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Inhibition of metal corrosion using *Ficus natalensis* and *Ficus ovata* bark extracts

***1 Magoola Abel, 2 Mghweno Leonard Richard**

[1] Assistant Lecturer, Department of Science Education, Bugema University, Kampala, Uganda
[2] Senior Lecturer, Department of Science Education, Bugema University, Kampala, Uganda

Abstract
The study investigated the inhibitive properties of *Ficus natalensis* and *Ficus ovata* bark extracts in inhibiting metal corrosion and determined the best metal corrosion inhibitor between the two bark extracts. Gasometrical method was conducted in two phases: the preparation phase where the bark extracts were made into solution form and the experimental phase. The experimental phase had three sets: the blank system which had the corrodent (hydrochloric acid) only, the factor that caused corrosion on the metal surface, the second and third sets had *Ficus natalensis* and *Ficus ovata* bark extracts as corrosion inhibitors, respectively. Hydrogen gas was collected from each set with time. The results revealed that an increase in concentration of the corrodent increased the corrosion rate on magnesium metal ranging from $0.2252m1s^{-1}$ to $0.3982m1s^{-1}$. Furthermore, an increase in concentration of any inhibitor into the corrodent reduced corrosion rate from 0.2775 mls^{-1} to $0.1230mls^{-1}$ and from $0.1858mls^{-1}$ to 0.0848 mls^{-1} for *Ficus natalensis* and *F.ovata,* respectively. It was concluded that the bark extracts can prevent corrosion in metals thus had corrosion inhibitive properties on metals; and that *F. ovata* had high efficiency at all concentrations (ranging from 29.1% to 54.6%) compared to *Ficus natalensis* (16.3% to 38.6%).

Keywords: corrodent, inhibition, *ficus natalensis*, *ficus ovata*

Introduction

Corrosion is a destructive attack on a metal or metal alloy by chemical or electrochemical reactions with its environment and can cause disintegration of engineered materials into constituent particles [1]. Rust on iron, tarnish on copper, and the green patina formed on copper and brass are some of the forms of corrosion [2]. Corrosion involves oxidation and reduction processes which take place on areas known as anode and cathode, respectively.

Many metals and metal alloys used in different human activities are susceptible to different mechanisms of corrosion due to their exposure to different corrosive media [3]. Corrosion can be concentrated locally to form a pit or a crack or it can extend across a wide area more or less uniformly corroding the metal surface [4]; and has been reported to cause great harm to many human activities in the world, such as loss of service, inconvenience, property damage, shutdown/power failures and great economic losses [5]. In that case, industrial corrosion has been called The Silent Killer as it stealthily attacks products in every industry-manufacturing, electronics, aerospace, transportation, and shipping, among many others. Every year millions of dollars are lost due to corrosion and rusting of material and cargo during transportation and shipment. Metal cargoes reach the destination rusted or oxidized due to moisture and humidity in the atmosphere [6]. It is estimated that economic loss from damage caused by corrosion in steel, the most important metal used in machinery, industrial plants, railways and shipping can amount to the global cost of corrosion of US$2.5 trillion, equivalent to roughly 3.4 percent of the global Gross Domestic Product (GDP) [7]. The two-year global study released at the Corrosion 2016 Conference in Vancouver, B.C., examined the economics of corrosion and the role of corrosion management in establishing industry best practices. The study found that implementing corrosion prevention best practices could result in global savings of between 15-35 percent of the cost of damage, or between $375-875 billion [7]. The estimated direct cost of corrosion in South African economy was R154 billion per annum in 2005 [8]. It is because of such losses which resulted to search for methods to reduce or prevent corrosion. As a result methods to reduce the rate of corrosion on exposed metal surfaces such as passivation, heteromater, conversion, and addition of corrosion inhibitors have been discovered [9]. Inhibition studies have reported that several inhibitors that are used to reduce metal corrosion are synthesized from expensive raw materials or chosen from compounds having hetero-atoms in their aromatic or long chain carbon system, hence causing toxic problems to the environment. Furthermore, some inhibitors together with other methods of corrosion inhibition have become costly [10]. This caused the search for green corrosion inhibitors that include plant extracts. These are preferable because they are biodegradable and environmentally friendly with minimal health and safety concerns. They originate from renewable biosources and are cost effective [11]. Plant extracts produce many chemical compounds including terpenes, alcohols, polyphenols, carboxylic compounds, and nitrogen containing compounds and alkaloids that may exhibit electro-chemical activity such as corrosion inhibition. The many compounds present in the extract identify the active inhibitive components that make corrosion difficult or impossible [12]. Many scholars from the western world and some from the African continent have conducted research work to examine the inhibitive properties in several plant extracts such as *Musa sapientum* peels [3]. *Artocarpus heterophyllus* bark extract [4] and *Zygophyllum* extracts [13]. The emphasis of this study was to investigate the inhibitive properties of *Ficus natalensis* and

