, and (c) filtration of banana peel ethanolic extract using filter paper.

The EEWBP (100 μL) was checked for the signals of biomolecules by UV-Vis spectrophotometer of Biotek (200-900 nm at 3 nms$^{-1}$) and FTIR instrument of Bruker (400-4000 cm$^{-1}$ at 4 cm$^{-1}$s$^{-1}$).

**2.2. Copper substrates and coating**

The Cu strips of dimensions 2500 mm × 20 mm × 0.20 mm was procured from Pure intent, United industries, Haryana. The strips for the experiments were cut into the dimensions of 40 mm × 10 mm × 0.20 mm. The strips were cleaned with air blower, ethanol, and a tissue paper. The strips were abraded with the emery papers for 10 minutes and again cleaned with the same procedure as mentioned above. Thus, prepared strips had been coated with different layers of EEWBP. For one layer deposition, 40 μL of EEBWP was cast on Cu through DC. The coated Cu was allowed to dry at room conditions for 20 minutes. The same procedure was repeated to deposit higher number of layers on Cu.

**2.3. Electrochemical Measurements**

The Cu strips as working electrodes, platinum electrode as counter, and Ag/AgCl electrode as reference were used in standard three electrode assembly connected with AUTOLAB potentiostat (M204), Metrohm for corrosion tests (Figure 2). First, the OCP of strips was monitored for 3600 s of initial immersion. Afterwards, EIS test had been conducted with an a.c. signal of 5 mV RMS amplitude in a wide frequency range (from 100 kHz to 10 mHz). TPT tests had been conducted in the end in the potential range of ±250 mV vs OCP. The corrosion prevention of EEWBP (η) coatings had been calculated by the formula given below [21]:

$$\%\eta = \left(\frac{i^{b}_{corr} - i^{c}_{corr}}{i^{b}_{corr}}\right) \times 100 \qquad \text{(i)}$$

Where, $i_{corr}$ is used for corrosion current density, superscript ‘b’ is used for bare Cu, and superscript ‘c’ is used for coated Cu.

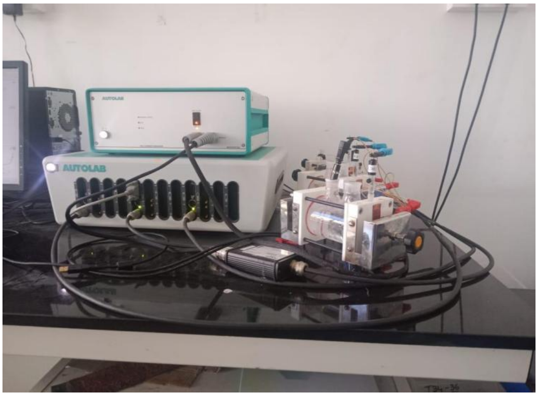

**Figure 2.** Electrochemical measurement setup showing the AUTOLAB workstation connected to the three-electrode corrosion cell.

## 3. Results and Discussions

### 3.1. FTIR and UV-Vis Spectrum of EEWBP

The FTIR spectrum of EEWBP is shown in Figure 3. The vibrational peaks at 3330 $cm^{-1}$ and 3640 $cm^{-1}$ showed C-H and O-H stretching of the molecules in the extract. The peaks at 1670 $cm^{-1}$ and 1045 $cm^{-1}$ showed C=C and C-O stretching of the functional groups in the extract. The peaks below 1000 $cm^{-1}$ showed vibration from aromatic molecules in the extract. The Figure 3 showed many peaks and every peak can not be assigned to the functional groups; however, it was confirmed that EEWBP had biomolecules.

