PERFORMANCE ASSESSMENT OF INVESTIGATION OF THE EFFICACY OF ABELMOSCHUS ESCULENTUS (OKRA) LEAF EXTRACT AS A SUSTAINABLE CORROSION-RESISTANT INHIBITOR FOR LOW CARBON STEEL

BY

ADJEKOTA PRINCE OGHENENYERHOVWO (ENG2002385)
AKPEME UFUOMA OLUWATUNMISE KELLY (ENG2002388)
ANOGHARA OLUCHUKUWU VALENTINE (ENG2002389)
AGBOZELE ADOMOKHE DESTINY (ENG2002386)
AGOSSOU EJEMEN DIVINE MARIUS (ENG2002387)

A FINAL YEAR PROJECT SUBMITTED TO THE DEPARTMENT OF MATERIALS AND METALLURGICAL ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY

SUPERVISOR: DR. U.G. UNUEROH

NOVEMBER, 2025

CERTIFICATION

This is to certify that this work was carried out by Adjekota Prince Oghenenyerhovwo ENG2002385, Akpeme Ufuoma Oluwatunmise Kelly ENG2002388, Anoghara Oluchukuwu Valentine ENG2002389, Agbozele Adomokhe Destiny ENG2002386Agossou Ejemen Divine Marius ENG2002387.

DR. (MRS.) U.G. UNUEROH	Date
Project Supervisor	

ENGR. J. JESUMIRHEWE	Date
Project Coordinator	

DR. (MRS.) U.G. UNUEROH	Date
Head of Department	

DEDICATION

I dedicate this project to God Almighty, who has given us the grace to complete this wonderful journey, I also dedicate this work to my beloved parents and family for their support , care and encouragement their unwavering support, your inspiration has been a constant source of motivation for me.

ACKNOWLEDGEMENTS

We sincerely acknowledge the Almighty God for His guidance, protection, and wisdom throughout the period of this research work. His grace has strengthened me at every stage of this project, from conception to completion.

Our profound gratitude goes to my project supervisor Dr. (Mrs.) Unuerho for her invaluable support, constructive feedback, and continuous encouragement. His dedication, patience, and expertise greatly shaped the quality and direction of this work. I am deeply grateful for the time and effort he invested in supervising this project.

We also extend our appreciation to all lecturers in the department for providing the academic foundation and learning environment that made this project possible. Their teachings, advice, and commitment to excellence have contributed immensely to my development.

Our heartfelt thanks go to our parents, family members, and friends for their prayers, love, and moral support during the course of this research. Their encouragement kept me focused and motivated even during challenging moments.

Lastly, we appreciate our colleagues, laboratory staff, and everyone who, in one way or another, contributed to the success of this project. Your assistance and cooperation are sincerely valued.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This study investigates the potential of okra (Abelmoschus esculentus) leaf extract as a green, eco-friendly corrosion inhibitor for low carbon steel in acidic environments. The research focuses on evaluating the inhibitory efficiency of the extract at different concentrations and exposure times using electrochemical methods, including potentiodynamic polarization and open circuit potential measurements. Surface characterization techniques, such as Scanning Electron Microscopy (SEM), were employed to analyze the steel surface morphology after exposure.

Results indicated that the okra leaf extract significantly reduced the corrosion rate of low carbon steel, forming a protective layer on the metal surface. The inhibition efficiency increased with higher extract concentrations, demonstrating the potential of bioactive compounds in okra leaves to adsorb onto the steel surface and block corrosion sites.

The study concluded that okra leaf extract can serve as an effective, environmentally safe corrosion inhibitor, providing a sustainable alternative to conventional chemical inhibitors. These findings highlight the applicability of plant-based extracts in corrosion control and open avenues for further research in green corrosion inhibition technologies.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Metal corrosion represents a pervasive challenge characterized by the gradual degradation of metals due to chemical interactions with their surrounding environment, primarily through oxidation processes. This phenomenon is exemplified by the rusting of iron and steel upon exposure to oxygen and moisture; however, corrosion is not confined to these metals alone but impacts nearly all metallic materials employed in construction, manufacturing, and other industrial sectors (Revie & Uhlig, 2011). The ubiquity of corrosion underscores its importance as a subject of study and mitigation.

From an economic perspective, the consequences of corrosion are profound and far-reaching. In the United States, the financial toll attributed to corrosion is estimated to reach an astonishing $276 billion annually, accounting for approximately 3.1% of the nation's gross domestic product (GDP) (NACE International, 2016). This figure encompasses both direct and indirect costs. Direct costs involve expenses related to the replacement of corroded materials, application of protective coatings, and utilization of corrosion-resistant alloys designed to extend the lifespan of metal components. Indirect costs are equally substantial, including losses from equipment downtime, implementation of safety measures to prevent accidents, and the over-engineering of structures intended to offset anticipated corrosion-related degradation (Shreir et al., 2010)). Infrastructure critical to societal functioning, such as bridges, pipelines, and buildings, necessitates ongoing maintenance and eventual replacement largely due to the impact of corrosion (Revie & Uhlig, 2011). Environmental ramifications linked to corrosion further amplify its significance. The deterioration of metal structures contributes to considerable resource inefficiency and environmental degradation.

When infrastructure fails prematurely due to corrosion, it precipitates increased demand for raw materials, which drives intensified mining, smelting, and manufacturing activities. These processes are notably energy-intensive and contribute significantly to greenhouse gas emissions, particularly CO2 (Frankel, G.S. (2017).). Moreover, the failure of corroded infrastructure can lead to environmental catastrophes; for instance, leaks in corroded pipelines may result in soil and water contamination, posing threats to ecosystems and public health (Koch et al., 2016). Thus, corrosion is not only a material and economic problem but also an environmental one.

Certain environments exacerbate corrosion rates, making management particularly challenging. Marine settings exemplify harsh environments where saltwater, rich in chlorides, acts as a powerful corrosive agent accelerating metal degradation (Jones, 1996). Similarly, industrial regions often feature acidic pollutants that promote corrosion through chemical interactions with metallic surfaces (Revie & Uhlig, 2011). The evolving global climate situation is expected to intensify corrosion risks. More frequent and severe weather events, alongside rising sea levels, will expose additional infrastructure to moisture and saline conditions, thereby increasing vulnerability to corrosion (Schweitzer, 2010). This highlights the dynamic nature of the corrosion challenge, requiring adaptive and forward-looking mitigation strategies.

Combatting corrosion demands a comprehensive and multi-dimensional approach. Among the most effective strategies are the development and application of advanced protective coatings that shield metal surfaces from corrosive agents. Additionally, the use of corrosion-resistant alloys has become widespread, leveraging material science innovations to enhance durability (Frankel, 2017). Cathodic protection systems, which reduce the electrochemical potential of metal surfaces to prevent oxidation, represent another cornerstone technology in corrosion control (Shreir et al., 2010). Furthermore, engineering design improvements, such as avoiding crevices where moisture can accumulate and selecting appropriate materials based on environmental conditions, contribute significantly to corrosion mitigation (Revie & Uhlig, 2011). Collectively, these measures require substantial investment and coordination across industries, underscoring the critical role of corrosion management in economic sustainability and infrastructure resilience.

In conclusion, corrosion remains a globally pervasive and economically burdensome issue driven by the chemical deterioration of metals through environmental interactions. Its impact extends beyond economic losses to environmental damage and increased carbon emissions, with certain environments, notably marine and industrial zones, presenting heightened risks. Climate change introduces additional complexities that necessitate ongoing innovation in protective technologies, material development, and design practices. Addressing corrosion is thus a vital, ongoing endeavor demanding interdisciplinary collaboration and significant resource allocation worldwide.

1.2 STATEMENT OF THE PROBLEM

Metal corrosion remains a persistent and costly issue across various industries, causing significant economic losses and environmental damage. Traditional corrosion inhibitors often rely on synthetic chemicals that can be expensive, toxic, and environmentally harmful. Therefore, there is a growing need to identify sustainable, eco-friendly, and cost-effective alternatives. Okra (Abelmoschus esculentus) leafs, rich in mucilaginous polysaccharides, polyphenols, and other bioactive compounds, exhibit properties that may inhibit corrosion through the formation of protective films and chemical adsorption on metal surfaces. However, despite the potential benefits, there is limited comprehensive research on the effectiveness and mechanisms of Okra leaf extracts as corrosion inhibitors for metals. This study aims to investigate the corrosion inhibition efficiency of Okra leaf extracts on commonly used metals, providing insights into its feasibility as a green corrosion inhibitor to reduce environmental impact and lower industrial costs.

1.3 AIM OF STUDY

To investigate the potential of Okra leaf extract as inhibitor for metal.

To characterize the properties of the Okra leaf-based coating (e.g., corrosion resistance, adhesion, mechanical properties).

To investigate the effect of concentration and exposure time of the okra leaf extract on the corrosion rate of low carbon steel.

1.4 OBJECTIVE OF STUDY

To identify the optimum control concentration for Okra leaf extract in HCl acid solution and to evaluate the heat of absorption of the extract for the unhibited and inhibited.

To examine the effect of different concentrations of Okra leaf extract on the corrosion rate of low carbon steel.

To investigate the absorption behavior and inhibition mechanism of Okra leaf extract on the surface of low carbon steel.

