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Assessment of Neem, Lemon and Orange Leaves Extracts for the Prevention of Corrosion on Mild Steel

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Abstract: *Corrosion of metals remains a critical issue in various industries, necessitating the development of sustainable and cost-effective solutions. This study investigates the potential of locally sourced plant extracts—orange leaves (*Citrus sinensis*), lemon leaves (*Citrus limon*), and neem leaves (*Azadirachta indica*)—as eco-friendly corrosion inhibitors. The extracts were prepared using ethanol and analyzed for their phytochemical constituents, including tannins, flavonoids, and alkaloids, which are known to influence corrosion inhibition. Mild steel samples were exposed to acidic environments representative of industrial conditions, with and without the addition of the plant extracts, over a duration of 16 weeks (four months). The gravimetric method was employed to evaluate corrosion rates by measuring weight loss. The findings indicate that the plant extracts serve as effective inhibitors, with orange leaves, lemon leaves, and neem leaves exhibiting inhibition efficiencies of 82.35%, 73.26%, and 64.71%, respectively. The superior performance of orange leaf extract was attributed to its higher concentration of active phytochemicals, facilitating the formation of a robust protective film on the metal surface. This study underscores the potential of these plant extracts as sustainable alternatives to synthetic corrosion inhibitors, with implications for reducing environmental impact and enhancing industrial corrosion management. Further research is recommended to optimize extraction techniques and assess long-term performance in various environments.*

Keywords: *neem leaves, orange leaves, lemon leaves, inhibition.*

1 Introduction

Steel has long been a highly valued resource and in recent years, its use has grown significantly. For instance, the yearly global production of crude steel (CS) grew from 200 Mt to 1804 Mt between 1950 and 2018 (Lopez *et al.*, 2022). Because they have so many advantageous qualities, such as excellent mechanical strength and affordability, metallic materials, especially alloys, are widely used in the building and construction industries. However, the majority of metals and their alloys in their pure state are extremely reactive and easily corrode when they react with substances in the environment (Alrefaee *et al.*, 2021). According to Kadhim *et al.* (2021), the damage which metals and alloys sustain following chemical or electrochemical reactions with their surroundings is known as corrosion.

Corrosion can be seen as an imminent threat in many engineering applications that requires quick attention because it endangers people's safety, raises material conservation and financial concerns, and generally leads to severe failure in some constructions, including the quickly corroding metallic components that require expensive restoration (Zakeri *et al.*, 2022). As a result of the above, a variety of techniques were used to reduce or stop the corroding of structures made of metal. The most often used techniques are cathodic or anodic protection employing organic or inorganic inhibitors, plastics, polymers, and protective coatings on metals made of organic molecules. Speller *et al.* (1927) is credited with the first report of organic inhibitors' ability to limit corrosion, in his study, he looked at how well-scaled water pipes inhibited corrosion in HCl. Since then, many organic and inorganic compounds that are added to the corrosive fluids have been investigated for this purpose so natural products from plant extracts known as green inhibitors and materials derived from more renewable resources are of interest to the scholars (Kesavan *et al.*, 2012)

Corrosion affects the aqueous environment, which includes rain, saltwater, and seawater. When steel pipes corrode and harmful metals leak into the environment, the aqueous environment's living systems may experience health issues. The outcome could be dangerous and lead to problems like fire, explosion, worker isolation, equipment loss, and financial loss.(Ajanaku *et al.*, 2015). Therefore, in recent years there are several studies on the application of plant extracts as electroplating additives or as a corrosion inhibitor (Loto *et al.*, 2013), because of the impacts corrosion has as a result of the metal interaction with the environment and what it causes, it is a process that cannot be ignored because poses a threat to environmental health and safety in several industries. The corrosive environmental conditions cause the metallic equipment used in the oil and gas industries to degrade. Maintenance and unavoidable mishaps cause enormous financial drains and losses to both people and plants (Sarkar *et al.*, 2023)

The capacity to protect metallic materials, particularly those employed in engineering, becomes crucial. Several techniques, including electroplating and the use of inhibitors, have been utilized to combat corrosion, these are chemicals that are introduced to corrosive media in modest quantities to lessen or stop the metal's reaction with the media (Ajanaku *et al.*, 2015). Natural green inhibitors have many benefits, such as being readily available, biodegradable, inexpensive to make and extract, and derived from renewable resources. One or more secondary metabolites, such as alkaloids, flavonoids, tannins, polyphenols, nitrogen bases, amino acids, proteins, and carbohydrates, have been found in plant-based natural inhibitors (Parthipan *et al.*, 2021).