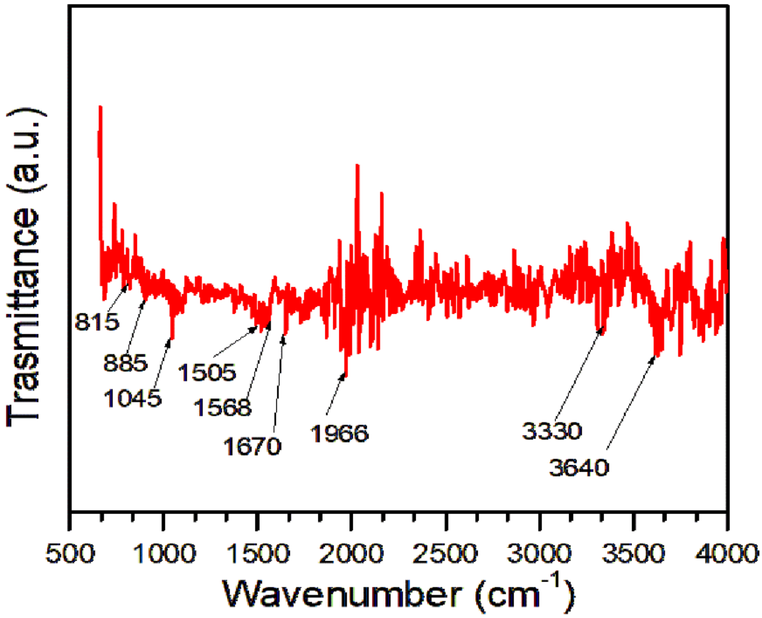

**Figure 3.** FTIR spectrum of the banana peel extract showing characteristic functional groups.

The UV-spectrum of EEWBP is shown in Figure 4. The peak at 234 nm could show presence of aromatic compounds (π-π*) in the extract [22]. The peak at 267 nm could show presence of phenolic compounds in EEWBP [23]. The peaks at 408 and 472 nm showed n- π* transitions in the compounds of the extract. The peak at 668 nm could correspond to color of the extract or presence of chlorophyll.

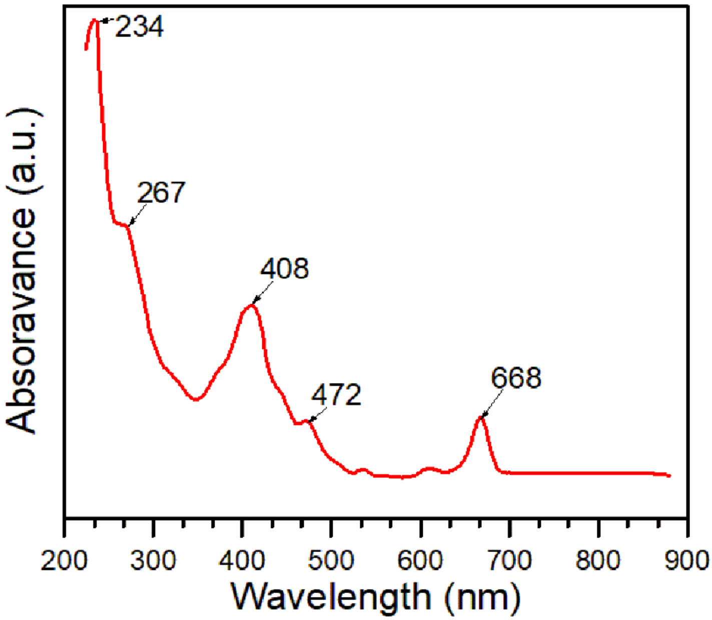


**Figure 4.** UV-vis spectrum of EEWBP.
Based on FS and UVS spectra of EEWBP it was known that the extract had diverse biomolecules.

### 3.2. Corrosion Tests

OCPs of the bare and coated Cu substrates has been shown in Figure 5. The OCP of bare Cu was round -0.16 V, which showed the vulnerability of Cu to corrosion [24]. After applying layers on Cu's surface, the OCPs were shifted towards zero volt, which indicated that the coatings prevented the damage of Cu in NaCl solution [25]. Furthermore, it was observed that OCP shifted towards positive potential zone with the number of layers, which could show that preventive effect of EEWBP strengthened for higher number of layers. However, the OCPs were still in the negative potential zone, indicating probability of Cu's damage (low) due to corrosion.