1.5 SCOPE OF WORK

1. Collection and Preparation of Okra Leaf Extracts:
2. Harvesting fresh Okra leafs and preparing extracts using suitable solvents (e.g., water, ethanol).
3. Characterizing the chemical composition of the extracts, focusing on polysaccharides, polyphenols, and other bioactive compounds.
4. Metal Sample Preparation:
5. Procuring standard metal coupons (e.g., Low Carbon Steel).
6. Surface cleaning and polishing to ensure reproducibility of corrosion tests.
7. Corrosion Inhibition Tests:

8. Conducting weight loss measurements and electrochemical tests (such as potentiodynamic polarization and electrochemical impedance spectroscopy) in corrosive media (e.g., acidic or saline solutions).
9. Comparing the corrosion rates of metal samples with and without Okra leaf extract treatment.
10. Surface Analysis: Examining the metal surfaces before and after corrosion testing using microscopy techniques like SEM and spectroscopy (FTIR, XPS) to confirm the formation of protective films.
11. Evaluation of Inhibition Efficiency and Mechanism:
12. Determining the percentage inhibition efficiency of the Okra leaf extracts.
13. Investigating the adsorption behavior and interaction mechanisms between the bio-compounds and the metal surface.
14. Environmental and Economic Assessment:

CHAPTER TWO

LITERATURE REVIEW

2.1 METAL CORROSION

Metal corrosion is a widespread problem where metals deteriorate through chemical reactions with their environment, typically involving oxidation. The most common example is rusting of iron and steel when exposed to oxygen and moisture, but corrosion affects virtually all metals used in infrastructure and manufacturing.

The economic impact is staggering. In the United States alone, corrosion costs an estimated $276 billion annually - roughly 3.1% of GDP. This includes direct costs like material replacement, protective coatings, and corrosion-resistant alloys, plus indirect costs from equipment downtime, safety measures, and over-design of structures to account for corrosion losses. Critical infrastructure like bridges, pipelines, and buildings require constant maintenance and eventual replacement largely due to corrosion damage.

Environmentally, corrosion creates a significant burden through resource waste and pollution. When metal structures corrode and require replacement, it drives increased mining, smelting, and manufacturing - energy-intensive processes that generate substantial CO2 emissions. The premature failure of infrastructure also leads to environmental disasters, such as pipeline leaks that contaminate soil and water supplies.

The problem is particularly acute in harsh environments like marine settings, where saltwater accelerates corrosion, and in industrial areas with acidic pollutants. Climate change may worsen the situation through more extreme weather patterns and rising sea levels that expose more infrastructure to corrosive conditions.

Addressing corrosion requires multi-faceted approaches including better protective coatings, corrosion-resistant materials, cathodic protection systems, and improved design practices - all representing significant ongoing investments across industries worldwide.

2.2 OKRA (ABELMOSCHUS ESCULENTUS):

Okra (Abelmoschus esculentus), commonly known as okra or lady's finger, is a flowering plant widely cultivated in tropical and subtropical regions for its edible green pods. Beyond its culinary uses, Okra has garnered attention in materials science and corrosion research due to its unique biochemical composition and properties.

The most distinctive characteristic of Okra is its mucilaginous nature. When the plant tissues are damaged or processed, they release a viscous, gel-like substance rich in polysaccharides, particularly mucilage. This mucilage consists primarily of galacturonic acid, rhamnose, and glucose units that form complex polymeric structures with excellent film-forming capabilities.

The suitability of okra leaf as a corrosion inhibitor stems from several key biochemical properties. First, the abundant polysaccharides present in okra tissues possess excellent film-forming capabilities due to their numerous hydroxyl groups, which can readily interact with metal surfaces to form protective barrier layers (Banerjee et al., 2012). FT-IR analysis suggested that it contains polysaccharides majorly composed of galactose, rhamnose, and galacturonic acid.

Secondly, phytochemical investigations have shown that the main bioactive components of HKC are quercetin, quercetin-3′-O-glucoside, isoquercitrin, and hyperoside

Okra (Abelmoschus Esculentus) as a Potential Dietary Medicine with Nutraceutical Importance for Sustainable Health Applications - PMC

(Sengul et al., 2021). These polyphenolic compounds possess multiple hydroxyl and carbonyl groups that can form stable chelate complexes with metal ions, effectively inhibiting electrochemical corrosion processes (Bentiss et al., 2002).

Thirdly, compounds, catechins, flavanols, tannins, polysaccharides, glycoproteins, etc. These play a key role in the reduction of metal ions to metal nanoparticles.

Frontiers Quantitative and qualitative analyses of grafted okra for corrosion inhibition of Low Carbon Steel in acidic medium (Hosny et al., 2022), indicating the presence of reducing agents that can interact with metal surfaces and alter their electrochemical behavior.

Recent research has demonstrated that natural plant polymers demonstrate effective corrosion inhibition abilities, because of their numerous binding sites and excellent adsorption abilities

Effects of okra (Abelmoschus esculentus L.) leafs, fruits and seeds extracts on European sea bass (Dicentrarchus labrax) leukocytes, and their cytotoxic, bactericidal and antioxidant properties – Science Direct.

(Haldhar et al., 2023). Specifically, plant extracts have been shown to effectively inhibit metal corrosion in acidic environments, with okra extracts showing particular promise (Haldhar et al., 2023).

The combination of mucilaginous polysaccharides, phenolic compounds, and other bioactive molecules makes okra leaf extract an attractive candidate for developing sustainable, biodegradable corrosion inhibitors that could provide both environmental and economic benefits over conventional synthetic alternatives.

2.3 METAL CORROSION: ELECTROCHEMICAL MECHANISMS

Metal corrosion is fundamentally an electrochemical process that involves the spontaneous degradation of metals through oxidation-reduction reactions. Understanding these mechanisms is crucial for developing effective corrosion prevention strategies.

2.4 ELECTROCHEMICAL NATURE OF CORROSION

Corrosion occurs when a metal loses electrons (oxidation) and is converted from its metallic state to an ionic form. This process is thermodynamically favorable for most metals because they exist in nature as compounds (oxides, sulfides, carbonates) rather than in their pure metallic form. The extraction of metals from ores requires significant energy input, making the reverse process - corrosion - energetically favorable.

2.5 BASIC ELECTROCHEMICAL REACTIONS

The fundamental corrosion process involves two simultaneous half-reactions:\

Anodic reaction (oxidation): $M \rightarrow M^{n+} + ne^-$

Where M represents the metal, n is the number of electrons transferred, and the metal ion M^{n+} is formed.

Cathodic reaction (reduction): The electrons released at the anode must be consumed at the cathode. Common cathodic reactions include:

In acidic environments:

$2H^+ + 2e^- \rightarrow H_2$ (hydrogen evolution)

In neutral or alkaline environments with oxygen:

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ (oxygen reduction in acidic conditions)

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (oxygen reduction in alkaline conditions)

2.6 ELECTROCHEMICAL CELLS IN CORROSION

Corrosion occurs through the formation of electrochemical cells, which can be:

Galvanic cells: Form when two dissimilar metals are in electrical contact in the presence of an electrolyte. The more active metal (lower in the electrochemical series) becomes the anode and corrodes preferentially, while the more noble metal acts as the cathode.

Concentration cells: Develop due to differences in electrolyte concentration, oxygen concentration, or metal ion concentration across the metal surface. Areas with lower oxygen concentration typically become anodic.

Differential aeration cells: A specific type of concentration cell where varying oxygen levels create potential differences. Areas with restricted oxygen access become anodic and corrode preferentially.

Thermodynamic Aspects: The driving force for corrosion is the change in Gibbs free energy (ΔG). For a spontaneous corrosion reaction:

$\Delta G = -nFE°$ Where: n = number of electrons transferred

F = Faraday constant (96,485 C/mol), $E°$ = standard cell potential

A positive $E°$ value indicates thermodynamic favorability for corrosion.

2.7 TYPES OF ELECTROCHEMICAL CORROSION

Uniform corrosion: Occurs when anodic and cathodic sites are randomly distributed and constantly shifting across the metal surface.

Localized corrosion: Results from fixed anodic and cathodic areas, leading to:

Pitting corrosion**,** Crevice corrosion**,** Intergranular corrosion**,** Stress corrosion cracking

Understanding these electrochemical mechanisms is essential for developing effective corrosion inhibitors.

2.8 CORROSION INHIBITOR

Corrosion inhibitors are chemical substances that, when added in small concentrations to a corrosive environment, significantly reduce the rate of metal deterioration. They are widely used in industries such as oil and gas, water treatment, automotive, and construction to extend the life of metal structures and reduce maintenance costs. Corrosion inhibitors are classified based on their mode of action and the part of the electrochemical corrosion process they affect. The main types include anodic inhibitors, cathodic inhibitors, mixed-type inhibitors, and film-forming inhibitors. Each type has distinct characteristics and mechanisms. Anodic inhibitors function by interfering with the anodic (oxidation) reaction in the corrosion process, where metal atoms lose electrons and become metal ions. These inhibitors reduce the metal dissolution rate by forming a protective oxide layer or passive film on the anodic sites of the metal surface. Anodic inhibitors typically cause the formation of an insoluble, adherent, and protective film on the metal surface, often through passivation. This film isolates the metal from the corrosive medium, thereby reducing metal ion formation. However, these inhibitors are effective only when they cover the entire anodic surface; partial coverage can lead to localized corrosion, such as pitting. Common examples are: Chromates (CrO_4^{2-}): Used in cooling systems and paints; form a passive chromium oxide layer, Phosphates (PO_4^{3-}): Common in boiler water treatment; promote formation of a protective phosphate layer, Silicates (SiO_3^{2-}): Used in water systems for Low Carbon Steel and cast iron. Cathodic inhibitors reduce the rate of the cathodic (reduction) reaction in the corrosion process, typically involving the reduction of oxygen or hydrogen ions. They function by either slowing down the diffusion of cathodic reactants to the metal surface or by forming a barrier at cathodic sites. Common examples are: Zinc salts (Zn^{2+}): Form insoluble hydroxide films at cathodic sites, Polyphosphates and polyphosphonates: Inhibit oxygen reduction reactions, Calcium compounds (Ca^{2+}): React with carbonates to form protective layers on steel.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 MATERIALS

3.1.1 LOW CARBON STEEL

Table 3.1: The spark test of the chemical compositions of the low carbon steel.