Ficus ovata bark extracts and compare their effectiveness as metal corrosion inhibitors.

Materials and Methods

This experiment was carried out in Chemistry Laboratory at Bugema University located 32km North of Kampala City in Uganda. Quasi experimental research design which allows the application of one test or replication was applied aiming at measuring the volumes of hydrogen gas evolved in the gasometrical technique from the corrosion of magnesium. High volume of hydrogen gas evolved indicated high rate of corrosion of magnesium. Magnesium sheet was mechanically press-cut to form different coupons, each of dimensions 5x4x0.11cm. Each coupon was degreased by washing with ethanol, dried in acetone, and preserved in desiccators. All reagents used for the study were of analytical grade and double distilled water was used for their preparation. The bark extracts were collected directly from mature Ficus trees that are found at Bugema University Main Campus. Pieces of the bark from the Ficus trees were cut into small segments and ground. The samples were dried completely in a force-air oven at 70°C for 1-2 days. The dried samples were homogenized in ethanol in a homogenizer and filtered. The filtrates were further subjected to evaporation at 32°c in order to get rid of ethanol from the sample. The stock solutions of the extract so obtained were used in preparing different concentrations of the extract by dissolving 1.0, 1.5, 2.0, 2.5, 3.0 g of the extract in 1 liter of 3.0M HCl, respectively. Hydrogen gas evolution measurements were carried out via the gasometrical assembly formally used by Ita and Offiong [14]. The reaction vessel (two-neck flask) was connected to a burette via delivery tube. The corrodent (2M HC*l*) was introduced into the vessel and initial volume of air in the burette was recorded. Thereafter two magnesium coupons were dropped into the corrodent and the flask quickly closed. All possible areas of leakages were adequately sealed with the help of petroleum jelly. The volumes of hydrogen gas evolved from the corrosion reaction were monitored by the volume change in the level of paraffin oil in the graduated burette. The changes in volumes were recorded every 2 minutes for a period of 30 minutes. In another experiment, freshly washed magnesium coupons were immersed in 200m1 of 2M HC*l* solution containing the inhibitors separately and the volumes of hydrogen gas evolved were measured. The experiment was performed at different concentrations; that was, 0.1, 0.2, 0.3, 0.4, and 0.5g/*l* of inhibitors.

Corrosion rates of magnesium metal in hydrochloric acid in the absence and presence of corrosion inhibitor were determined by the equation below:

$$CR = \frac{V^0}{t_0},$$

Where; CR = corrosion rate

v^0 = vol. of hydrogen evolved

t_0 = time taken for hydrogen to be evolved

From the volume of hydrogen evolved per minute, inhibition efficiency (Q) was determined for both bark extracts using the equation below:

$$Q = 1 - \left[\frac{V^1{}_{HT}}{V^0{}_{HT}}\right] x100,$$

Where; V^1_{HT} = vol. evolved by inhibited solutions.

V^0_{HT} = vol. evolved by uninhibited solution.

The inhibitive properties of *F. natalensis* and *F. ovata* bark extracts in inhibiting metal corrosion and their obtained data for efficiencies were analyzed using descriptive statistic.

Results and Discussions

Table 1 below presents the corrosion rates of magnesium metal at different concentrations of hydrochloric acid (corrodent).

