INVESTIGATING THE INHIBITION OF CORROSION OF MILD STEEL IN CASSAVA FLUID BY SOME AMINO ACID DERIVATIVES

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CERTIFICATION

This is to certify that this project was conducted by **ADEOYE, MELODY JOESPH,** with Matriculation Number **HND/23/MET/FT/0010**, of the Department of Metallurgical Engineering, Kwara State Polytechnic, Ilorin, Nigeria, in partial fulfillment of the requirements for the award of Higher National Diploma (HND) In Metallurgical Engineering.

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DEDICATION

I dedicate this project to God Almighty, who is my creator, my helper and my strength, who has granted me wisdom and understanding, I also dedicate it to my parents who has played a great role in my education and life.

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ABSTRACT

This study investigates the inhibition of mild steel corrosion in cassava fluid, using selected amino acid derivatives: leucine, alanine, and methionine. The cassava fluid, known for its acidic as cyanic acid, accelerates the degradation of steel equipment. The research aimed to assess the corrosion rates in the presence and absence of amino acid inhibitors through a weight loss method over a 10-day exposure period.

The result obtained indicate that alanine was observed to be more efficient than leucine and methionine by providing corrosion inhibition at molar concentrations of 0.20M, 0.30M and 0.30M respectively.

The study confirms that amino acid-based inhibitors are environmentally friendly, cost-effective, and viable alternatives for protecting mild steel equipment used in agro-processing industries—particularly cassava processing—thereby improving operational longevity and reducing maintenance costs.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Corrosion is a naturally occurring phenomenon that leads to the gradual destruction of metals as a result of chemical or electrochemical interactions with their environment. It is a serious industrial problem that affects the durability, strength, and functionality of metallic materials, particularly in environments where moisture, acids, or oxygen are present (Fontana, 2005). Globally, corrosion accounts for billions of dollars in losses each year due to the cost of maintenance, equipment replacement, system failures, and safety hazards. In developing countries like Nigeria, the effect is even more pronounced in agricultural and food processing industries, where metallic equipment is exposed to aggressive organic environments without proper corrosion management strategies.

Mild steel, a widely used engineering material, is especially vulnerable to corrosion due to its low alloy content and high iron composition. Its popularity arises from its low cost, ease of fabrication, and good mechanical properties, but in corrosive environments such as those involving food fermentation, its lifespan can be significantly reduced. One such environment is cassava processing. Cassava is a staple crop in Nigeria, processed into products like garri, fufu, and starch. During fermentation and processing, cassava releases acidic compounds, cyanide derivatives, and other corrosive substances that attack mild steel components used in grating, pressing, and sieving machines (Agunsoye et al., 2014).

To mitigate this, the use of corrosion inhibitors has gained attention. Inhibitors are chemical substances that, when added in small quantities to a corrosive environment, reduce the corrosion rate of metals. Among the various classes of inhibitors, organic inhibitors — especially those derived from naturally occurring compounds — have become highly desirable due to their eco-friendly and biodegradable nature (Ahamad et al., 2010). Amino acids, in particular, are promising because of their ability to adsorb onto metal surfaces through functional groups like amine ($-NH_2$), carboxyl (-COOH), and sulfur (-S-) in the case of sulfur-containing amino acids like methionine.

This research, therefore, investigates the effectiveness of selected amino acids — alanine, valine, and methionine — as corrosion inhibitors for mild steel in cassava extract using the weight loss method. The study aims to simulate real conditions faced in cassava-processing environments and propose a green corrosion control method that is affordable and safe for the agro-industry.

1.2 Aim of the Study

The aim of this project is to investigate the inhibition of corrosion of mild steel in cassava fluid by some amino acid derivatives.

1.3 Objectives of the Study

1. To examine inhibitive characteristics of amino acids and their kinds of corrosion

2. To identify new inhibitors among some known proteinous derivatives.

3. To determine the corrosion rate of mild steel with and without the presence of amino acid inhibitors.

1.4 Scope of the Study

This project work is limited to the investigation of the corrosion behavior of mild steel in cassava extract environment and the effectiveness of selected amino acid derivatives as corrosion inhibitors, it covers specific areas in this research which include the preparation of mild steel samples for corrosion testing, extraction and preparation of cassava environment (cassava fluid or solution) to simulate real-life cassava processing conditions and the selection of some amino acid derivatives based on availability and previous research work.

The Evaluation of corrosion rate of mild steel in cassava extract both in the absence and presence of amino acid inhibitors helps in the analysis of results to determine the inhibition efficiency of the selected amino acids, which can be used in agro-allied based industries.This study will not cover other types of metals or alloys aside mild steel. It will also not focus on synthetic chemical inhibitors but will strictly consider selected amino acid derivatives as a natural alternative.

1.5 Statement of the Research Problem

Corrosion remains a persistent and costly challenge in industries that rely heavily on metallic components, particularly mild steel. In agro-processing sectors like cassava production, equipment made from mild steel is constantly exposed to acidic fluids and organic by-products that accelerate corrosion. Cassava fluid contains cyanide (Alagbe M, 2009) compounds that significantly reduce the lifespan of processing equipment through chemical attack on exposed metallic surfaces.

The result is frequent equipment failure, increased maintenance costs, risk of contamination, and potential safety hazards during food production. Chemically synthesized corrosion inhibitors are effective, often toxic, expensive, environmentally unfriendly, making them unsuitable for food-processing applications. Despite increased awareness of corrosion in food-related environments, limited research has been conducted on the use of safe, biodegradable, and food-compatible inhibitors that can be applied in cassava-rich regions like Nigeria.

This research, therefore, addresses the need for a sustainable and effective corrosion control method by investigating the use of selected amino acid derivatives — alanine, valine, and methionine — as organic inhibitors for mild steel in cassava extract. The study aims to bridge the gap between laboratory corrosion studies and practical application in agro-industrial environments.

1.6 Justification of the Study

This study is justified by the need to develop a safe, cost-effective, and environmentally friendly method for controlling corrosion in cassava-processing environments. Since cassava is a major food crop in Nigeria and mild steel is widely used in processing equipment, it is important to explore corrosion inhibitors that are non-toxic and suitable for contact with food. Amino acids, being biodegradable and naturally occurring, present a viable alternative to conventional chemical inhibitors. Investigating their effectiveness will not only contribute to corrosion science but also support local industries in reducing maintenance costs and improving food safety standards.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Corrosion of Mild Steel

The corrosion of metals, particularly mild steel, remains a significant concern across various industries, especially in environments that involve the processing of food substances, such as cassava. Cassava, a widely cultivated crop in many tropical regions, is known for its acidic properties, which can significantly contribute to the deterioration of metal surfaces in processing equipment (Adedeji et al., 2020). Given that mild steel is a common material used in many food processing industries due to its cost-effectiveness and versatility, understanding how to mitigate corrosion in these environments is crucial.

The use of corrosion inhibitors, particularly organic inhibitors, has been widely studied. Among these, amino acids and their derivatives have garnered attention for their potential to effectively inhibit corrosion in various acidic environments, including those found in cassava processing (Olusola & Ibrahim, 2018). This chapter reviews the existing literature on the corrosion of mild steel, with a focus on the corrosive effects of cassava and the role of amino acids as corrosion inhibitors.

2.2 Chemistry of Corrosion

Corrosion, at its core, is a chemical or electrochemical reaction between a material—usually a metal—and its environment, leading to the gradual deterioration of the material. For mild steel, which is composed mainly of iron (Fe), corrosion typically involves the transformation of iron into its oxidized form, such as rust (iron oxide or hydroxide), especially when in contact with acidic or moist environments (Revie & Uhlig, 2008).

There are two main categories of corrosion based on the process:

2.2.1 Chemical Corrosion

This type of corrosion involves direct chemical reactions between the metal and substances in the environment, without involving any electric current. A good example is when dry chlorine or sulfur reacts directly with a metal to form a surface layer of corrosion products. It's common in high-temperature environments like furnaces and exhaust systems.

2.2.2 Electrochemical Corrosion

This is the most common type and the one most relevant to this study.

It occurs in the presence of an electrolyte (e.g., cassava extract, water) and involves electrochemical reactions. The metal surface acts as a galvanic cell with distinct anodic and cathodic regions.

Basic Electrochemical Reaction in Acidic Environment:

In the case of mild steel (iron) in cassava extract (which contains acids like HCN), the reaction follows:

At the anode (oxidation):

$Fe \rightarrow Fe^{2+} + 2e^-$

Iron loses electrons to form ferrous ions (Fe^{2+}), which go into solution.