Sample Re	Type	Measure	Recalculate	Origin	Method	Check Type	Check State	Correction
STEEL /SP	Unknown	07/08/2025	07/08/2025	Measured	Fe-10	None	Not Used	None
Sample	Area	Sample	Grade ID					
	C Conc %	Si Conc %	Mn Conc %	P Conc %	S Conc %	Cr Conc %	Mo Conc %	Ni Conc %
Mean	0.181	0.189	0.431	0.025	0.036	0.184	0.013	0.074

Five specimens of low carbon steel were use for this experiment. Each specimen contains a diameter of 2cm by 2cm.

3.1.2 OKRA LEAF EXTRACT

Fresh okra leaf extract were used for this experiment.

Figure 3.1: Okra leaf

3.2 METHODOLOGY

3.2.1 METAL SAMPLE PREPARATION

The low carbon steel was cut into suitable size of 2cm by 2cm then it was polish with emery paper (grade 400 – 1200) to smooth the surface.

3.2.2 OKRO LEAF EXTRACT PREPARATION

The Fresh Okra Leaf's were washed with distilled water (for preparing extracts or solutions from the leaf) and undergo natural under the sun, after the leafs were very dried, the dried leafs were grinded into a fine particle using a blender. Ethanol was used to extract the solute from the okra leaf, the okra leaf extract is put inside a beaker and the okra leaf extract was used as a corrosion inhibitor in the low carbon steel. It was taken to the laboratory for experiment.

3.2.3 ELECTROPOTENTIAL TEST (OCPT)

Electropotential test was carried out on the okra leaf extract which measures the voltage between two electrodes immersed in a solution without passing any external current. The OCPT was conducted using different quantity of the okra leaf extract ranging from 20ml to 80ml at different intervals.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESUTS

4.1.1 PHYTOCHEMICAL TEST

Table 4.1: phytochemical test of different constituents, test and observation.

CONSTITUENTS	TEST	OBSERVATION
Glycoside	General Test	+
Saponins	Frothing	+
Alkaloids	Picric Acid or Wasner’s Reagent	+
Phenolics	Ethanol/FeCl3	+
Eugenols	KOH/HCl	+
Steroids	Acetic Hydride and H2SO4	+
Terpenoids	Salkowski Test	+
Flavonoids	LEAD Acetate	+
Tannins	FeCl3	-
Reducing Sugars	Fehlings A & B	+

+ = Present

__ = Absent

++ = Largely Present

The phytochemical screening confirms that the okra leaf extract is a rich source of diverse bioactive compounds, particularly polyphenols (Flavonoids and tannins), Saponins and alkaloids. These results collectively support the traditional use of okra leaf in herbal medicine attributing its potential antioxidant, anti-inflammatory, antimicrobial and blood sugar regulating properties to this unique chemical profile.

4.1.2 FTIR TEST

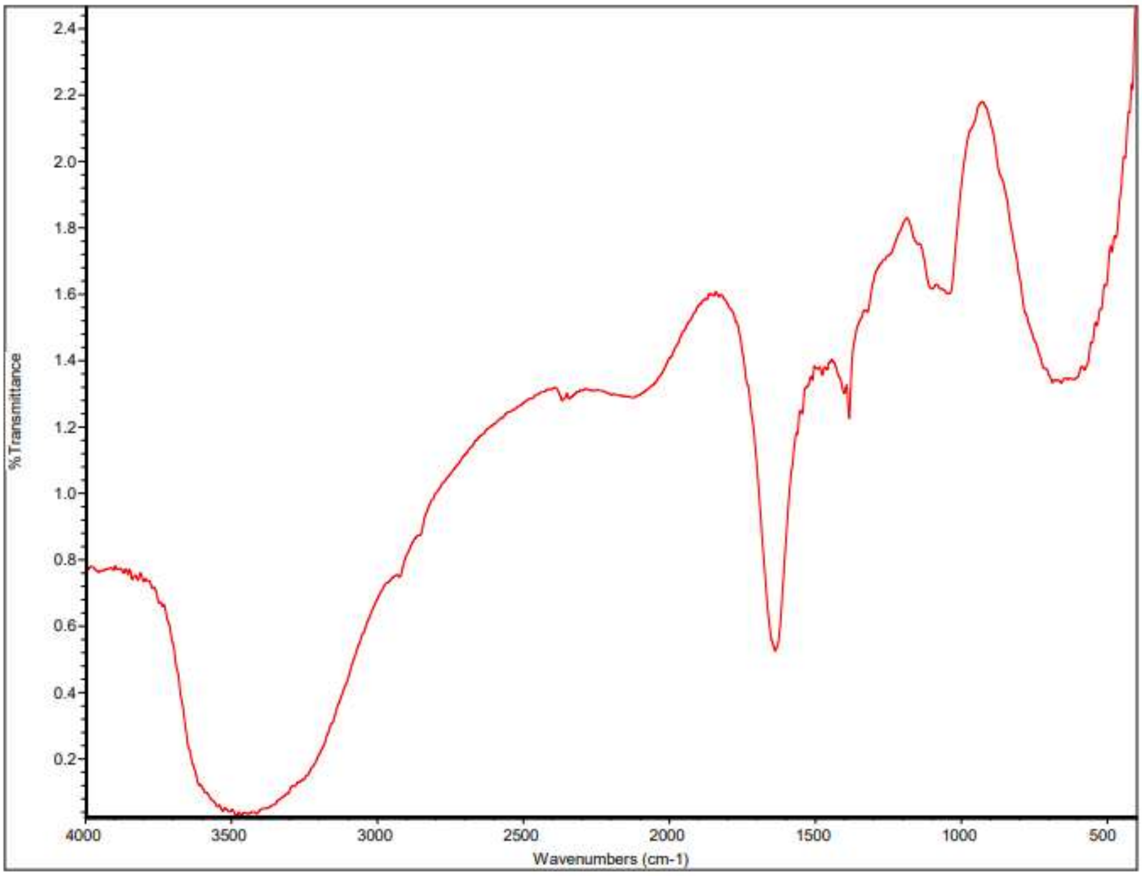
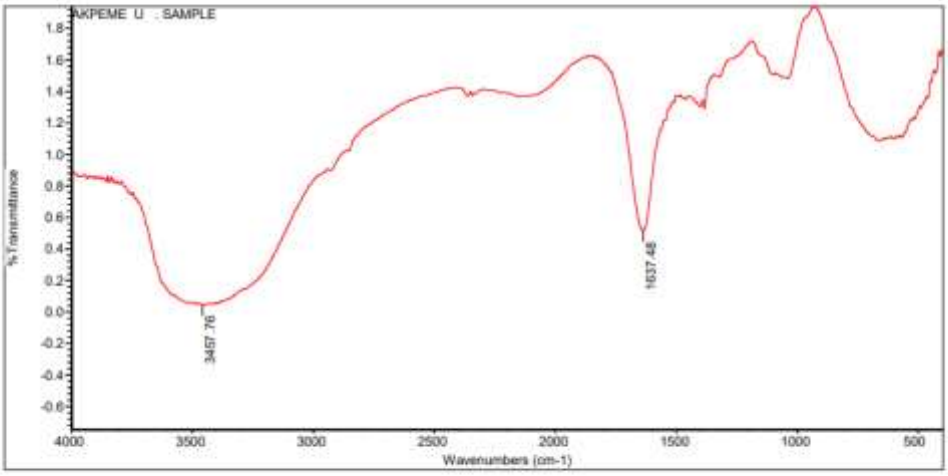


Figure 4.1: FTIR Test and it spectrum



```
Thu Aug 21 15:45:17 2025 (GMT+01:00)
FIND PEAKS:
     Spectrum:          AKPEME  U   : SAMPLE
     Region:            4000.00     400.00
     Absolute threshold: 0.990
     Sensitivity:       50
     Peak list:
                         Position:   1637.48   Intensity:   0.509
                         Position:   3457.76   Intensity:   0.0426
```

Figure 4.2: FTIR Test and it spectrum

The result confirms that the okra leaf extract is a complex mixture, rich in bioactive compounds, the major components identified by these functional groups are:

Polysaccharides: These are the major structural components of okra characteristic sliminess. The strong O-H stretching, C=O stretching of carboxylate groups (uronic acids) and numerous C-O/C-O-C stretching vibrations are definitive makers.

Phenolic Compounds and Flavonoids: The broad O-H band and the aromatic C=C stretching confirm the presence of these compounds which are known for their strong antioxidant properties.

Lipids and Aliphatic Compounds: the C-H stretching bands (around 2900cm^{-1}) point to the presence of fatty acids and other simple C-H containing organic molecules.