2 MATERIALS AND METHODS

2.1 Materials

The materials used for this study included mild steel coupons, neem leaves, orange leaves, lemon leaves, and an acidified solution (3 M HCl solution). All materials were sourced from Maiduguri Metropolis. The leaves were carefully collected, dried in a shaded environment to preserve their active components, and subsequently ground into fine powder in the laboratory.

2.2 Methods

2.2.1 Preparation of the Green Plant Leaves Sample

Neem, orange, lemon leaves were collected in their natural state from plants located across Maiduguri Metropolitan Council. The leaves were then dried in the open for ten to fifteen days in natural shade at room temperature. After being pounded into a powder, the dried leaves were put in various containers.

2.2.2 Weight Loss Measurement

After weighing the dried coupons (W_1) and letting them sit in 60 milliliters of 3 M HCl for seven days, without adding any leaf extract, another setup was made and observed for the same amount of time as the first one, but with three milliliters of leaf extract added. Using a thread, each mild steel coupon that had been weighed was suspended in a beaker. Following each exposure period, the mild steel coupons were taken out and cleaned using tissue paper. They were then completely cleaned using emery paper to get rid of the corrosion product (rust stain), rinsed with distilled water, and dried in acetone as before. To calculate the weight loss in grams—that is, the difference between the mild steel's pre- and post-immersion weights—the mild steel was reweighed (W_2). For sixteen weeks, the procedure was repeated.

The weight loss (ΔW) was calculated using the following equation:

Weight Loss $\Delta W = W1 - W2$ 1

The weight of the mild steel before and after it is submerged in the corrosive solution is denoted by W_1 and W_2, respectively.

The surface coverage is a crucial metric for assessing the degree of extract adsorption on the mild steel surface. Equation (2) was utilized in its computation.

Surface Coverage $\theta = \frac{(CR1 - CR2)}{CR1}$ 2

where the corrosion rate without an inhibitor (control) is denoted by CR_1 and the corrosion rate with an inhibitor present by CR_2.

Equation 3 is used to calculate the corrosion rates both in the presence and absence of the inhibitors. Equations 3 and 4 are used to calculate the inhibition efficiency (I.E.) and corrosion rate (CR).

Corrosion Rate $CR = \frac{\Delta W}{AT}$ 3

A represents the coupon's surface area (cm^2), T denotes the immersion time in days, and ΔW represents the weight loss (g).

Inhibition efficiency (IE%) is calculated using the corrosion rates measured in the presence and absence of the inhibitor, as shown in equation 4:

Inhibition Efficiency $IE(\%) = \Theta\ x100$ 4

Where IE (%) is inhibition efficiency (Adekunle *et al.*, 2020)

3 Results and Discussion

3.1 Results of Phytochemical Analysis

Table 1 presents the experimental findings of the phytochemical examination of the plant extract samples.

Table 1: Phytochemical analysis of the samples

Samples/ Parameters	Alkaloids	Saponins	Tannins
Neem leaves	_	+	+
Orange leaves	+	+	+
Lemon leaves	+	++	++

Notes: ++ = highly present; + = moderately present and - = absent

The phytochemical results presented in table 1 of the plant extract, Neem leaves shows negative trace of Alkaloids while Saponins and Tannins are moderately present, whereas orange leaves have all the parameter tested in moderate proportion. Lastly from same results it can be deduced that lemon leave has alkaloids moderately presents while Saponins and tannins are significantly present. The presence of all these compound at various degree shows that it can inhibit corrosion most especially the presence of tannins as investigated by (Nardeli *et al.*, 2019).