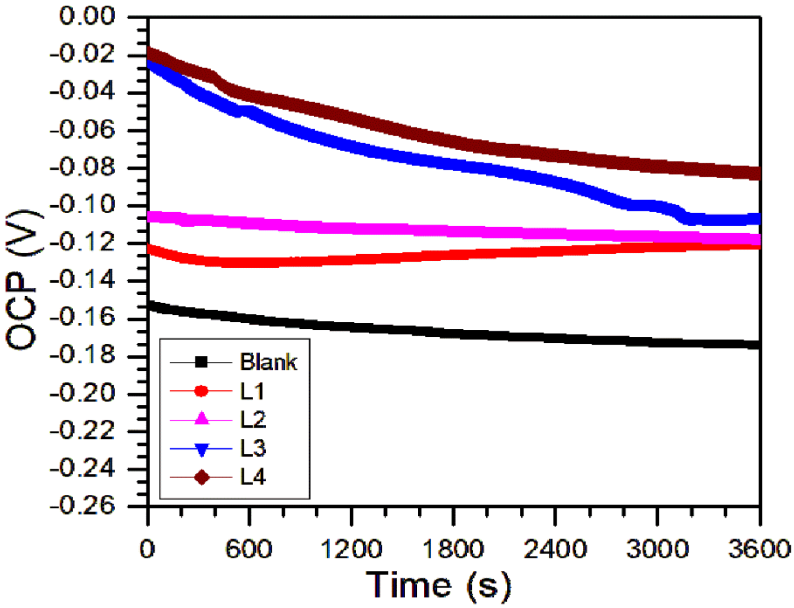


**Figure 5.** OCP of bare and coted Cu substrates in 3.5% NaCl at room temperature.

The Tafel polarization curves (TPC) for bare and coated Cu are shown in Figure 6. The curves for coated Cu shifted towards lower current and positive potential zones in comparison to bare Cu, which indicated that EEWBP coating prevented the damage of Cu in NaCl [26].

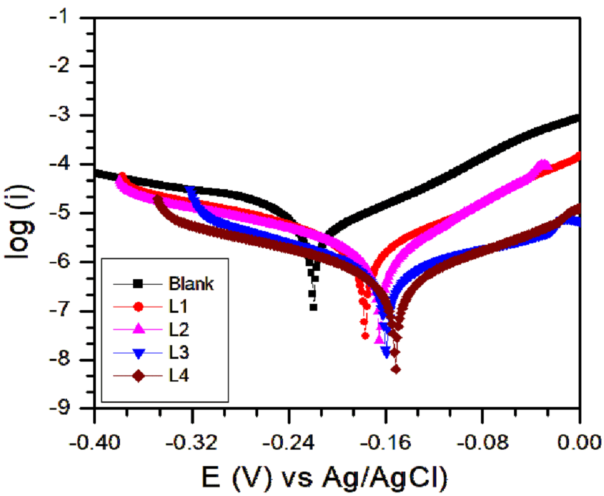

**Figure 6.** Tafel polarization curves for bare and coated Cu substrates in 3.5% NaCl at room temperature.

Figure 6 evidently showed that EEWBP significantly prevented damage of Cu in NaCl. However, quantification of the prevention can only be done based on equation (i). For the same, TPC had been fitted and the parameters were obtained (Table1). The equilibrium corrosion potential ($E_{corr}$) was found to be shifted towards positive potentials with respect to bare Cu, which indicated that EEWBP made Cu more thermodynamic stable [27]. In other words, it could be said that the vulnerability of Cu to corrosion had been reduced by EEWBP coatings. The $i_{corr}$ for bare Cu was noticed as 10.47 μA $cm^{-2}$, which was lowered for EEWBP coated Cu. The lowering of $i_{corr}$ happened with the increase in number of layers. The lowering of $i_{corr}$ corresponded to lowering of corrosion rate in a comparative system [28]. The lowest $i_{corr}$ of 0.45 μA $cm^{-2}$ was observed for four EEWBP layer-coated Cu, which meant that four layers of EEWBP provided the best protection to Cu (96%). These facts were also supported by the η values.

**Table 1.** Corrosion related parameters extracted from the polarization curves for bare and coated Cu substrates.

| Investigated Systems | $-E_{corr}$ (mV) | $I_{corr}$ (μA $cm^{-2}$) | η (%) |
|---|---|---|---|
| Blank (bare) | 199 | 10.47 | - |
| L1 (One-layer coating) | 171 | 2.63 | 75 |
| L2 (Two-layer coating) | 164 | 1.81 | 82 |
| L3 (Three-layer coating | 158 | 0.62 | 94 |
| L4 (Four-layer coating) | 152 | 0.45 | 96 |

To further evaluate the corrosion behavior of EEWBP coatings, EIS results are shown in Figure 7a (Nyquist plots) and 7b (bode phase angles). The impedance of the bare Cu was around 6000 Ω $cm^2$. On the other side, the impedances for different layers of EEWBP were noticed greater than bare Cu, especially three and four layers. The greater impedance of the systems shows greater corrosion resistance [29], which meant that four layers of EEWBP provided the highest corrosion resistance among the studied Cu samples. The bode phase angles also showed this fact. Generally, the higher phase angle corresponds to more corrosion resistive systems [30]. Hence, it could be said that four layers of EEWBP prevented Cu in a most effective manner. The finding of EIS tests were in well agreement with the findings of OCP and TPT analysis.