At the cathode (reduction):

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

The hydrogen ions from the acid gain electrons and form hydrogen gas

Overall Reaction:

$Fe + 2H^+ \rightarrow Fe^{2+} + H_2\uparrow$

This is why bubbling or fizzing is sometimes seen — it’s the hydrogen gas escaping

Formation of Iron Hydroxide in the presence of moisture and oxygen, the Fe^{2+} ions can further react to form rust (iron hydroxide)

$4Fe^{2+} + O_2 + 6H_2O \rightarrow 4Fe(OH)_3$

This $Fe(OH)_3$ is what we commonly see as reddish-brown rust.

This fundamental understanding is key to corrosion control since we know the metal is being "eaten up" by these electrochemical processes, it makes sense to either prevent the environment from triggering these reactions (e.g., coating the metal), or add substances (like amino acids) that will interfere with this reaction and form a protective layer instead.

2.3 Mechanism of Corrosion of Steel

The mechanism of corrosion in steel, particularly in environments rich in moisture and acids (like cassava extract), is predominantly electrochemical. This means corrosion occurs through a redox (reduction-oxidation) reaction involving electron transfer between metal atoms and environmental species such as hydrogen ions, oxygen, and water (Revie & Uhlig, 2008).

2.3.1 Formation of Electrochemical Cells

Corrosion begins when microscopic electrochemical cells are established on the steel surface. These cells have two regions:

1. Anodic region: Where iron atoms lose electrons and become Fe^{2+} ions (oxidation).

2. Cathodic region: Where a reduction reaction takes place, usually involving hydrogen ions or oxygen.

These regions form naturally due to imperfections in the metal's microstructure (grain boundaries, inclusions, impurities, stress zones, etc.).

2.3.2 Electrochemical Reactions on Mild Steel

In acidic environments (like cassava extract), the main reactions involved are:

At the anode:

$Fe \rightarrow Fe^{2+} + 2e^-$

Iron atoms release electrons, forming ferrous ions and creating metal loss at the anode.

At the cathode:

$2H^+ + 2e^- \rightarrow H_2\uparrow$

Hydrogen ions gain electrons and form hydrogen gas, which bubbles off.

The presence of dissolved oxygen can also contribute:

$0_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

This means that both hydrogen evolution and oxygen reduction can act as cathodic reactions.

2.3.3 Role of Electrolyte (Cassava Extract)

An electrolyte is a medium that contains free ions and conducts electric current, playing a critical role in the corrosion process. In the case of cassava processing environments, cassava extract acts as the electrolyte, facilitating the electrochemical reactions that lead to the corrosion of mild steel.

Cassava extract is naturally rich in organic acids such as citric acid, formic acid, and acetic acid, and also contains hydrogen cyanide (HCN), soluble carbohydrates, and other ionic species. These components lower the pH of the extract, creating a highly acidic environment that increases the conductivity of the medium. In such an environment, the mild steel surface becomes anodically active, and the oxidation of iron to ferrous ions (Fe^{2+}) is significantly promoted.

The cassava extract provides the necessary ionic movement between anodic and cathodic sites on the mild steel surface, completing the electrochemical cell required for corrosion to occur. Hydrogen ions (H^+) present in the acidic solution accept electrons from the metal surface at the cathodic sites, leading to the release of hydrogen gas and further dissolution of the metal at the anodic sites.

Furthermore, the presence of moisture and dissolved oxygen in cassava extract accelerates corrosion reactions by facilitating both anodic oxidation and cathodic reduction processes. The fermentation of cassava also introduces microbial activities that can indirectly influence the corrosion mechanism by altering local pH and producing additional corrosive substances.

In summary, cassava extract, acting as an electrolyte, provides the ionic conductivity, acidic medium, and chemical species required for the continuous electrochemical attack on mild steel, making it a significant contributor to corrosion in cassava processing industries.

2.3.4 Development of Corrosion Products

The Fe^{2+} ions from the anode can react with water and oxygen to form iron hydroxide:

$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$

Then: $Fe(OH)_2 + O_2 + H_2O \rightarrow Fe(OH)_3 \rightarrow Fe_2O_3 \cdot xH_2O$ (Rust)

This layered product doesn't adhere well, so it flakes off, exposing fresh metal to continue the process.

2.4 Microstructure and Nature of Mild Steel

Mild steel, also known as low-carbon steel, is widely used in industrial applications due to its good mechanical properties, weldability, and affordability. However, its microstructure plays a significant role in determining its corrosion behavior (Callister & Rethwisch, 2018).

2.4.1 Composition of Mild Steel

Mild steel typically contains 0.05% to 0.25% carbon.

It also includes small amounts of manganese, silicon, phosphorus, sulfur, and oxygen.

The low carbon content makes it softer, more ductile, and easier to machine and weld compared to high-carbon steels.

2.4.2 Phases in Mild Steel

Mild steel, also known as low-carbon steel, is composed primarily of iron with a small amount of carbon, typically between 0.05% and 0.25%. The microstructure of mild steel is made up of different phases that influence its mechanical properties, corrosion behaviour, and overall performance. These phases develop during the cooling of molten steel and depend on factors such as carbon content and thermal history.

The two major phases present in mild steel are ferrite and pearlite.

1. Ferrite is a relatively soft and ductile phase of iron with a body-centered cubic (BCC) crystal structure. It contains very little carbon (up to about 0.02%) and provides mild steel with its high formability, weldability, and magnetic properties. Ferrite appears as a light region under a microscope and is the primary matrix in which other phases are embedded.

2. Pearlite, on the other hand, is a combination of alternating layers of ferrite and cementite (iron carbide, Fe_3C). It forms as a result of the eutectoid reaction during cooling, where austenite transforms into a mixture of ferrite and cementite. Pearlite is harder and stronger than ferrite but less ductile, contributing to the overall strength and wear resistance of mild steel.

The amount and distribution of ferrite and pearlite in mild steel depend largely on its carbon content. Low-carbon steels, such as mild steel, have a higher proportion of ferrite and a smaller proportion of pearlite, resulting in a good balance between strength and ductility. However, the dominance of the soft ferrite phase also makes mild steel more susceptible to corrosion, as ferrite offers less inherent resistance to chemical attack compared to more stable phases like cementite or alloyed phases found in higher-grade steels.

2.4.3 Influence of Microstructure on Corrosion

Ferrite Phase:

Being more electropositive, ferrite tends to corrode more easily when exposed to acidic or moist environments.

It acts as an anode when exposed to electrolytes like cassava extract.

Pearlite Phase:

Pearlite is relatively more corrosion-resistant than ferrite but can still corrode under harsh conditions.

Grain Boundaries:

Grain boundaries act as weak points where corrosion can initiate faster due to differences in chemical potential across grains.

Thus, the microstructure of mild steel, particularly the high proportion of ferrite and the presence of grain boundaries, contributes significantly to its susceptibility to corrosion in acidic environments like cassava extracts.

2.4.4 Practical Implications

Understanding the microstructure helps in:

1. Choosing proper corrosion inhibitors.

2. Designing better surface treatments.

3. Predicting failure mechanisms in mild steel applications.

2.5 Corrosion in Acidic Environments: Cassava Context

Cassava (Manihot esculenta) is a staple crop in many tropical regions, prized for its high carbohydrate content. However, its processing environment presents a serious corrosion threat to metallic equipment, particularly mild steel (Ogunniyi et al., 2018).

2.5.1 Acidic Nature of Cassava

During cassava processing (especially in the fermentation stage), cassava releases various organic acids and cyanogenic compounds such as:

1. Hydrocyanic acid (HCN)

2. Citric acid

3. Acetic acid

These compounds reduce the pH of the environment, creating a highly acidic medium (often pH 4–5). This acidic nature aggressively attacks metal surfaces, leading to accelerated corrosion.

Recent studies confirms that cassava extract contains hydrogen cyanide, citric acid, acetic acid, starch, moisture, and other organic compounds that make it highly corrosive (Onyemaobi et al., 2021; Agunsoye et al., 2014). The fermentation of cassava also promotes microbial activity, further reducing pH and increasing corrosion risk (Ubalua, 2007).

2.5.2 Influence of Cassava Extract on Mild Steel

Cassava extract has a significant influence on the corrosion behaviour of mild steel, mainly due to its chemical composition and acidic nature. During cassava processing, especially after fermentation, the extract becomes rich in organic acids such as citric acid, formic acid, and acetic acid, alongside hydrogen cyanide (HCN) and soluble ions. These components create a highly aggressive environment that accelerates the corrosion process.