Table 1: Corrosion rate at different corrodent concentration

Concentration of corrodent (HCl M)	1.0	1.5	2.0	2.5	3.0
Corrosion rate ($m1s^{-1}$)	0.2252	0.2480	0.2802	0.3232	0.3982

According to the findings, corrosion rate of Magnesium metal increased with increasing concentrations of the corrodent (hydrochloric acid) without the inhibitor. Similar observations were obtained by several researchers [10, 13, 15]. This is due to the fact that rates of chemical reactions generally increase with increasing acid concentration. The observed trend can also be attributed to the increase in rate of ionization and diffusion of active species in the corrosion process. Also in acidic solution hydrogen evolution increases thus an increase in the cathodic reaction and this leads to increase in the corrosion rate.

Table 2: Corrosion rate and inhibition efficiency of *F. natalensis*

Concentration of HCI with *Ficus natalensis* added (g/1)	1.0	1.5	2.0	2.5	3.0
Corrosion rate (m/s^{-1})	0.2775	0.1947	0.1668	0.11433	0.1230
Efficiency (%)	16.3	20.4	24.8	34.6	38.6

Table 2 presents corrosion rates of Magnesium metal in 3.0M HC*l* in presence of *F. natalensis* and its efficiency at different concentrations. It was observed that increasing the concentration of *F. natalensis* retarded the corrosion rate of magnesium in the solution. Also the inhibition efficiency of *F. natalensis* bark extract increased with increasing concentration. Hence low efficiency (16.3 %) was at low concentration (1.0g/l) and high efficiency (36.6 %) was at high concentration (3.0g/l).

Table 3: Corrosion rate and inhibition efficiency of *F. ovate*

Concentration of HC*l* with *Ficus ovata* added (*g/1*)	1.0	1.5	2.0	2.5	3.0
Corrosion rate (m/s^{-1})	0.1858	0.1504	0.1241	0.1038	0.08848
Efficiency (%)	29.1	34.5	40.2	40.2	54.6

Table 3 shows the corrosion rate of Magnesium in 3.0M HC*1* in the presence of *F. ovata* bark extract and its efficiency at different concentrations. It was observed that an increase in the concentration of *F. ovata* bark extract in the solution reduced the corrosion rate. The efficiency of *F. ovata* increased with its increasing concentration. Therefore, a low efficiency (29.1 %) of *F. ovata* was at lower concentration (1.0*g/l*) and high efficiency (54.6%) was at higher concentration (3.0*g/l*) of the *F. ovata* bark extract.
The behavior in corrosion rates and efficiency in table 2 and 3 can be attributed to the adsorption of the natural compounds on the surface of Magnesium metal as the inhibitor concentrations increase. Due to adsorption the corrosion sites of Magnesium get blocked and adsorbed films act as barriers between Magnesium surface and corrosion medium [16, 17, 18, 19].

Inhibitive properties of *F. natalensis* and *F. ovata*
Figure 1 below shows the comparison of corrosion rates of the inhibitors. The curves indicate a decrease in corrosion rates for both inhibitors thus this implies that the inhibitors had corrosion inhibitive properties.