4.1.3 SEM

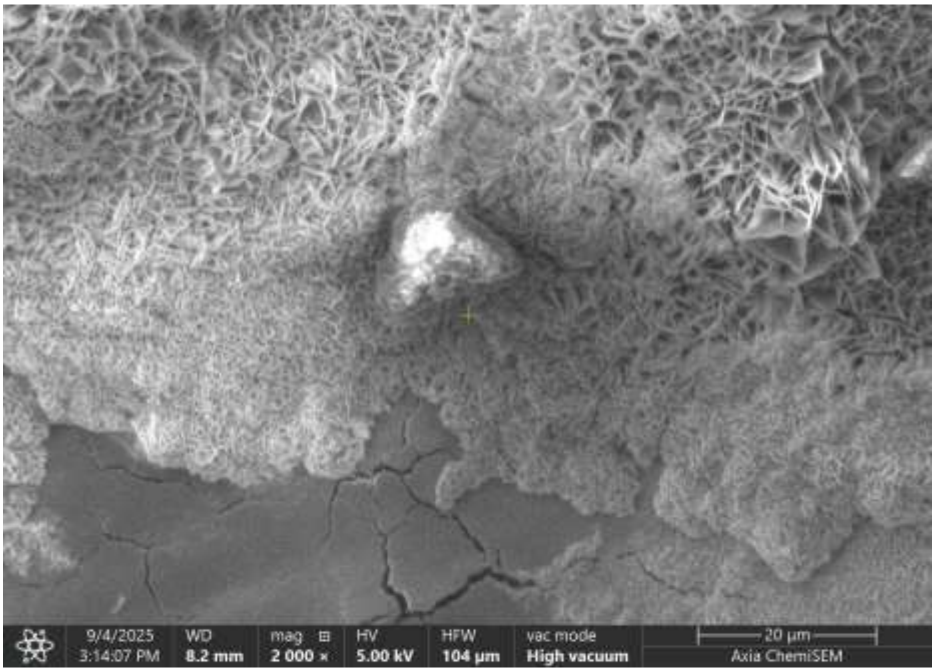


Figure 4.3: Low carbon steel (blank 0.5HCl)

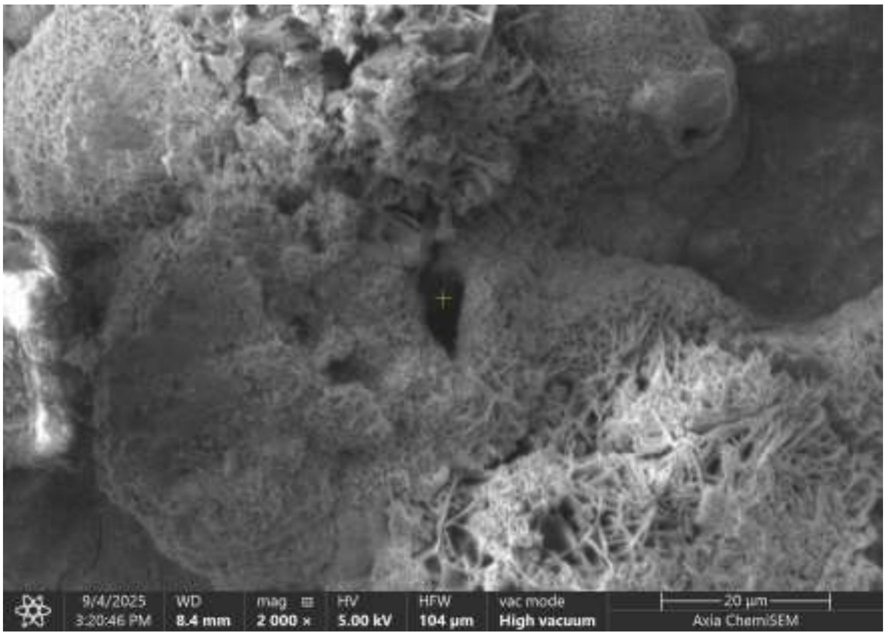


Figure 4.4: low carbon steel (0.5HCl + 20ML extract)

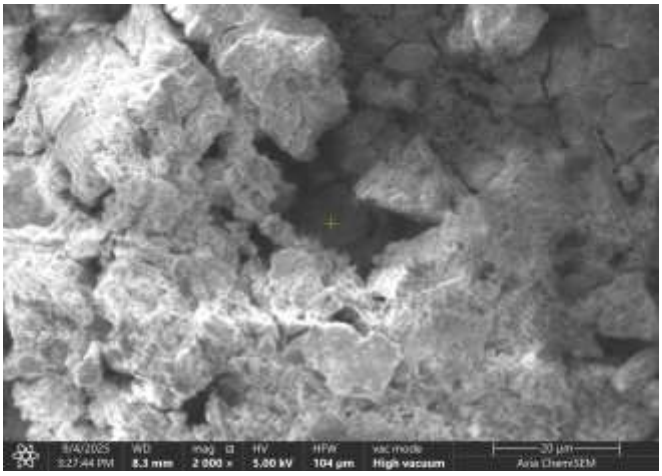


Figure 4.5: low carbon steel (0.5HCl + 40ML extract)

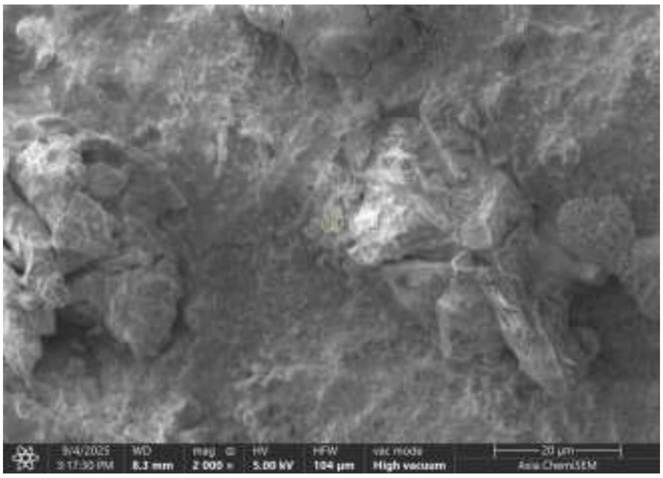


Figure 4.6: low carbon steel (0.5HCl + 60ML extract)

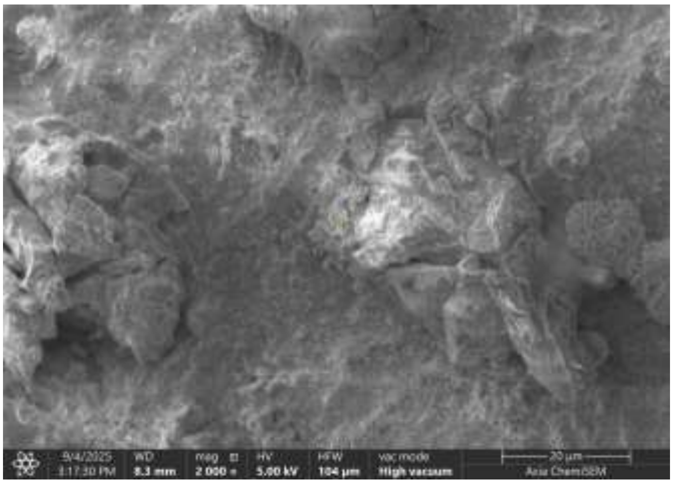


Figure 4.7: low carbon steel (0.5HCl + 80ML extract)

4.1.4 TAFEL PLOT

1. BLANK / CONTROL SAMPLE

```
Sept. 1, 2025   08:44:34
Tech: TAFEL
File: C:\Users\USER\Documents\PROF VICTOR VICTOR TAFEL\blank tafel.csv
Init E (V) = -1.5
Final E (V) = 1.5
Segment = 1
Hold Time at Ef (s) = 0
Scan Rate (V/s) = 0.01
Quiet Time (s) = 2

Cat Slp (1/V)=4.891
Ano Slp (1/V)=4.973
Cat Int (log i)=-1.379
Ano Int (log i)=-1.387
Lin Pol R (ohm)=1
Corr i (A)=5.739e-002
Rate (mil/year)=2.858e+003
Rate (Angs/min)=1.381e+003
Rate (gram/hr)=2.602e-002
```

Figure 4.8: Blank

This plot visually represents the relationship between the applied electrochemical potential and the logarithm of the current density flowing in an electrochemical cell. It's used to determine key corrosion parameters that tell us how susceptible a material is to corrosion and at what rate it degrades in a specific environment.

Details on the Plot

1. **X-Axis:** Labeled "Potential / V," this axis represents the applied electrical potential, typically measured relative to a reference electrode.
2. **Y-Axis:** Labeled "log(Current / A)," this axis displays the logarithm of the current density. The logarithmic scale is essential because current values during electrochemical processes can vary dramatically.
3. **The Curve:**
   - The **anodic branch** (the right side of the curve, where potential increases) shows the oxidation reaction, which is the process of the metal corroding. As

the potential becomes more positive, the rate of corrosion (and thus current density) increases.

- The **cathodic branch** (the left side of the curve, where potential decreases) represents the reduction reaction. This reaction occurs to balance the oxidation process.

2. 0.5mHCl + 20ml extract

```
Sept. 1, 2025   09:25:38
Tech: TAFEL
File: C:\Users\USER\Documents\PROF VICTOR VICTOR TAFEL\0.5mhcl + 20ml extract  tafel.csv
Init E (V) = -1.5
Final E (V) = 1.5
Segment = 1
Hold Time at Ef (s) = 0
Scan Rate (V/s) = 0.01
Quiet Time (s) = 2

Cat Slp (1/V)=4.864
Ano Slp (1/V)=4.885
Cat Int (log i)=-1.457
Ano Int (log i)=-1.457
Lin Pol R (ohm)=1
Corr i (A)=4.556e-002
Rate (mil/year)=2.269e+003
Rate (Angs/min)=1.097e+003
Rate (gram/hr)=2.066e-002
```

Figure 4.9: 0.5mHCl + 20ml extract

1. **Axes**:
    - **X-Axis (Potential)**: This axis represents the potential (in volts) applied to the electrochemical cell. It indicates the driving force for the electrochemical reactions occurring at the surface of the material.
    - **Y-Axis (Log(Current Density))**: This axis shows the logarithm of the current density (in amperes per square meter). Current density is a measure of the electric current per unit area of the electrode surface, which reflects the rate of electrochemical reactions.