The low pH of cassava extract promotes an increase in the concentration of hydrogen ions (H^+), which enhances the anodic dissolution of mild steel. At the anodic sites, iron atoms lose electrons and dissolve into the solution as ferrous ions (Fe^{2+}). Meanwhile, at the cathodic sites, the hydrogen ions accept electrons and evolve as hydrogen gas. The cassava extract acts as an electrolyte that facilitates this electrochemical reaction, completing the corrosion cell.

Additionally, cassava extract often contains dissolved oxygen and moisture, both of which further contribute to the corrosion process. Oxygen reduction reactions occur at the cathodic regions, leading to the formation of iron oxides and hydroxides, commonly recognized as rust. The presence of soluble carbohydrates and microbial activities associated with cassava fermentation can also modify the local environment, introducing variations in pH and increasing corrosion aggressiveness through microbially influenced corrosion mechanisms.

Prolonged exposure of mild steel to cassava extract results in significant material degradation, surface roughening, and pitting. This deterioration compromises the structural integrity of processing equipment, leading to increased maintenance costs, frequent equipment replacement, and potential contamination of food products.

2.6 Chemical Constituents of Cassava and Their Relevance to Corrosion

Cassava (Manihot esculenta) is widely cultivated across tropical regions, especially in Nigeria, and serves as a staple crop for both human consumption and industrial processing. Chemically, the cassava tuber contains various organic and inorganic compounds that influence its properties, including its corrosive potential when processed or fermented.

The major chemical constituents of cassava tuber include carbohydrates, cyanogenic glycosides, organic acids, moisture, minerals, and minor amounts of proteins and lipids. During processing, especially fermentation, these components undergo transformations that significantly affect the pH and corrosivity of cassava extract.

Key Constituents and Their Corrosive Effects:

1. Hydrogen Cyanide (HCN):

Derived from the breakdown of cyanogenic glycosides like linamarin. HCN is acidic and toxic, contributing to the low pH and electrochemical aggressiveness of cassava extract (Ubalua, 2007).

Organic Acids (e.g., citric, formic, acetic acids):

Formed during fermentation, they lower the pH of the extract and promote both anodic and cathodic corrosion reactions (Onyemaobi et al., 2021). These acids accelerate the dissolution of iron in mild steel.

2. Starch / Carbohydrates:

While not directly corrosive, they ferment into sugars and acids, contributing indirectly to corrosion. Some starches also increase viscosity, affecting diffusion of corrosive species.

3. Moisture Content:

High water content in cassava extract increases ionic conductivity, making it easier for electrochemical reactions to occur on metal surfaces.

Minerals (e.g., Ca^{2+}, Mg^{2+}, K^+, Cl^-):

These ions support the electrical conductivity of the solution. Chloride ions in particular are known to aggravate pitting corrosion in steel surfaces.

4. Tannins / Phenolic Compounds:

Present in small amounts, they may alter microbial growth and acid production, indirectly influencing corrosiveness.

2.7 Environmental Factors Affecting Corrosion

The corrosion of mild steel is not solely dependent on the metal or its composition; it is heavily influenced by environmental factors that control the rate and nature of the corrosion process. In cassava processing environments, several key environmental conditions accelerate corrosion, making them critical to understand and control.

2.7.1 PH of the Environment

Low pH = High Corrosion Rate

The cassava extract environment is acidic, often having a pH as low as 4–5, especially during fermentation. Acidic conditions increase the concentration of hydrogen ions (H^+), which participate in cathodic reactions and speed up the oxidation of iron.

The lower the pH, the more aggressive the environment becomes to mild steel.

2.7.2 Temperature

Increased Temperature = Faster Reaction

Higher temperatures accelerate the kinetics of electrochemical reactions, causing corrosion rates to rise. In cassava processing (boiling, fermentation), local heat zones can increase susceptibility.

Effect on Inhibitor Performance

Temperature also affects the adsorption of inhibitors like amino acids — too much heat can reduce their effectiveness.

2.7.3 Moisture and Humidity

Water is a key part of the corrosion process because it acts as an electrolyte.

High humidity increases the availability of water on the steel surface, especially in storage areas, creating conditions for rust formation even without full immersion.

2.7.4 Oxygen Concentration

Oxygen plays a major role at the cathodic site of the corrosion process. More oxygen = more rust, especially in environments that combine air + moisture + acids (like grated cassava mash or cassava juice).

2.7.5 Time of Exposure

Prolonged exposure to corrosive environments allows the electrochemical reactions to continue without interruption, leading to deeper penetration of rust and weakening of the metal over time. Even short exposures, if frequent, can initiate long-term damage.

2.7.6 Concentration of Corrosive Species

High levels of chloride ions, cyanides, and organic acids in cassava extract increase the corrosivity. These ions break down passive films on the steel surface, making the metal more vulnerable.

2.8 Types of Corrosion

Corrosion does not occur in a single manner; rather, it presents itself in different forms depending on the nature of the metal, the environment, and the corrosive agents involved. Understanding the different types of corrosion is crucial to identifying the best method of prevention and control in cassava processing environments.

1. Uniform Corrosion: Uniform corrosion is the most common form of corrosion where the metal surface is attacked at a consistent rate across a large area. It results in the even thinning of the metal and generally leads to predictable material loss. In cassava processing equipment, this type of corrosion is expected where surfaces are continuously exposed to cassava extract without proper protection.

2. Pitting Corrosion: Pitting corrosion is a localized form of corrosion that leads to the formation of small holes or pits on the metal surface. It is particularly dangerous because it can cause unexpected equipment failure even if the majority of the surface appears unaffected. Pitting is often triggered by the presence of chloride ions aProceeagnant acidic solutions, both of which can be found in fermented cassava environments.

3. Galvanic Corrosion: Galvanic corrosion occurs when two dissimilar metals are electrically connected in the presence of an electrolyte, causing the more active metal to corrode faster. In cassava processing plants, if mild steel components are connected to stainless steel parts without proper insulation, galvanic corrosion can severely damage the mild steel.

4. Crevice Corrosion: Crevice corrosion arises in confined spaces such as under gaskets, washers, lap joints, or deposits where stagnant solutions can collect. The cassava environment can easily create such crevices, especially in improperly cleaned or poorly designed equipment, leading to rapid localized corrosion in hidden areas.

5. Stress Corrosion Cracking (SCC): Stress corrosion cracking is a serious form of corrosion that involves the combined action of tensile stress and a corrosive environment, resulting in the formation of cracks. Although less common in cassava processing industries, SCC can occur in welded joints, bent pipes, or pressure vessels exposed to acidic cassava by-products over time.

2.9 Corrosion Control and Prevention

Preventing corrosion is critical in cassava processing environments to ensure equipment longevity, product safety, and operational efficiency. Various methods exist to control or prevent corrosion, and the most effective strategies often involve a combination of these methods rather than relying on just one (Revie & Uhlig, 2008).

2.9.1 Design and Proper Material Selection

1. Designing for Drainage: Avoiding fluid traps by ensuring smooth curves, sloped surfaces, and drain holes helps prevent moisture buildup that leads to crevice corrosion.

2. Avoiding Dissimilar Metals: Prevent galvanic corrosion by using metals of similar nobility (e.g., don’t pair mild steel with stainless steel without isolation).

3. Selecting the Right Materials: Use of more corrosion-resistant metals or alloys like stainless steel, plastic linings, or coated steels can minimize direct exposure.

4. Economic Consideration: In cassava processing, mild steel is common due to cost, but material selection should balance cost, corrosion resistance, and maintenance needs.

2.9.2 Alteration of Environment

Alteration of the environment is one of the most effective strategies for controlling corrosion, particularly in aggressive media such as cassava extract. Since corrosion is highly dependent on the chemical and physical conditions surrounding the metal surface, modifying these environmental factors can significantly reduce the rate and severity of corrosion.

One major approach to altering the environment involves adjusting the pH. In highly acidic media like cassava extract, corrosion rates are typically high due to the abundance of hydrogen ions. By neutralizing the environment through the addition of alkaline substances, the concentration of hydrogen ions can be reduced, thereby slowing down the electrochemical reactions responsible for corrosion.

Another method is the reduction of moisture and oxygen content. Water acts as an electrolyte that enables the movement of ions, while dissolved oxygen serves as a reactant at the cathodic sites. By minimizing moisture through proper drying of equipment and limiting oxygen exposure, the overall corrosion process can be controlled.