3.2 Weight Loss Method (Gravimetric Method)

The result for the surface coverage, corrosion rate, inhibitory effectiveness, and weight loss of neem leaves, lemon leaves and orange leaves are shown on Figure 1- 3 which was conducted for the period of 16 weeks with metal coupon of 2 x 2 x 0.2 cm suspended in 3 M HCl. With the use of the plant extracts, both in the inhibited environment (figure 1) and the control (uninhibited) environment, the weight loss increases with exposure time.

3.3 Corrosion Rate

The Comparison between the corrosion rate (CR) of all the four plant extracts against the control (CON) is presented in Figure 1

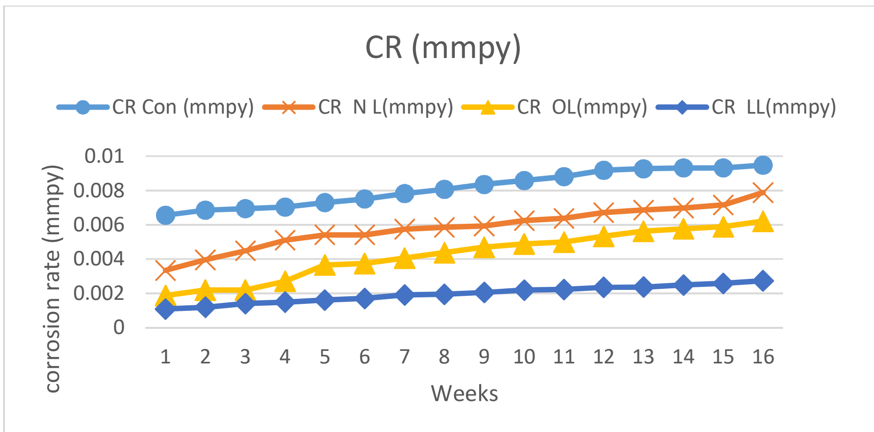

Figure 1: Comparison between the CR of all the four plant extracts against the control CON

The corrosion rates, both in the presence and absence of extracts within an acidic medium, exhibit a discernible temporal trend, as illustrated in Figure 1. Initially, during the first week, a notable discrepancy is observed: the control demonstrates a relatively high corrosion rate, starting at approximately 0.007 mmpy, contrasting with lemon leaves exhibiting the lowest rate at about 0.001 mmpy, followed by neem leaves at 0.003 mmpy, and orange leaves at 0.002 mmpy. Subsequently, in the second week, corrosion rates continue to fluctuate, with lemon leaves registering 0.001 mmpy, orange leaves at 0.002 mmpy and neem leaves at 0.004 mmpy.

Despite the variation observed during the initial weeks, week 3 shows minimal changes in corrosion rates, maintaining relative stability across all samples. This trend persists into week 4, with a positive progression noted in the graph. Week 5 exhibits steady corrosion rates for most extracts, with only a slight increase observed in the corrosion rate of orange leaves, rising from 0.002 mmpy to 0.0039 mmpy. Week 6 reflects a continuation of stable corrosion rates across all extracts.

Noteworthy changes in corrosion rates become evident from week 8 to 13, with lemon leaves displaying consistent positive progression at 0.002 mmpy. Conversely, changes in corrosion rates for neem leaves, and orange leaves during this period are negligible. Minor fluctuations are observed from week 14 to 16 for all extracts, except for neem leaves, which experience a slight spike from week 15 to 16.

Through comprehensive analysis, as depicted in Figure 1, it becomes apparent the corrosion rates follow a distinct hierarchy: lemon leaves exhibit the highest resistance to corrosion, followed by orange leaves and neem leaves respectively.

3.4 Inhibition Efficiency

The inhibition efficiency of neem leaves, orange leaves and lemon leaves is presented in Figure 2