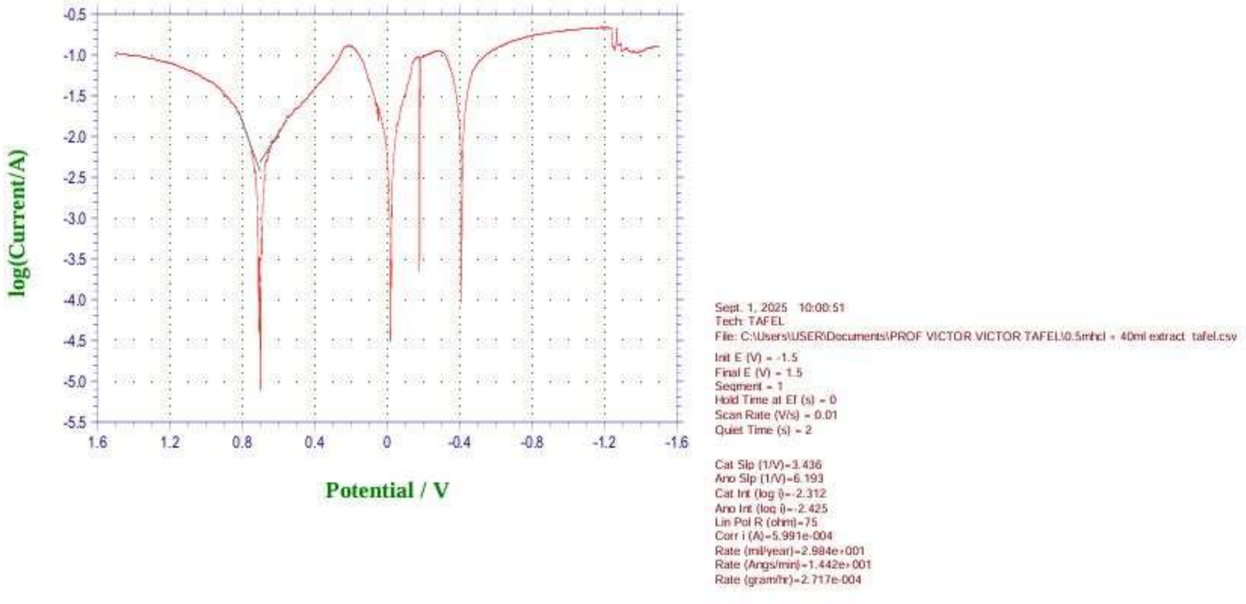
2. **Shape of the Plot**:
    - The Tafel plot typically displays a non-linear shape with distinct peaks and troughs. This complexity suggests that multiple electrochemical processes are occurring simultaneously, influenced by the presence of the okro leaf extract.

Interpretation of the Plot

1. **Peaks and Troughs**:
    - The peaks in the Tafel plot correspond to higher rates of electrochemical reactions, indicating areas where the corrosion process is more aggressive. Conversely, troughs represent lower reaction rates, suggesting better corrosion resistance.
    - The specific positions of these peaks can provide insights into the mechanisms of corrosion and how the okro leaf extract interacts with the material.
2. **Key Parameters**:
    - **Corrosion Current (Corr i)**: This parameter is derived from the Tafel plot and indicates the current density at which corrosion occurs. A higher corrosion current suggests a more aggressive corrosion environment, while a lower value indicates better protection.
    - **Polarization Resistance (Lin Pol R)**: This is calculated from the slope of the Tafel lines. A higher polarization resistance indicates that the material is less susceptible to corrosion, as it requires more energy to initiate the corrosion process.
    - **Corrosion Rate (Rate)**: This value quantifies the speed at which the material is corroding. It is often expressed in terms of mass loss per unit area per unit

time (e.g., mg/cm²/day). The corrosion rate can be influenced by the concentration and effectiveness of the okro leaf extract.

3. 0.5mHCl + 40ml extract



```
Sept. 1, 2025   10:00:51
Tech: TAFEL
File: C:\Users\USER\Documents\PROF VICTOR VICTOR TAFEL\0.5mhcl + 40ml extract  tafel.csv
Init E (V) = -1.5
Final E (V) = 1.5
Segment = 1
Hold Time at EI (s) = 0
Scan Rate (V/s) = 0.01
Quiet Time (s) = 2

Cat Slp (1/V)=3.436
Ano Slp (1/V)=6.193
Cat Int (log i)=-2.312
Ano Int (log i)=-2.425
Lin Pol R (ohm)=75
Corr i (A)=5.991e-004
Rate (mil/year)=2.984e+001
Rate (Angs/min)=1.442e+001
Rate (gram/hr)=2.717e-004
```

Figure 4.10: 0.5mHCl + 40ml extract

Key Components of the Tafel Plot

1. **Axes:**
    - **X-axis:** Represents the potential (E) in Volts (V). This is the voltage applied during the experiment.
    - **Y-axis:** Represents the logarithm of current density (log(I)), where I is the current in Amperes (A). This indicates the rate of electrochemical reactions occurring at the electrode surface.
2. **Regions of the Plot:**
    - The plot typically shows two distinct regions:
        - **Cathodic Region:** Where reduction reactions occur (e.g., hydrogen evolution).

        - **Anodic Region:** Where oxidation reactions occur (e.g., metal dissolution).

Values Reported in the Image

- **Corrosion Environment:** The experiment was conducted in a solution of 0.5 M HCl with 40 ml of Okro leaf extract.
- **Tafel Slopes:**
    - **Cathodic Tafel Slope (Cat Slp):** Indicates the rate of the cathodic reaction.
    - **Anodic Tafel Slope (Ano Slp):** Indicates the rate of the anodic reaction.
- **Intrinsic Currents:**
    - **Cathodic Intrinsic Current (Cat Int):** Logarithmic value related to the cathodic reaction.
    - **Anodic Intrinsic Current (Ano Int):** Logarithmic value related to the anodic reaction.
- **Polarization Resistance (Lin Pol R):**
    - A value of 75 ohms, which is inversely related to the corrosion current. Higher polarization resistance typically indicates a lower corrosion rate.

4. 0.5mHCl + 60ml extract

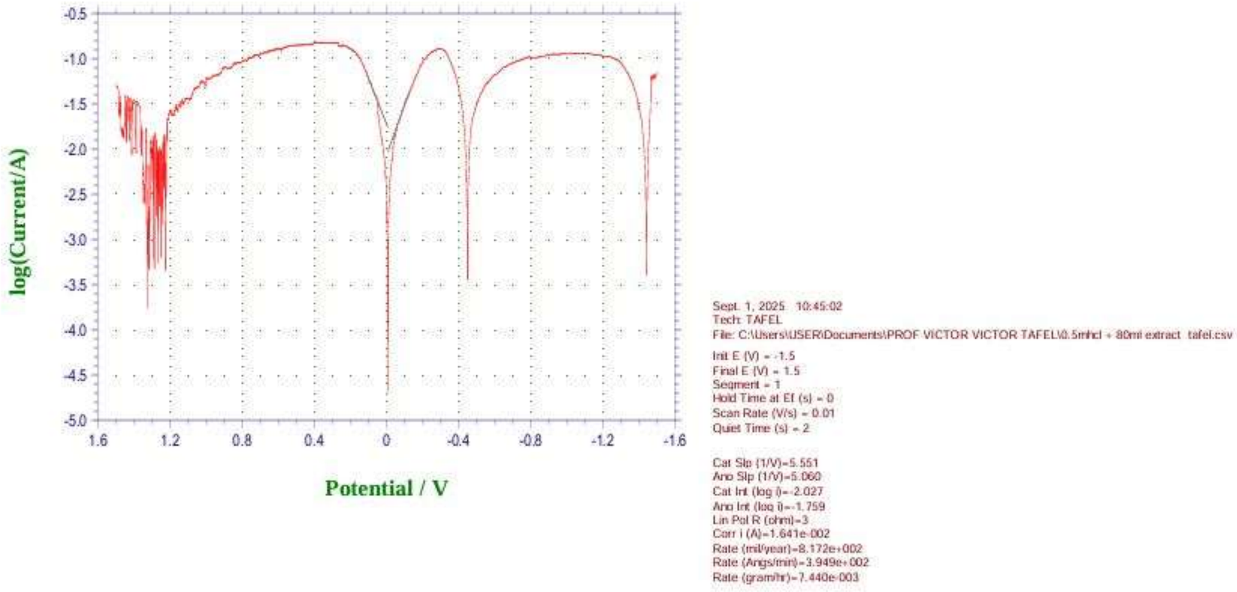
```
Sept. 1, 2025   10:22:06
Tech: TAFEL
File: C:\Users\USER\Documents\PROF VICTOR VICTOR TAFEL\0.5mhcl + 60ml extract  tafel.csv
Init E (V) = -1.5
Final E (V) = 1.5
Segment = 1
Hold Time at Ef (s) = 0
Scan Rate (V/s) = 0.01
Quiet Time (s) = 2

Cat Slp (1/V)=5.782
Ano Slp (1/V)=7.899
Cat Int (log i)=-2.367
Ano Int (log i)=-2.885
Lin Pol R (ohm)=6
Corr i (A)=5.415e-003
Rate (mil/year)=2.697e+002
Rate (Angs/min)=1.303e+002
Rate (gram/hr)=2.455e-003
```

Figure 4.11: 0.5mHCl + 60ml extract

Key Features of the Tafel Plot

1. **Axes:**
    - **Y-axis (log(Current/A)):** This axis represents the logarithm of the electric current density (in amperes per unit area) flowing through the electrochemical cell. It is indicative of the rate of oxidation or reduction reactions occurring at the electrode surface.
    - **X-axis (Potential / V):** This axis shows the applied voltage or potential difference across the electrochemical cell.
2. **Curve:**
    - The plot features a red line that traces a curve with two distinct segments on either side. This shape indicates how the current density changes in response to variations in the applied potential. The almost symmetrical nature of the curve suggests that the anodic (oxidation) and cathodic (reduction) reactions are balanced under the experimental conditions.