Temperature control is also an important environmental alteration technique. Since corrosion reactions tend to accelerate with an increase in temperature, maintaining a lower, stable temperature around cassava processing equipment can reduce corrosion rates.

In cassava processing industries, regular rinsing of equipment with clean water or mild alkaline solutions after use can help flush out residual acidic substances, thereby altering the immediate environment on the metal surface and preventing prolonged exposure to corrosive agents.

By implementing these environmental alteration techniques alongside other corrosion prevention methods, the lifespan of mild steel equipment used in cassava processing can be extended, and operational efficiency can be improved.

2.9.3 Application of Inhibitors

Inhibitors are chemicals added to the environment to slow or prevent corrosion. Organic inhibitors (like amino acids) adsorb onto the steel surface to form a protective barrier.

In this project, amino acid derivatives are studied as natural, eco-friendly alternatives to synthetic inhibitors.

2.9.4 Cathodic Protection

Impressed Current or Sacrificial Anode systems are used to make mild steel the cathode of an electrochemical cell, preventing it from corroding.

While mostly used in pipelines and buried structures, it’s also applicable in large cassava processing plants using submerged tanks or equipment.

2.9.5 Application of Coatings

Inhibitors are substances that reduce the corrosion rate when added to a corrosive environment (Popova et al., 2003).

1. Metallic Coatings: Zinc (galvanizing), aluminum, or chrome coatings can offer excellent corrosion resistance.

2. Non-Metallic Coatings: Paints, enamels, and epoxy resins create physical barriers between the metal and corrosive agents. Coatings are often used alongside other methods like inhibitors for better protection.

2.10 Corrosion Inhibitors

Corrosion inhibitors are substances added in small concentrations to a corrosive environment to significantly reduce or prevent the corrosion of metals. They are widely used in industrial applications as a cost-effective and adaptable method of corrosion control, especially where equipment is exposed to aggressive media like cassava extract (Ibrahim & Adebayo, 2017).

2.10.1 How Corrosion Inhibitors Work

Corrosion inhibitors function by interfering with the electrochemical reactions responsible for the deterioration of metals in corrosive environments. They achieve this by adsorbing onto the metal surface and forming a protective layer that isolates the metal from the aggressive environment, thereby reducing the rate of corrosion.

The mechanism by which corrosion inhibitors work generally falls into three main categories. First, they can block anodic reactions by preventing the oxidation of metal atoms into metal ions, thereby slowing the rate at which the metal dissolves. Secondly, they can suppress cathodic reactions by inhibiting the reduction processes, such as the reduction of hydrogen ions to hydrogen gas or the reduction of oxygen to hydroxide ions. Thirdly, some inhibitors function by forming a barrier film over the entire metal surface, reducing the transport of corrosive species like oxygen, hydrogen ions, or chloride ions to the metal.

Organic inhibitors, such as amino acid derivatives, typically act by adsorbing through their functional groups like amine ($-NH_2$), carboxyl (-COOH), hydroxyl (-OH), or sulfur (-S-) groups. This adsorption is either physical (physisorption), involving weak van der Waals forces, or chemical (chemisorption), involving the formation of coordinate bonds between the inhibitor molecules and the metal surface atoms. The result is a continuous, adherent film that protects the steel from direct attack by the environment.

In the case of cassava extract, which contains acidic compounds and moisture that promote corrosion, the presence of an effective inhibitor like alanine, valine, or methionine significantly slows down the metal degradation process by minimizing direct contact between the steel and the corrosive medium.

2.10.2 Types of Corrosion Inhibitors

1. Anodic Inhibitors

Anodic inhibitors are chemical compounds that control corrosion by affecting the anodic reaction in the corrosion process. These inhibitors promote the formation of a thin, passive oxide layer on the surface of the mild steel, thereby reducing the rate at which metal ions are released into the environment. By encouraging passivation, anodic inhibitors slow down or completely suppress the dissolution of the metal, making it more resistant to aggressive attack from corrosive agents present in the environment.

Examples of anodic inhibitors include chromates, phosphates, and molybdates. These compounds react with the metal surface, often forming complex oxide films such as iron oxide (Fe_2O_3) or ferric phosphate, which serve as a barrier against further corrosion. For instance, phosphate-based inhibitors are commonly used in industrial water treatment systems, cooling towers, and boilers where metal equipment needs protection from acidic or corrosive media.

In the context of cassava processing environments, where the mild steel equipment is exposed to acidic cassava extract, the use of anodic inhibitors can theoretically provide a protective film on the steel surfaces. However, due to environmental concerns and food safety regulations, especially relating to chromates which are toxic, the application of anodic inhibitors in food processing industries is limited. Instead, safer alternatives like organic inhibitors are often preferred.

2. Cathodic Inhibitors

Cathodic inhibitors are substances that slow down the corrosion process by interfering with the cathodic reaction, which typically involves the reduction of hydrogen ions or dissolved oxygen on the metal surface. These inhibitors work by either decreasing the availability of cathodic reactants, such as oxygen, or by precipitating onto the cathodic areas of the metal, thus blocking further electron transfer and reducing the overall corrosion rate.

Typical examples of cathodic inhibitors include zinc salts, polyphosphates, and calcium salts. These compounds often form insoluble precipitates like zinc hydroxide or calcium carbonate on the metal surface, particularly at cathodic sites, thereby impeding the access of hydrogen ions or oxygen needed to sustain the corrosion reaction. Cathodic inhibitors are widely used in systems like pipelines, water cooling systems, and boilers where protection against uniform corrosion is essential.

In cassava processing environments, the use of cathodic inhibitors could theoretically help by reducing the oxygen reduction reactions that accelerate corrosion in acidic cassava extract. However, similar to anodic inhibitors, the choice of cathodic inhibitors in food-related industries must consider environmental friendliness and food safety, which limits the use of certain inorganic compounds.

3. Mixed inhibitors

These are chemical compounds that act simultaneously on both the anodic and cathodic sites of a metal surface to control corrosion. Rather than targeting only the metal dissolution process or the cathodic reduction reaction, mixed inhibitors interfere with both processes, making them highly effective in reducing the overall corrosion rate. They achieve this by adsorbing onto the metal surface, forming a protective film that blocks active corrosion sites and reduces the movement of corrosive agents like hydrogen ions and oxygen molecules.

Examples of mixed inhibitors include organic compounds such as amino acids, plant extracts, and some synthetic organic molecules like imidazoles and triazoles. These substances typically contain functional groups such as amines ($-NH_2$), carboxyls ($-COOH$), or hydroxyls ($-OH$), which allow them to attach firmly to metal surfaces and form stable, corrosion-resistant layers.

In cassava processing environments, mixed inhibitors like amino acids are particularly useful because they can protect mild steel against the acidic and oxygenated conditions present in fermented cassava extract. By simultaneously reducing both metal ion release and oxygen reduction reactions, mixed inhibitors offer a more comprehensive corrosion protection strategy compared to inhibitors that target only one side of the electrochemical reaction.

4. Organic Inhibitors

Organic inhibitors are corrosion inhibitors that are composed mainly of carbon-containing compounds. They function by adsorbing onto the metal surface and forming a protective, hydrophobic film that acts as a barrier between the metal and the corrosive environment. This adsorption is often facilitated by the presence of functional groups such as amine ($-NH_2$), carboxyl

(-COOH), hydroxyl (-OH), and sulfur-containing groups (-S-) within the molecular structure of the organic compounds.

Organic inhibitors are particularly attractive because of their ability to offer good corrosion protection while being biodegradable, non-toxic, and environmentally friendly. Their mode of action typically involves either physical adsorption through electrostatic interactions or chemical adsorption involving the sharing or transfer of electrons between the inhibitor molecules and the metal surface.

Examples of organic inhibitors include amines, aldehydes, urea derivatives, and plant extracts rich in tannins or flavonoids. In recent years, the use of amino acid derivatives as organic inhibitors has gained significant attention due to their unique structural advantages and eco-friendly nature.

In this study, three amino acids — Alanine, Valine, and Methionine — are selected as organic corrosion inhibitors for mild steel in cassava extract. These amino acids possess both amine and carboxyl functional groups, which allow strong interaction with the steel surface, leading to the formation of a protective film that minimizes corrosion. Methionine, in particular, contains a sulfur atom in its side chain, which enhances its adsorption capability and makes it a more effective inhibitor compared to simpler amino acids like alanine. Valine, with its branched structure, and alanine, with its smaller, highly soluble structure, also contribute significantly to surface protection, though to varying degrees.