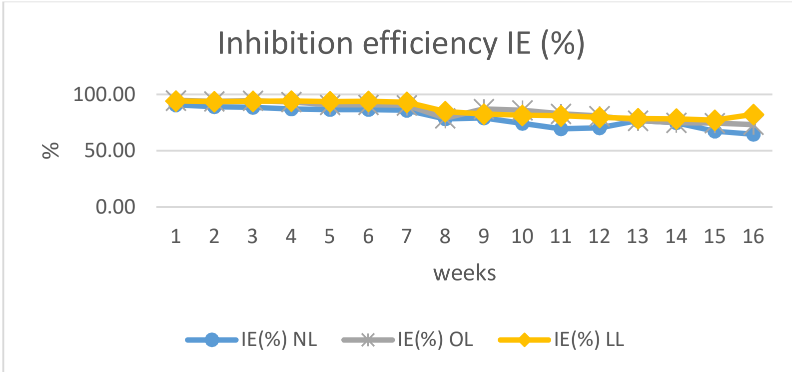

Figure 2: Inhibition Efficiency of neem leaves, orange leaves and lemon leaves

Upon the culmination of the 16-week period, meticulous examination of the inhibition efficiency of the extracts revealed a hierarchy in corrosion inhibition. Lemon leaves (LL) emerged as having the highest corrosion inhibition, showcasing an unparalleled inhibition efficiency (IE) of 82.35%, symbolizing robust preservation potential. Following closely is the orange leaf (OL) extract which displayed a commendable IE of 73.26%, underscoring its notable resilience. Trailing behind is the neem leaf (NL) extract which demonstrated a respectable IE of 64.71%, indicating its moderate but notable preservation capacity after the designated 16-week period.

The inhibitors, based on their inhibition efficiencies can be ranked from most effective to the worst as: lemon leaves > orange leaves > neem leaves in acidic medium.

3.5 Surface Coverage

The surface coverage of neem leaves, orange leaves and lemon leaves is presented in figure 3

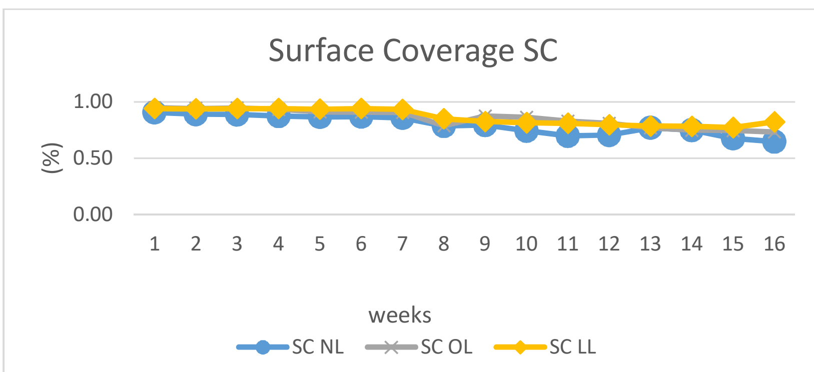

Figure 3: Surface Coverage of neem leaves, orange leaves and lemon leaves

Similar to inhibition efficiency, surface coverage exhibits a significant tendency over time. Initially, in week one, all three plant extracts—neem, orange and lemon leaves — display significantly higher surface coverage. However, as the duration of exposure increases, a gradual decline in surface coverage is observed from weeks 1 to 8. Furthermore, from weeks 9 to 16, a slightly steeper decline is evident, attributed to the oxidation of phytochemical compounds within the plants extract responsible for corrosion inhibition.

Despite this decline, the overall result for surface coverage throughout the 16-week experiment is satisfactory, suggesting that the extracts maintain their corrosion inhibition properties. The hierarchy of surface coverage follows a similar order to inhibition efficiency, with lemon leaves exhibiting the highest coverage, followed by orange leaves and neem leaves in an acidic medium.

Conclusions

The research's findings and analysis allow for the deduction of the following conclusions: The extracts from the samples were successfully extracted using a Soxhlet apparatus. Phytochemical screening of the samples revealed the presence of alkaloids, tannins, and saponins in neem, orange, and lemon leaves. In the presence of plant extracts, inhibition efficiency (IE) improves, and corrosion rate (CR) dramatically reduces, whereas corrosion increases in the absence (control) of the plant extract in the corrosive media. Additionally, the plant extracts, assessed using CR, IE, and SC graph, maintains a steady positive progression for the experimental period of four months, indicating that plant extract as a corrosion inhibitor has the potential inhibit corrosion. Recommendations include conducting experiments on thicker metal coupons to validate findings.

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