5. 0.5mHCl + 80ml extract



```
Sept. 1, 2025   10:45:02
Tech: TAFEL
File: C:\Users\USER\Documents\PROF VICTOR VICTOR TAFEL\0.5mhcl + 80ml extract  tafel.csv
Init E (V) = -1.5
Final E (V) = 1.5
Segment = 1
Hold Time at Ef (s) = 0
Scan Rate (V/s) = 0.01
Quiet Time (s) = 2

Cat Slp (1/V)=5.551
Ano Slp (1/V)=5.060
Cat Int (log i)=-2.027
Ano Int (log i)=-1.759
Lin Pol R (ohm)=3
Corr i (A)=1.641e-002
Rate (mil/year)=8.172e+002
Rate (Angs/min)=3.949e+002
Rate (gram/hr)=7.440e-003
```

Figure 4.12: 0.5mHCl + 80ml extract

- The Tafel plot indicates that the material being tested exhibits a high corrosion rate, which suggests poor corrosion resistance.
- The presence of multiple peaks in the Tafel curve implies that various electrochemical reactions are taking place, complicating the analysis.
- The experimental parameters suggest that the conditions under which the test was conducted were controlled, with a slow scan rate that typically enhances the reliability of the results.

4.1.5 OCPT

1. Blank / CONTROL SAMPLE

Figure 4.13: Blank

Curve Analysis:

1. **Initial Phase (0 to ~30 seconds):** A **rapid decrease in potential** is observed. This is common at the beginning of an OCPT measurement as the system adapts and stabilizes after a possible disruption or change in conditions. The potential may be adjusting to its open-circuit equilibrium value.
2. **Later Phase (~30 to 300 seconds):** After the initial drop, the potential shows a **gradual and more linear increase**. This suggests that the system is slowly stabilizing towards a more constant open circuit potential, or that slow processes are occurring on the electrode surface causing this progressive increase. Around 300 seconds, the potential appears to **stabilize**, indicating that the system has reached an equilibrium or pseudo-equilibrium state during the test run time.

2. 0.5m HCl + 20ml extract OCPT

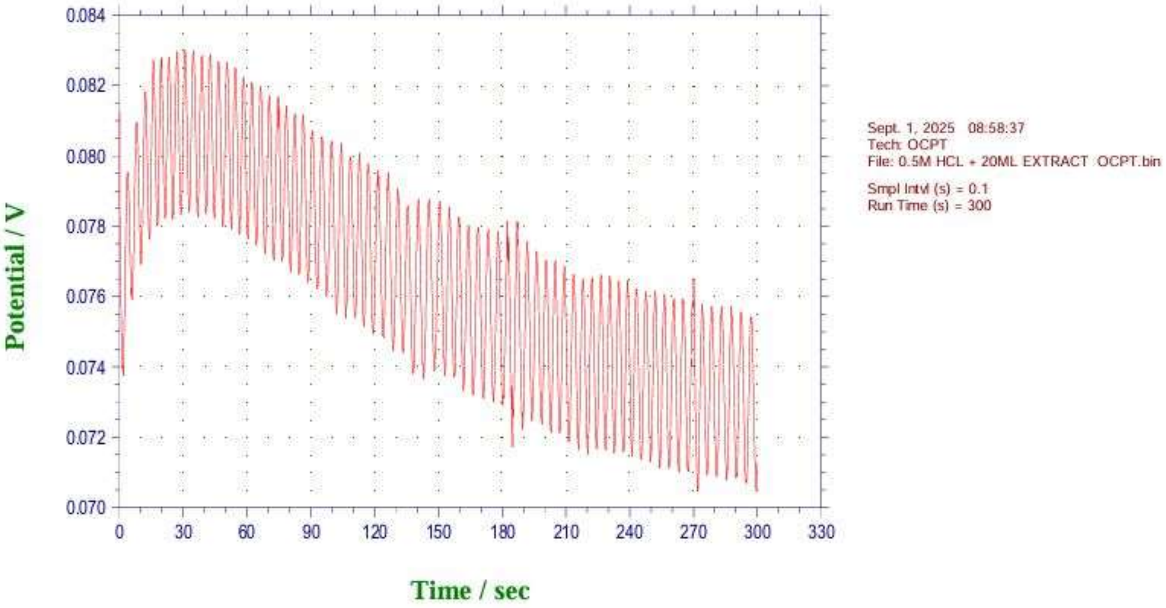


Figure 4.14: 0.5mhcl + 20ml

- **Y-axis:** Potential (V), ranging from approximately 0.070 V to 0.084 V.
- **X-axis:** Time (sec), showing a total run time of 300 seconds (5 minutes).
- **Graph Shape/Trends:**
    - **Pronounced Oscillations:** The most striking feature is the periodic rise and fall in potential. These suggest dynamic processes like adsorption/desorption, formation/dissolution of passive layers, or cyclic electrochemical reactions.
    - **Overall Decreasing Trend:** Despite the oscillations, the average potential gradually decreases over time, indicating the system is evolving towards a state where the electrode might be becoming less noble (more susceptible to oxidation).

Possible Interpretations & Next Steps:

- **Corrosion:** The decreasing potential and oscillations could suggest a corrosion process, potentially accelerated by chloride ions from HCl and influenced by the extract.

- **Surface Phenomena:** Oscillations likely point to complex reactions, film formation/breakdown, or adsorption/desorption on the electrode surface.
- **Crucial Missing Information:** The composition of the "EXTRACT" is vital for a deeper understanding. Knowing its nature would allow for predictions about reactions and its role as a catalyst or inhibitor.

3. 0.5m HCl+ 40ml extract OCPT

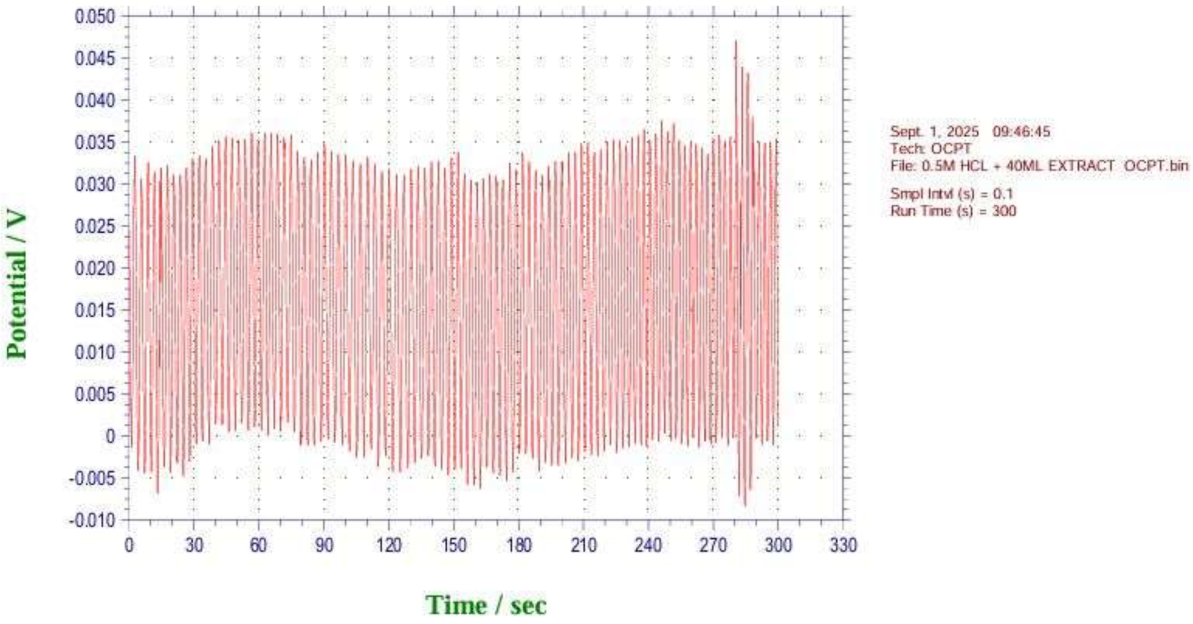


Figure 4.15: 0.5mHCl + 40ml

1. **Axes:**
    - **X-axis:** Represents time in seconds. The experiment ran for 300 seconds (5 minutes).
    - **Y-axis:** Indicates the open circuit potential (OCP) of the electrode, measured in volts (V). The potential fluctuates between approximately -0.01 V and 0.045 V.
2. **The Oscillating Pattern:**
    - The most striking feature is the highly periodic, almost sinusoidal oscillation of the potential.

    - **Possible causes of oscillations:**
        - **Localized Corrosion:** Periodic formation and healing of corrosion product layers can give rise to voltage oscillations.
        - **Adsorption/Desorption Phenomena:** Cycles of adsorption of species from the liquid extract onto the electrode surface followed by their desorption.
        - **Redox Reactions:** There could be periodic changes in redox species at the electrode that are fluctuating in their concentration or being periodically blocked/unblocked by surface adsorption of substances from the liquid extract.
        - **Hydrogen Evolution:** Electrochemical measurements in HCl at sufficiently negative potentials (close to the negative potential limit of about -0.01 Volt) might trigger a hydrogen evolution side reaction with the formation of hydrogen bubbles, resulting in periodic blocking/unblocking of the electrode surface.

3. **Possible Hypothesis related to the material extracted in 40 ml:**
    - The overall high frequency of electrochemical oscillations suggests the role of electro-active species in the 40 ml extract.
4. **Last stage - Spike at 300 sec:**
    - There is a sharp change in electrochemical potential near the end of the measurement (at about 300 sec), where the potential spikes up.
    - It is difficult to judge its true origin, but it could be due to:
        - Change in reaction conditions through mass transfer or convective diffusion from the vicinity of the electrode to the bulk electrolyte.

- Disturbance of the electrode due to external intervention (e.g., vibration of the lab table on which the experiment was performed).