The use of amino acids aligns well with the goals of ensuring food safety, environmental protection, and operational efficiency in industries such as cassava processing, where direct metal contact with food products occurs.

5. Inorganic Inhibitors

Inorganic inhibitors are corrosion inhibitors that are primarily composed of mineral-based or metallic compounds. Unlike organic inhibitors that rely on carbon-based structures, inorganic inhibitors function by altering the electrochemical environment around the metal surface. They often work by forming insoluble precipitates that either passivate the anodic sites, block cathodic sites, or modify the corrosive medium to make it less aggressive towards the metal.

Common examples of inorganic inhibitors include chromates, nitrites, phosphates, silicates, and molybdates. These compounds can react with the metal ions released during the corrosion process to form stable, adherent films such as metal oxides or metal phosphates. For instance, chromate ions react with iron to form a passive chromium-iron oxide film that significantly reduces further corrosion. Similarly, phosphates are widely used in industrial cooling water systems to form protective iron phosphate layers.

In applications where environmental and food safety concerns are not primary issues, inorganic inhibitors are highly valued for their high efficiency and durability. However, some inorganic inhibitors, particularly chromates, have raised environmental and health concerns due to their toxicity. As a result, their use has been restricted or banned in several countries, especially in industries involving food contact or environmentally sensitive areas.

In cassava processing environments, the application of inorganic inhibitors would generally be limited due to the need for non-toxic and biodegradable options. Therefore, safer alternatives like organic inhibitors, including amino acid derivatives, are preferred for corrosion control where contact with food products is possible.

2.10.3 Why Organic Inhibitors (Like Amino Acids)?

The use of organic inhibitors, particularly amino acids, in preventing corrosion of mild steel in cassava extract is both scientifically effective and practically suitable for agro-processing industries. Cassava fluid, especially after fermentation, becomes highly acidic due to the presence of organic acids like citric acid, formic acid, and hydrogen cyanide (HCN). These acidic compounds aggressively attack mild steel surfaces, leading to material degradation, equipment failure, and potential contamination of food products (Agunsoye et al., 2014)

Organic inhibitors such as amino acids offer a safer and more environmentally acceptable alternative to traditional inorganic inhibitors like chromates and phosphates, which are often toxic and unsuitable for food-related applications. Amino acids are naturally occurring biomolecules that are non-toxic, biodegradable, and water-soluble, making them ideal for corrosion inhibition in environments where food safety is a priority (Ahamad et al., 2010; Iroha et al., 2021).

The corrosion inhibition mechanism of amino acids is based on their ability to adsorb onto the steel surface through their functional groups, such as the amine group (-NH_2), carboxyl group (-

COOH), and, in some cases, sulfur-containing side chains (e.g., in methionine). This adsorption leads to the formation of a protective film on the steel surface, which acts as a barrier, preventing the interaction between the metal and corrosive species present in the cassava extract (Onyemaobi et al., 2021).

In addition, amino acids can act as mixed-type inhibitors, meaning they interfere with both the anodic metal dissolution and the cathodic reduction of hydrogen ions. This dual action enhances their overall efficiency and makes them effective in a complex environment like cassava fluid, where multiple corrosive agents are present (Popova et al., 2003).

Using amino acids as inhibitors also aligns with the principles of green chemistry and sustainable engineering. Since cassava is a food crop, it is essential to use inhibitors that do not pose health or environmental risks. Amino acid-based inhibitors meet this requirement and can be integrated easily into small- and medium-scale processing setups without complex handling or disposal concerns (Adejo et al., 2020).

2.11 Gaps in Literature

Despite significant progress in the study of corrosion and the use of inhibitors to mitigate it, several gaps still exist in the literature, particularly concerning the corrosion of mild steel in cassava processing environments and the application of amino acid derivatives as inhibitors. Highlighting these gaps provides the justification for this research work and underscores the importance of investigating eco-friendly corrosion control methods under local, agro-industrial conditions. Few studies have investigated the corrosion of mild steel in cassava extract using amino acid derivatives, especially under Nigerian tropical conditions (Onyemaobi et al., 2021; Iroha et al., 2021).

2.11.1 Limited Studies on Cassava-Specific Corrosion

Most corrosion studies available in literature focus on traditional, synthetic acidic environments such as hydrochloric acid (HCl), sulfuric acid (H_2SO_4), or nitric acid (HNO_3). There is a notable lack of studies specifically addressing corrosion in natural agro-industrial media such as cassava extract, which presents a unique combination of organic acids, cyanides, and fermentation by-products. The complex chemistry of cassava effluent creates a different corrosion mechanism that remains underexplored.

2.11.2 Few Investigations Using Amino Acids in Natural Media

While numerous researches have studied amino acids as corrosion inhibitors in synthetic acid environments, only very few have applied these inhibitors in natural media like cassava filtrate. The effectiveness of amino acids can vary significantly between clean, controlled environments and real-world natural environments that contain mixed organic and inorganic species, microorganisms, and fluctuating pH levels. There remains a gap in validating the performance of amino acids under these more practical conditions.

2.11.3 Lack of Comparative Studies Between Different Amino Acids

Although various amino acids have individually been studied for their corrosion inhibition properties, comprehensive comparative studies evaluating multiple amino acids (such as alanine, valine, and methionine) under the same environmental conditions are still scarce. Understanding how molecular structure (e.g., presence of sulfur atoms, side chain branching) influences inhibition efficiency remains incomplete and requires further investigation.

2.11.4 Insufficient Focus on Food-Safe Corrosion Inhibitors

Many industrial corrosion inhibitors, including chromates and phosphates, are highly efficient but pose serious health and environmental risks. In the context of food-processing industries like cassava production, there is an urgent need for inhibitors that are non-toxic, biodegradable, and safe for human consumption. Literature on food-safe, organic inhibitors suitable for agro-industrial environments is still developing and remains insufficiently covered

2.11.5 Few Studies Conducted Under Nigerian and Tropical Conditions

Corrosion behavior is heavily influenced by environmental factors such as temperature, humidity, and local water chemistry. Many studies are conducted under temperate, laboratory-controlled conditions that do not accurately reflect the humid, high-temperature conditions found in tropical regions like Nigeria, where cassava processing is predominant. There is a gap in region-specific studies that account for these tropical realities.

2.12 Economic Importance of Corrosion Control

Corrosion in cassava processing industries isn't just a scientific problem — it’s a financial burden. The degradation of mild steel components due to the acidic nature of cassava extract leads to high maintenance costs, frequent equipment replacement, and potential contamination of food products. Understanding the economic impact of corrosion helps highlight the practical value of using effective inhibitors like amino acids.

Corrosion control has a significant economic impact by reducing maintenance costs, preventing equipment failure, and improving productivity (NACE International, 2016).

CHAPTER THREE

3.0 EXPERIMENTAL PROCEDURE

3.1 Materials

Cyanic acid solution used in this study was extracted directly from cassava tubers. The tubers were initially peeled, thoroughly washed, and mechanically grated. The resulting pulp was sieved and then subjected to hydraulic pressing to obtain the organic acid extract.

The mild steel samples employed for the experiment were sourced from the steel market in Ilorin. Their chemical composition was determined using an emission spectrometer. The results of the analysis are presented in Table 3.1. Each mild steel sample was machined into cylindrical shapes with a length of 40 mm and a diameter of 5 mm using a precision cutting machine. The specimens were then sequentially polished with silicon carbide abrasive papers of grit sizes 220, 320, 400, and 600 to achieve a smooth surface finish. After polishing, the samples were rinsed with distilled water and subsequently air-dried to prepare them for testing.

Table 3.1: Chemical Analysis of the Mild Steel Sample

S/N	Element	Composition (%)
1	Carbon (C)	0.20
2	Manganese (Mn)	0.75
3	Silicon (Si)	0.30
4	Sulphur (S)	0.04
5	Phosphorus (P)	0.05
6	Chromium (Cr)	0.10
7	Copper (Cu)	0.25
8	Nickel (Ni)	0.20
9	Lead (Pb)	0.30
10	Nitrogen	0.25
11	Iron (Fe)	Balance

3.1.1 Weight Loss Test Specimen

Weight loss test specimens were from the samples whose compositions are given above. The original cylindrical rods were cut into short pieces having a cross section of 5mm and a gauge length of ‘40mm and their surfaces were given similar surface finishes using the same grades of emery papers for each sample. The specimens were then kept in soluble oil to prevent oxidation.

The original cylindrical rod was cut into twenty pieces having a cross section of 8mm. they were then fabricated and cleaned for the test.