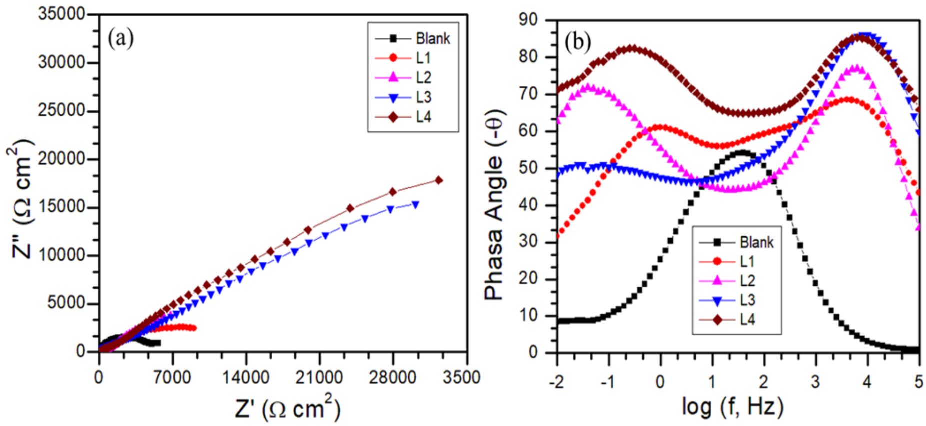


**Figure 7.** (a) Nyquist and (b) Bode phase curves for bare and coated Cu substrates in 3.5% NaCl at room temperature.

### 3.3 Discussion of Corrosion Analysis

It was observed in OCP analysis that EEWBP coated Cu was nobler in NaCl than bare Cu. The same fact was revealed by $E_{corr}$ and $I_{corr}$ values. It was further observed that nobility of coated Cu increased with the number of layers, which was well supported by the EIS results. All the above-mentioned facts indicated that EEWBP prevented Cu in layer-dependent manner. This trend was continued till the four layers of EEWBP. Hence, the reason of corrosion prevention of Cu by EEWBP coating can be given as surface blockage of Cu by EEWBP coatings, confirming barrier effect of EEWBP. The NaCl molecules could not reach the surface sites blocked by EEWBP. Hence, the corrosion prevention had been acknowledged. The blockage ability of EEWBP increased with the number of layers because it was reported elsewhere that pores and defects (micro-channels) in the layers got reduced with the increase in the number of layers [31]. Hence, increase in the corrosion prevention had been acknowledged for the higher number of layers. For the fifth layer, no improvement in corrosion prevention was noticed. Hence, the results for fifth layer of EEWBP-coated Cu were not shown in the work.

## 4. Conclusion

The EEWBP layers had been used to prevent Cu in saline water. A high amount of corrosion prevention (96%) for four layers EEWBP-coated Cu had been achieved. Overall, it could be said based on the findings that EEWBP impressively prevented Cu in saline water. However, point-wise conclusion is given below:

1. UVS and FS analysis confirmed that EEWBP had biomolecules.
2. OCP and $E_{corr}$ analysis revealed that EEWBP layers-coated Cu substrates were nobler than Cu.
3. EIS results disclosed that EEWBP prevented corrosion of Cu in NaCl. It also showed that EEWBP's prevention ability increased with the number of layers deposited on Cu.
4. $I_{corr}$ analysis supported the findings of EIS.
5. The maximum corrosion prevention of 96% was achieved with four layers of EEWBP.
6. Surface blockage of Cu by noble EEWBP coatings was found to be the main reason of corrosion prevention.
7. Findings of the work recommend EEWBP coatings for the effective corrosion prevention of Cu in saline water (sea-side conditions).
8. Findings of the work promote waste natural materials-based formulations of modern coatings and show high potential for a sustainable future of coatings.

## Conflict of Interests

Authors do not have conflict of interests.

## Funding Statement

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