4. 0.5m HCl + 60ml extract OCPT

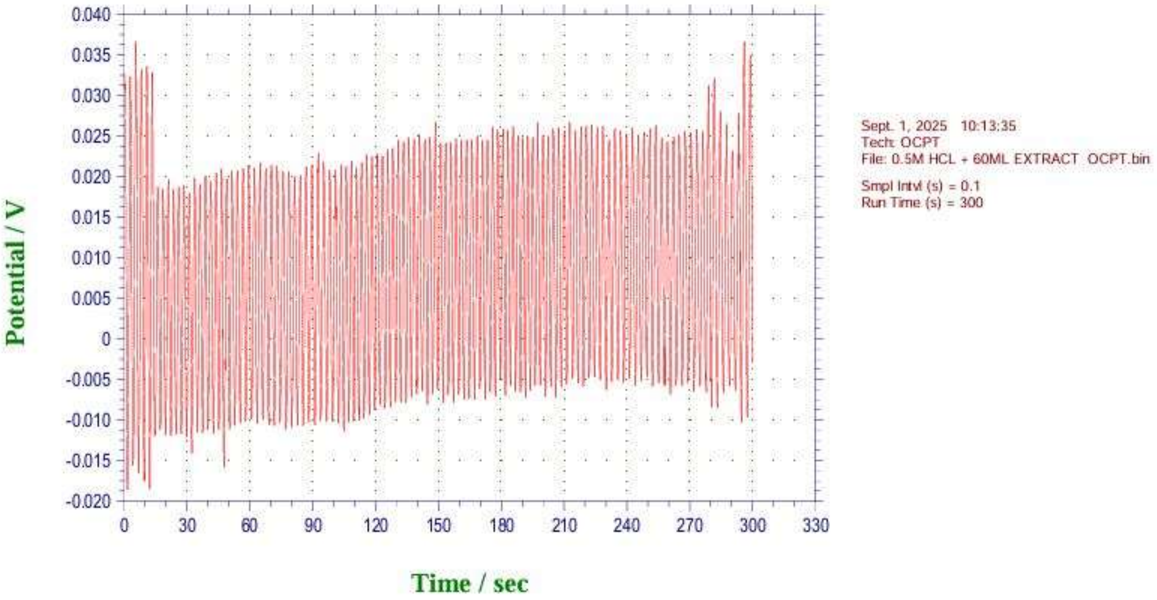


Figure 4.16: 0.5mHCl + 60ml

1. **Axes**:
    - **X-axis**: Represents **Time** in seconds. The experiment duration is 300 seconds (5 minutes).
    - **Y-axis**: Represents **Potential** in Volts (V). This axis shows the measured electrical potential difference during the experiment.
2. **Data Representation**:
    - The **red line** in the diagram illustrates how the OCP changes over the 300 seconds. The line exhibits significant oscillations, indicating fluctuations in the potential.

Interpretation of Results

1. **Oscillating Potential**:
    - The most notable feature of the diagram is the **strong oscillations** in the OCP. Typically, OCP values stabilize over time, but in this case, the potential fluctuates significantly. This behavior can indicate:
        - **Unstable Surface Processes**: The oscillations may suggest that there are dynamic processes occurring at the electrode surface, such as repeated adsorption and desorption of species.
        - **Electronic Noise**: The fluctuations could also be due to electronic noise or interference in the measurement system, especially when measuring low potential values.

5. **0.5ml + 80HCl**

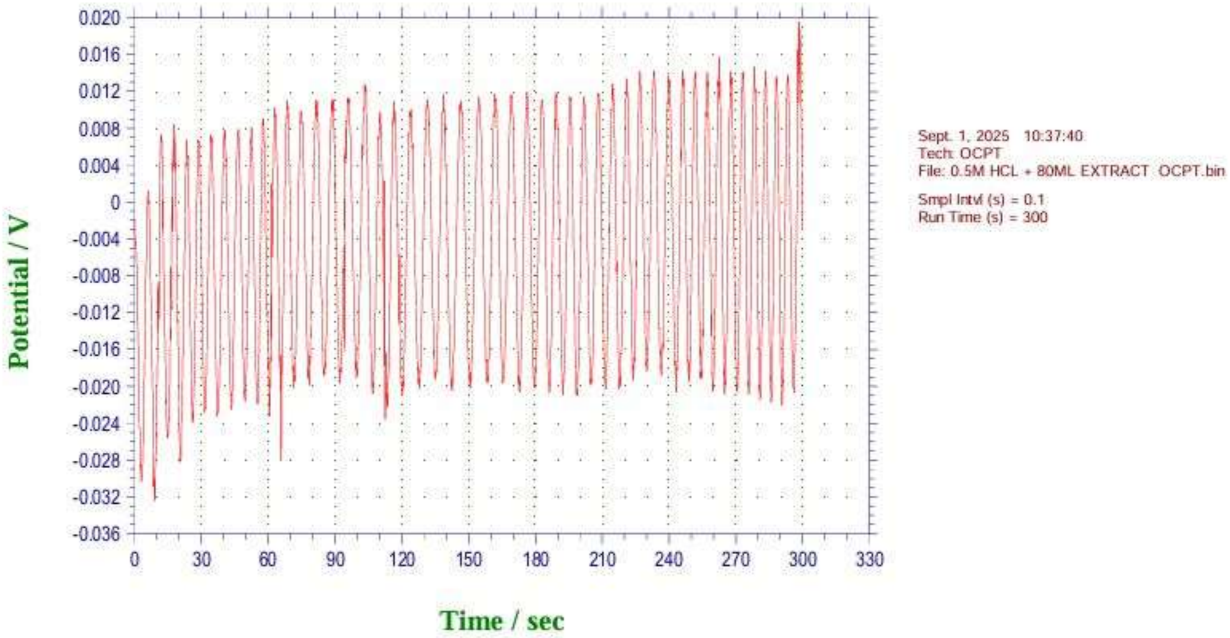


Figure 4.17: 0.5mHCl + 80ml

- **X-axis (Time in seconds)**: This axis represents the duration of the measurement, which in this case lasted for 300 seconds.

- **Y-axis (Potential in Volts)**: This axis shows the open circuit potential of the sample, measured in volts (V).
- **Curve**: The red line on the graph illustrates how the potential changes over time.

1. Diagram Interpretation

- **Oscillating Behavior**: The plot shows significant oscillations in potential, suggesting instability in the system. This could be due to processes like repetitive oxide formation and breakdown or adsorption/desorption reactions on the surface.
- **Potential Increase Over Time**: The potential appears to trend upward gradually. If this increase stabilizes, it may indicate the formation of a stable surface oxide film or a dynamic equilibrium.

2. Inferences

- The OCP indicates that the electrode material is actively reacting, which could suggest ongoing corrosion processes.

4.2. DISCUSSION

BLANK

The inhibitor molecules at this concentration can interact effectively with the metal surface**,** forming a more stable, tightly packed adsorbed layer. This stability reduces electron transfer and slows the corrosion process.

At concentrations higher than 80 mL, excess inhibitor molecules can begin to **cluster or aggregate**, which disrupts the uniformity of the protective film, this can create weak points where corrosion can initiate also Lower concentrations (e.g., 80 mL) do not supply enough molecules to cover the surface, leaving many active corrosion sites exposed. The 40 mL is the point where the inhibitor achieves its highest adsorption efficiency before negative effects of oversaturation appear at higher concentrations (60 mL and 80 mL).

OCPT

The OCPT graph test on okra leaf extract likely demonstrate its efficacy as a corrosion inhibitor due to the bioactive compounds present. This aligns with its antioxidant and anti-inflammatory properties, which enhance its protective capabilities. from the OCP GRAPH, we can see that okra leaf extract is a medium corrosion inhibitor for low carbon steel.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From our experiment, we can conclude that indeed okra leaf extract is a good corrosion inhibitor for low carbon steel. From our experiment the 0.5HCl + 80Ml is the best corrosion inhibitor among the four.

5.2 RECOMMENDATION

This experiment explored just one concentration, we recommend that more experiment of like nature are carried on different concentrations with different compositions of steel.

REFERENCES

Sastri, V. S. (2011). Green Corrosion Inhibitors: Theory And Practice. Hoboken, NJ: John Wiley & Sons.

Hussain, C.M., Verma, C., & Aslam, J. (2021). Environmentally Sustainable Corrosion Inhibitors: Fundamentals And Industrial Applications. Elsevier

Callister, W.D, & Rethwisch, D.G. (2020). Materials Science And Engineering: An Introduction (10th ed.). Wiley.

Callister, W.D., & Rethwisch, D.G. (2021). Fundamentals Of Materials Science And Engineering: An Integrated Approach (6th ed.). Wiley.

Meyers, M.A., & Chawa, K. K. (2009). Mechanical Behavior Of Materials (2th ed.). Cambridge University Press.

Fontana, M. G. (1986). Corrosion Engineering (3rd ed.). New York: McGraw-Ill.

Jones, D. A. (1996). Principles And Prevention Of Corrosion (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Sengul (2011). Effect of corrosion on materials.

Bentiss (2012). Corrosion inhibitors: a review on it effect.

Hosny (2022). Quantitative analysis of Okra leaf extract as a inhibitor.

Haldhar (2023). Plant extract and it effect on low carbon steel.

Stansbury, E. E., & Buchanan, R. A. (2000). Fundamentals Of Electrochemical Corrosion. ASM International.

Revie & Uhlig, 2011. Corrosion Handbook (3rd ed.)

Shreir, L.L., Jarman, R.A., & Burstein, G.T. (2010). Shreir's corrosion (4th ed.). Elsevier.

Frankel, G.S. (2017). Pitting corrosion of metals: A review of the critical factors.

Koch (2016). International measures of prevention, application, and economics of corrosion technologies study.

Schweitzer (2010). Fundamentals of Corrosion: Mechanisms, causes and preventative methods.