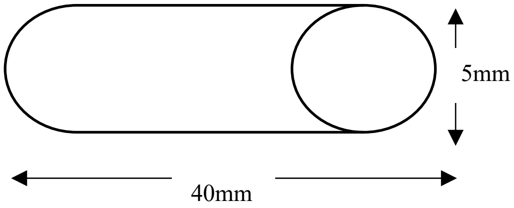

Fig. 3.1 Weight Loss Specimen

3.2 Corrosion Environments and Inhibitors

3.2.1. Environments

(i) Cassava juice was obtained from fresh cassava tubers which were grated and squeezed.

3.2.2. Inhibitors

The inhibitors used were amino acid derivatives:

(i) Leucine $(CH_3)_2CH.CH_2CH(NH2)COOH$
(ii) Alanine CH, CH(NH2)COOH
(iii) Methionine CH.S. (CH2)2CH(NH2)COOH

These four inhibitors were used at room temperature throughout the period of the experiments.

3.3 Preparation of Weight Loss Setup

For the weight loss tests, the specimens were suspended in the media by means of threads. This was to ensure the specimens were completely immersed in the acid solutions.

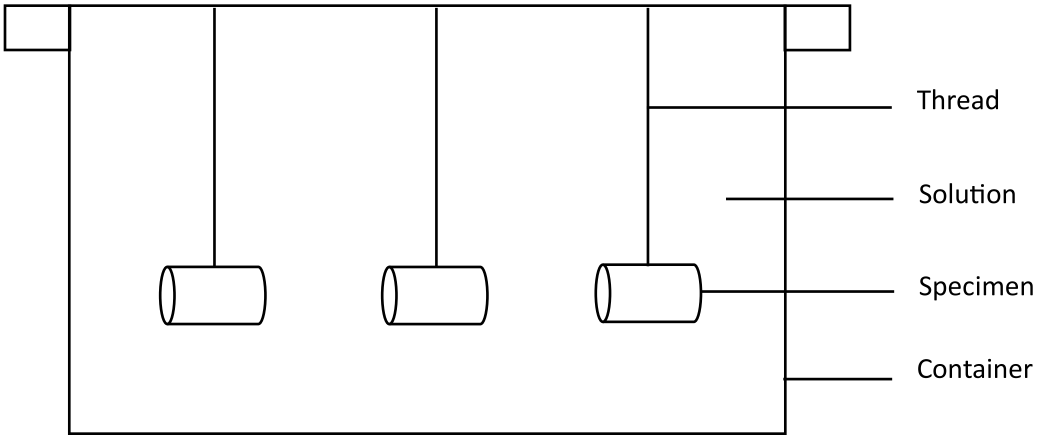

Figure 3.1 Schematic view of the weight loss immersion setup.

3.4 Calculations

The following calculations were done for the preparation of different concentrations of (i) leucine, (ii) alanine, (iii) methionine

For Leucine

Molecular weight $(CH_3)_2$ CH. CH.CH $(NH)_2$.COOH = 131.18g of leucine

1.00M leucine solution = 131.18grams/liter of leucine

0.10M leucine solution = 13.118grams/liter

0.10M = 0.656gram/50ml solution

0.05M = 0.328gram/50ml solution

0.20M = 1.312grams/50ml solution

0.30M = 1.968grams/50ml solution

0.40M = 2.624grams/50ml solution

For Alanine

Molecular weight of alanine CH_3 . CH (NH). COOH = 89.10g

1.00M alanine solution = 89.10grams/liter of Alanine

0.10M alanine solution = 8.910grams/liter

0.10M = 0.446gram/50ml solution

0.05M = 0.223gram/50ml solution

0.20M = 0.891gram/50ml solution

0.30M = 1.337grams/50ml solution

0.40M = 1.782grams/50ml solution

For Methionine

Molecular weight of methionine

CH_3 S. $(CH_2)_2$ $CH(NH_2)$. COOH = 149.219

1.00M methionine solution = 149.21grams/liter of Methionine

0.10M methionine solution = 14.921grams/liter

0.10M = 0.746mm/50ml solution

0.05M = 0.373gram/50ml solution

0.20M = 1.492grams/50ml solution

0.30M = 2.238grams/50ml solution

0.40M = 12.984grams/50ml solution

3.4 Corrosion Tests

The corrosion tests were carried out in the laboratory using weight loss method, for steel sample specimens immersed in cassava fluids separately with and without corrosion inhibitors to study the extent of corrosion at the surface condition.

The, different environments at which these tests were carried out are:

I. Cassava fluid without inhibitor
II. Solution of five different concentrations of leucine inhibitor in cassava fluids separately,
III. Solution of five different concentrations of alanine inhibitor in cassava fluids separately,

IV. Solution of five different concentrations of methionine inhibitor in cassava fluids separately.

3.5 Exposure Test

Specimens were removed from soluble oil, washed under a running tap water, degreased in benzene and dried. Before weighing, the specimens were left in the desiccator for 2 days to allow the oxide film on the surface reach steady state.

Specimens were weighed in turn and their original weight recorded. Five were then placed in each of the fluids. They were suspended in the solution with the aid of strings hanging from rigid-sticks placed across the top of the containers. This approach was adopted to ensure that all the surface of each specimen was surrounded by the fluid. In order to minimize change in concentration of the fluids arising from evaporation, each container was partly covered. For each container, the specimens were removed after every 2 days and weighed after cleaning off the corrosion products and dried. This process lasted 10 days.

The cleaning of the specimens at the end of each 2days was done by scrubbing under a running tap water using fine emery papers.

CHAPTER FOUR

4.0 RESULTS, OBSERVATION AND DISCUSSION

4.1 Results

Table 4.1 shows the corrosion rate in cassava fluid without inhibitor.

Table 4.2a, b, c, d, and e show the weight loss in cassava fluid in the presence of 0.05m, 0.10m, 0.20m, 0.30m and 0.40m concentration of leucine inhibitor.

Table 4.3a, b, c, d, and e show the weight loss in cassava fluid in the presence 0.05m, 0.10m, 0.20m, 0.30m and 0.40m concentration of alanine inhibitor.

Table 4.4a, b, c, d and e show the weight loss in cassava fluid in the presence 0.05m, 0.10m, 0.20m, 0.30m and 0.40m concentration of methionine inhibitor.

Figure 4.1 shows the effect of leucine inhibitor of mild steel corrosion in cassava fluid.

Figure 4.2 shows the effect alanine of inhibitor of mild steel corrosion in cassava fluid.

Figure 4.3 show the effect of methionine inhibitor of mild steel corrosion in cassava fluid.

4.2 Observation

The experimental procedures employed weight loss analysis to investigate the corrosion behavior of mild steel in cassava fluid, both in the absence and presence of various concentrations of amino acid inhibitors—specifically leucine, alanine, and methionine. The test specimens were exposed to the cassava fluid for a period of 10 days, with weight measurements taken at 2-day intervals to determine the extent of material degradation.

1. Baseline Observation (Cassava Fluid without Inhibitor): Mild steel specimens exposed to cassava fluid without any inhibitor showed a steady and significant loss in weight over the 10-day period. The corrosion rate (in mpy) was highest in the early exposure days and gradually reduced over time. This reduction is attributed to the formation of corrosion products on the steel surface, which may have partially hindered further metal dissolution.
2. Leucine as Inhibitor: The inclusion of leucine at various molar concentrations (0.05 M to 0.40 M) resulted in a noticeable reduction in corrosion rate compared to the uninhibited system. At lower concentrations (0.05 M and 0.10 M), the inhibition was moderate. The

inhibition efficiency increased significantly at concentrations between 0.20 M and 0.30 M. Beyond 0.30 M (i.e., at 0.40 M), the corrosion rate did not decrease appreciably, suggesting a saturation point where additional leucine had no further protective effect.

3. Alanine as Inhibitor: Similar to leucine, alanine inhibited corrosion progressively with increasing concentration. A substantial decrease in corrosion rate was observed between 0.05 M and 0.20 M. However, beyond 0.20 M, the rate of inhibition plateaued, indicating that alanine's adsorption on the metal surface reached its maximum effective coverage at this point.
4. Methionine as Inhibitor: Methionine displayed behavior similar to leucine: A consistent decrease in corrosion rate was recorded from 0.05 M up to 0.30 M. Beyond 0.30 M (at 0.40 M), the rate of corrosion reduction was minimal, pointing again to a saturation point in the adsorption of the inhibitor on the steel surface.