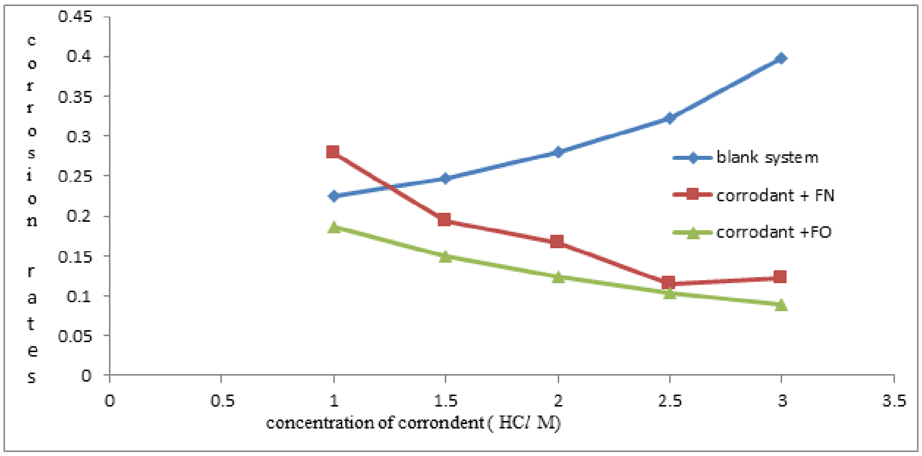

Fig 1: Comparison of corrosion rates of *F. natalensis* and *F. ovata*

As shown in Figure 1, the presence of either *F. natalensis* or *F. ovata* in solution lowered the corrosion rate of Magnesium metal in solution; hence this implied that *F. natalensis* and *F. ovata* had the corrosion inhibitive properties. However, in comparison there were higher corrosion rates in a solution containing *F. natalensis* that ranged from (0.2775 to 0.1230) mls^{-1} than in *F ovata* which ranged from (0.1858 to 0.0848) mls^{-1}.
The above information matched with those of Oguzie [3] who studied the inhibitive properties of *Musa sapientum* plant extracts. It is observed that *F. natalensis* and *F ovata* inhibit corrosion in metals.
However, when compared (Fig. 2) *F ovata* shows to be more effective than *F. natalensis.* The efficiencies of *F. ovata* were at higher percentages ranging from 29.1% to 54.6% as compared to *F. natalensis* which ranged from 16.3% to38.6%. Thus *F. ovata* was recommended to be the most effective corrosion inhibitor than *F. natalensis*.

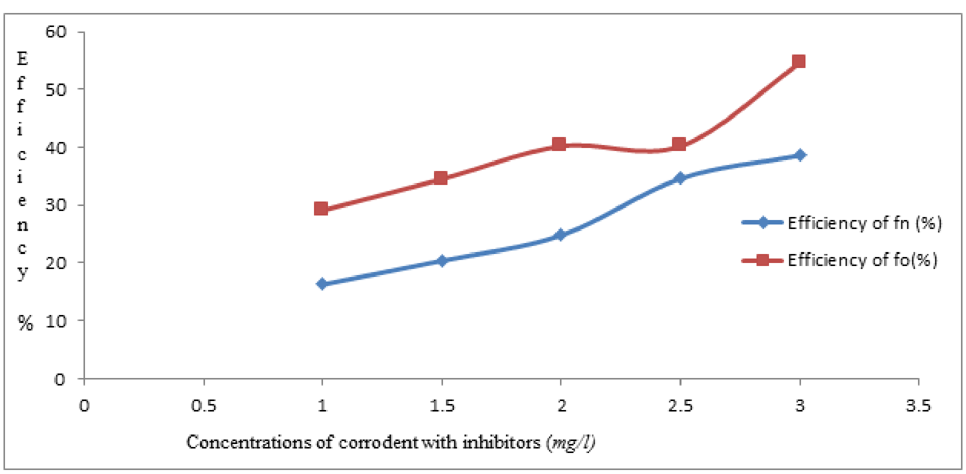

Fig 2: Comparison of inhibition efficiency of *F. natalensis* and *F. ovata*

Generally, from the results, corrosion rate was affected by concentration of corrodent, concentration of bark extracts of *F. natalensis* and *F. ovata*. The volumes of hydrogen evolved at different concentrations of bark extracts of *F. natalensis* and *F. ovata* are lower than volumes of hydrogen gas evolved by hydrochloric acid.

Conclusion and Recommendations

It was concluded from the results that bark extracts of *F. natalensis* and *Ficus ovata* in solution of hydrochloric acid had corrosion inhibitive properties when applied on corroding metal surface therefore can be used to inhibit corrosion in metals. It was also concluded that *Ficus ovata* in solution is more effective in preventing corrosion than that solution of *F. natalensis*. Basing on the results, it is recommended that *F. natalensis* and *F. ovata* bark extracts in solution can be applied to prevent metal corrosion. Furthermore, *F. ovata* should be preferred to *F. natalensis* because of its greater efficiency as compared to *F. natalensis*; and that a study be conducted to compare the efficiency of *F. ovata* with known commercial inhibitors.

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