APPENDIX 1

INSTRUMENT MODEL:	**CHI604E**
Init E (V) = 1.5	Final E (V) = 1.5
Segment = 1	Hold Time at Ef (sec) = 0
Scan Rate (V/s) = 0.01	Quiet Time (Sec) = 2

POTENTIAL	**CURRENT**	**LOG(i/A)**
-1.5	-1.17E-01	-9.31E-01
-1.499	-1.19E-01	-9.26E-01
-1.498	-1.20E-01	-9.22E-01
-1.497	-1.21E-01	-9.17E-01
-1.496	-1.22E-01	-9.13E-01
-1.495	-1.23E-01	-9.09E-01
-1.494	-1.24E-01	-9.06E-01
-1.493	-1.25E-01	-9.02E-01
-1.492	-1.26E-01	-8.99E-01
-1.491	-1.28E-01	-8.95E-01
-1.49	-1.29E-01	-8.91E-01
-1.489	-1.29E-01	-8.88E-01
-1.488	-1.30E-01	-8.85E-01
-1.487	-1.31E-01	-8.82E-01
-1.486	-1.32E-01	-8.80E-01

-1.485	-1.33E-01	-8.77E-01
-1.484	-1.34E-01	-8.74E-01
-1.483	-1.34E-01	-8.72E-01
-1.482	-1.35E-01	-8.70E-01
-1.481	-1.36E-01	-8.67E-01

0.5MHCL + 20ML EXTRACT ON LOW CARBON STEEL

POTENTIAL	CURRENT	LOG(i/A)
-1.5	-2.67E-01	-5.74E-01
-1.499	-2.67E-01	-5.74E-01
-1.498	-2.67E-01	-5.74E-01
-1.497	-2.67E-01	-5.74E-01
-1.496	-2.67E-01	-5.74E-01
-1.495	-2.67E-01	-5.74E-01
-1.494	-2.67E-01	-5.73E-01
-1.493	-2.67E-01	-5.73E-01
-1.492	-2.68E-01	-5.73E-01
-1.491	-2.68E-01	-5.73E-01
-1.49	-2.68E-01	-5.73E-01
-1.489	-2.68E-01	-5.73E-01
-1.488	-2.68E-01	-5.73E-01
-1.487	-2.68E-01	-5.73E-01
-1.486	-2.67E-01	-5.73E-01
-1.485	-2.67E-01	-5.74E-01
-1.484	-2.67E-01	-5.74E-01
-1.483	-2.67E-01	-5.73E-01
-1.482	-2.67E-01	-5.74E-01
-1.481	-2.67E-01	-5.73E-01

0.5MHCL + 40ML EXTRACT ON LOW CARBON STEEL

POTENTIAL	**CURRENT**	**LOG(i/A)**
-1.5	-1.28E-01	-8.93E-01
-1.499	-1.27E-01	-8.95E-01
-1.498	-1.27E-01	-8.95E-01
-1.497	-1.28E-01	-8.95E-01
-1.496	-1.28E-01	-8.94E-01
-1.495	-1.28E-01	-8.94E-01
-1.494	-1.28E-01	-8.94E-01
-1.493	-1.28E-01	-8.94E-01
-1.492	-1.28E-01	-8.94E-01
-1.491	-1.28E-01	-8.94E-01
-1.49	-1.27E-01	-8.95E-01
-1.489	-1.28E-01	-8.94E-01
-1.488	-1.27E-01	-8.96E-01
-1.487	-1.27E-01	-8.96E-01
-1.486	-1.26E-01	-8.99E-01
-1.485	-1.26E-01	-8.99E-01
-1.484	-1.26E-01	-8.99E-01
-1.483	-1.26E-01	-8.99E-01
-1.482	-1.26E-01	-9.01E-01
-1.481	-1.26E-01	-9.01E-01

0.5MHCL + 60ML EXTRACT ON LOW CARBON STEEL

POTENTIAL	**CURRENT**	**LOG(i/A)**
-1.5	-1.46E-01	-8.35E-01
-1.499	-1.46E-01	-8.34E-01
-1.498	-1.46E-01	-8.34E-01
-1.497	-1.47E-01	-8.34E-01
-1.496	-1.47E-01	-8.33E-01
-1.495	-1.47E-01	-8.32E-01
-1.494	-1.47E-01	-8.32E-01
-1.493	-1.48E-01	-8.30E-01
-1.492	-1.48E-01	-8.30E-01
-1.491	-1.48E-01	-8.29E-01
-1.49	-1.48E-01	-8.29E-01
-1.489	-1.49E-01	-8.28E-01
-1.488	-1.49E-01	-8.27E-01
-1.487	-1.49E-01	-8.26E-01
-1.486	-1.50E-01	-8.25E-01
-1.485	-1.50E-01	-8.25E-01
-1.484	-1.50E-01	-8.24E-01
-1.483	-1.50E-01	-8.25E-01
-1.482	-1.50E-01	-8.25E-01
-1.481	-1.50E-01	-8.24E-01

0.5MHCL + 80ML EXTRACT ON LOW CARBON STEEL

POTENTIAL	**CURRENT**	**LOG(i/A)**
-1.5	7.12E-02	-1.15E+00
-1.499	6.99E-02	-1.16E+00
-1.498	6.85E-02	-1.17E+00
-1.497	6.68E-02	-1.18E+00
-1.496	6.56E-02	-1.18E+00
-1.495	6.57E-02	-1.18E+00
-1.494	6.47E-02	-1.19E+00
-1.493	6.58E-02	-1.18E+00
-1.492	6.46E-02	-1.19E+00
-1.491	6.41E-02	-1.19E+00
-1.49	6.26E-02	-1.20E+00
-1.489	6.13E-02	-1.21E+00
-1.488	6.06E-02	-1.22E+00
-1.487	6.03E-02	-1.22E+00
-1.486	6.11E-02	-1.21E+00
-1.485	6.34E-02	-1.20E+00
-1.484	6.15E-02	-1.21E+00
-1.483	6.80E-02	-1.17E+00
-1.482	6.44E-02	-1.19E+00
-1.481	6.60E-02	-1.18E+00

APPENDIX 2

Calculations

Blank Tafel (log(i/A) = -9.31E-01)

Corr. Rate =$\frac{\boldsymbol{K\ x\ icorr.\ EW}}{\boldsymbol{\rho}}$

Where K is constant (0.00327 mm/year),

Icorr. = Corrosion current density (0.1172A/cm^2)

EW = Equivalent weight of the steel

$\boldsymbol{\rho}$ = density of the steel 7.85g/cm^3

Corr. Rate = $\frac{\mathbf{0.00327\ \boldsymbol{x}\ 0.117\ \boldsymbol{x}\ 27.92}}{\mathbf{7.87}}$ = 1.35 x 10^{-3}mm/yr (Corrosion rate very high)

0.5MHCL + 20ML EXTRACT (log(i/A) = -5.74E-01)

Corr. Rate = $\frac{\boldsymbol{K\ x\ icorr.\ EW}}{\boldsymbol{\rho}}$

Where K is constant (0.00327 mm/year),

Icorr. = Corrosion current density (0.266A/cm^2)

EW = Equivalent weight of the steel

$\boldsymbol{\rho}$ = density of the steel 7.87g/cm^3

Corr. Rate = $\frac{\mathbf{0.00327\ \boldsymbol{x}\ 0.266\ \boldsymbol{x}\ 27.92}}{\mathbf{7.87}}$ = 3.1 x 10^{-3} mm/yr (Corrosion rate reduced)

0.5MHCL + 40ML EXTRACT (log(i/A) = -5.74E-01)

Corr. Rate = $\frac{\boldsymbol{K\ x\ icorr.\ EW}}{\boldsymbol{\rho}}$

Where K is constant (0.00327 mm/year),

Icorr. = Corrosion current density (0.128A/cm^2)

EW = Equivalent weight of the steel

$\boldsymbol{\rho}$ = density of the steel 7.87g/cm^3

Corr. Rate = $\frac{\mathbf{0.00327\ x\ 0.128\ x\ 27.92}}{\mathbf{7.87}}$ = 1.49 x 10^{-3} mm/yr (Corrosion rate reduced)

0.5MHCL + 60ML EXTRACT (log(i/A) = -8.35E-01)

Corr. Rate = $\frac{\boldsymbol{K\ x\ icorr.\ EW}}{\boldsymbol{\rho}}$

Where K is constant (0.00327 mm/year),

Icorr. = Corrosion current density (0.145A/cm^2)

EW = Equivalent weight of the steel

$\boldsymbol{\rho}$ = density of the steel 7.87g/cm^3

Corr. Rate = $\frac{\mathbf{0.00327\ x\ 0.145\ x\ 27.92}}{\mathbf{7.87}}$ = 1.69 x 10^{-3} mm/yr (corrosion rate reduced)

0.5MHCL + 80ML EXTRACT (log(i/A) = -1.15E+00)

Corr. Rate = $\frac{\boldsymbol{K\ x\ icorr.\ EW}}{\boldsymbol{\rho}}$

Where K is constant (0.00327 mm/year),

Icorr. = Corrosion current density (0.0.0708A/cm^2)

EW = Equivalent weight of the steel

$\boldsymbol{\rho}$ = density of the steel 7.85g/cm^3

Corr. Rate = $\frac{\mathbf{0.00327\ x\ 0.0708\ x\ 27.92}}{\mathbf{7.85}}$ = 8.23 x 10^{-4} mm/yr (Moderate Corrosion Rate)

CORROSION INHIBITOR

Blank + 0.5HCl + 80Ml Okra Leaf Extract

IE (%) = 39% (This is a moderate inhibition efficiency)

Surface Coverage = 39/100 = 0.3 (it s a moderate inhibitor efficiency)