Table 4.1: Corrosion rate in Cassava Fluid Without Inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	17.3562	17.3243	0.0319	29.0272
4	17.1923	17.1322	0.0601	27.4807
6	16.9033	16.8220	0.0813	24.6615
8	17.4520	17.3640	0.0880	20.0599
10	16.6254	16.5316	0.0938	17.0713

Table 4.2a: Weight Loss in Cassava Fluid in the Presence of 0.05M Concentration of Leucine Inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.6470	16.6213	0.0257	23.3736
4	16.7000	16.6616	0.0384	17.4593
6	17.1098	17.0571	0.0527	15.9871
8	16.5426	16.4625	0.0801	18.2205
10	16.6948	16.6139	0.0809	14.6865

Table 4.2b: Weight Loss in Cassava Fluid in the Presence of 0.10M Concentration of Leucine Inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	17.2350	17.2099	0.0251	22.8404
4	16.4080	16.3724	0.0356	16.2001
6	17.0337	16.9821	0.0516	15.6489
8	17.2542	17.1807	0.0735	16.7180
10	16.9707	16.8966	0.0741	13.4735

Table 4.2c: Weight Loss in Cassava Fluid in the Presence of 0.20M Concentration of Leucine Inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.4840	16.4600	0.0240	21.8421
4	17.2650	17.2300	0.0350	15.9226
6	16.5463	16.4991	0.0472	14.2822
8	16.5009	16.4393	0.0616	14.0122
10	16.7959	16.7330	0.0629	11.4454

Table 4.2d: Weight Loss in Cassava Fluid in the Presence of 0.30M Concentration of Leucine Inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.4251	16.4044	0.0207	18.8385
4	16.5578	16.5268	0.0310	14.1057
6	16.4291	16.3880	0.0411	12.4674
8	16.9341	16.8839	0.0502	11.4173
10	16.4922	16.4405	0.0517	9.4043

Table 4.2e: Weight Loss in Cassava Fluid in the Presence of 0.40M Concentration of Leucine Inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.4524	16.4322	0.0202	18.3791
4	16.4500	16.4200	0.0300	13.6494
6	17.0413	17.0010	0.0403	12.2251
8	17.0779	17.0284	0.0495	11.2632
10	16.8033	16.7527	0.0506	9.2094

Table 4.3a: Weight Loss in Cassava Fluid in the Presence 0.05M Concentration of Alanine inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.9224	16.8975	0.0248	22.5717
4	16.7619	16.7229	0.0390	17.7420
6	16.8523	16.7989	0.0534	16.2002
8	17.3310	17.2500	0.0810	18.4220
10	17.2236	17.1404	0.0832	15.1395

Table 4.3b: Weight Loss in Cassava Fluid in the Presence of 0.10M Concentration of Alanine inhibitor. Area 2rl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	17.1238	17.1010	0.0228	20.7520
4	17.2145	17.1782	0.0363	16.4992
6	17.2088	17.1586	0.0502	15.2233
8	17.0984	17.0317	0.0667	15.1745
10	16.5858	16.5160	0.0698	12.6827

Table 4.3c: Weight Loss in Cassava Fluid in the Presence of 0.20M Concentration of Alanine inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.5561	16.5378	0.0183	16.6375
4	17.1736	17.3477	0.0259	11.7963
6	17.3902	17.3500	0.0402	12.1929
8	16.6504	16.6022	0.0482	10.9654
10	17.3149	17.2659	0.0490	8.9196

Table 4.3d: Weight Loss in Cassava Fluid in the Presence of 0.30M Concentration of Alanine inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.8627	16.8450	0.0177	16.0911
4	17.3377	17.3127	0.0250	11.3763
6	16.8266	16.7875	0.0391	11.8616
8	17.3129	17.2650	0.0479	10.8889
10	16.9024	16.8549	0.0475	8.6447

Table 4.3e: Weight Loss in Cassava Fluid in the Presence of 0.40M Concentration of Alanine inhibitor. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.7419	16.7244	0.0175	15.9582
4	17.1984	17.1739	0.0245	11.1717
6	16.6326	16.5937	0.0389	11.8236
8	17.0712	17.0248	0.0464	10.5778
10	17.2010	17.1548	0.0462	8.4267

Table 4.4a: Weight Loss in Cassava Fluid in the Presence of 0.05M Concentration Inhibitor of Methionine. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.8565	16.8300	0.0265	24.1209
4	17.2865	17.2474	0.0391	17.7852
6	16.9576	16.8834	0.0742	22.4485
8	17.1519	17.0723	0.0796	18.0806
10	16.5100	16.4298	0.0802	14.5966

Table 4.4b: Weight Loss in Cassava Fluid in the Presence of 0.10M Concentration Inhibitor of Methionine. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	17.3474	17.3215	0.0259	23.5354
4	17.2916	17.2538	0.0378	17.1829
6	17.0811	17.0300	0.0511	15.4857
8	16.4869	16.4247	0.0722	16.4048
10	16.4878	16.4128	0.0750	13.6389

Table 4.4c: Weight Loss in Cassava Fluid in the Presence of 0.20M Concentration Inhibitor of Methionine. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.6221	16.5969	0.0252	22.9777
4	16.4615	16.4250	0.0365	16.6447
6	17.2271	17.1773	0.0498	15.1376
8	17.1931	17.1300	0.0631	14.3867
10	16.7105	16.6465	0.0640	11.6729

Table 4.4d: Weight Loss in Cassava Fluid in the Presence of 0.30M Concentration Inhibitor of Methionine. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	17.2808	17.2575	0.0233	21.2477
4	16.5244	16.4943	0.0301	13.7239
6	16.7904	16.7462	0.0442	13.4354
8	17.2635	17.2111	0.0524	11.9433
10	17.3900	17.3368	0.0532	9.7023

Table 4.4e: Weight Loss in Cassava Fluid in the Presence of 0.40M Concentration Inhibitor of Methionine. Area = 2πrl = 10.05cm²

Days of Exposure	Original Weight (gm)	New Weight (gm)	Weight Loss (gm)	Mils Per Year (mpy)
2	16.6058	16.5828	0.0230	20.9401
4	16.7802	16.7500	0.0302	13.7346
6	16.6246	16.5817	0.0429	13.0637
8	16.6697	16.6188	0.0509	11.5776
10	16.7983	16.7470	0.0513	9.3376

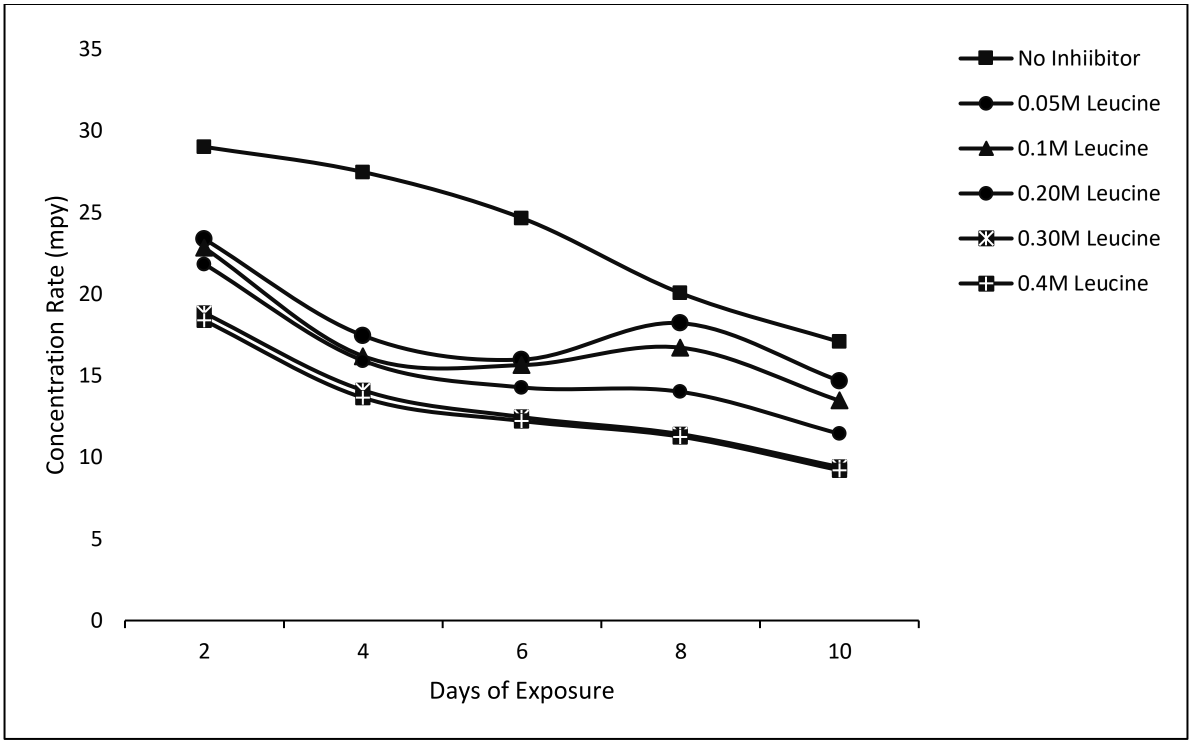

Figure 4.1 Effect of Leucine Inhibitor of mild steel corrosion in Cassava fluid

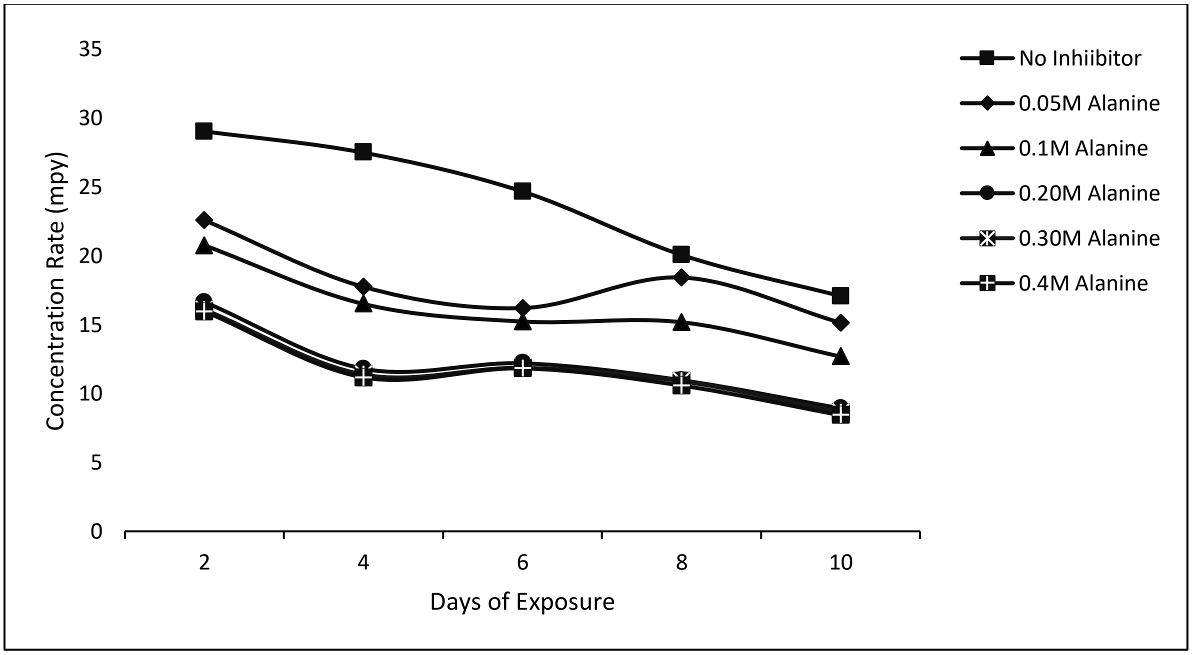

Figure 4.2 Effect of Alanine Inhibitor of Mild Steel Corrosion in Cassava Fluid

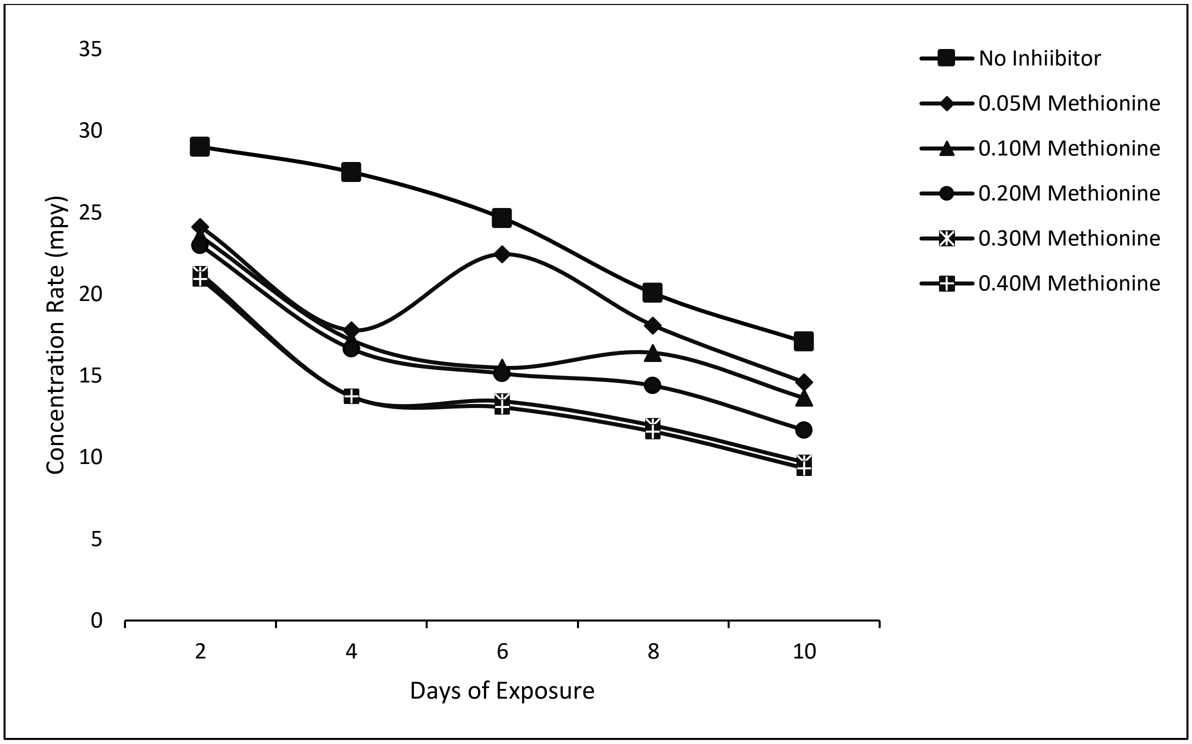

Figure 4.3 Effect of Methionine Inhibitor of Mild Steel Corrosion in Cassava fluid

4.3 Discussion of Result

This research has demonstrated that the corrosion of mild steel in cassava fluid—a highly aggressive environment due to the presence of cyanic acid—can be effectively inhibited using amino acid derivatives. Through a systematic weight loss analysis over a 10-day exposure period, it was established that leucine, alanine, and methionine serve as efficient corrosion inhibitors, significantly reducing material degradation compared to uninhibited conditions.

The relationships between corrosion rate in mill per year (mpy) and duration of exposure of mild steel in cassava fluid with different concentrations of inhibitors are shown in Figures 4.1 to 4.3. Figures 4.1 and 4.3 show that leucine and methionine caused a continuous decrease in corrosion rate with increase in their molar concentration over the concentration ranges of 0.05-0.30 M. Beyond 0.30 M concentration, no appreciable decrease in corrosion rate occurred. Figure 4.2 shows that alanine caused a significant occurred. Figure 4.2 shows that alanine caused a significant decrease in corrosion rate with increase in the concentration of the inhibitor in cassava fluid over the range 0.05 to 0.20 M. However, above 0.20 M, no significant decrease in corrosion rate was observed. In other words, the effectiveness of the inhibitors varied with their concentrations, while each of them had a peak concentration for optimal inhibition in the cassava fluid.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

The main conclusions drawn from this investigation were:

The corrosion of carbon steel in cassava fluid can be inhibited by the amino acid derivatives alanine, methionine and leucine to varying degrees of molar concentration

Alanine was observed to be ore efficient than leucine and methionine by providing corrosion inhibition at molar concentration of 0.20M, 0.30M and 0.30M respectively.

The Inhibitive power of these inhibitors increased with increase in concentration but there was a peak concentration beyond which inhibition efficiency decreased

The inhibitive power of amino-acid derivative in cassava fluid decreased in the following ranking order: alanine > leucine > and methionine.

5.2 Recommendation

Depending on the specific agro-processing conditions (pH, temperature, fluid composition), the choice of amino acid inhibitor may be optimized. For example, alanine may be preferred in environments requiring quick inhibition at lower concentrations.

Since the amino-acid used are proteinous derivatives, more inhibitors in plant-based extracts should be used in order to a good comparison.

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