**Journal of Energy, Environmental & Chemical Engineering**
2023; 8(2): 45-52
http://www.sciencepublishinggroup.com/j/jeece
doi: 10.11648/j.jeece.20230802.13
ISSN: 2637-4331 (Print); ISSN: 2637-434X (Online)

# A Comparative Study of the Use of Alligator Pepper Pods and Mango Peels Extracts as Corrosion Inhibitor on Carbon Steel in Acidic Medium

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## To cite this article:

Azike Rowland Ugochukwu, Azuokwu Augustine Azubike, Odisu Teddy, Nikoro Oghenetejiri. A Comparative Study of the Use of Alligator Pepper Pods and Mango Peels Extracts as Corrosion Inhibitor on Carbon Steel in Acidic Medium. *Journal of Energy, Environmental & Chemical Engineering*. Vol. 8, No. 2, 2023, pp. 45-52. doi: 10.11648/j.jeece.20230802.13

**Received**: June 11, 2023; **Accepted**: June 30, 2023; **Published**: July 11, 2023

**Abstract:** Carbon steel enjoys wide usage across many industries and sectors due to the wide range of its mechanical characteristics and costs. However, carbon steels are highly prone to corrosion. Corrosion is an undesirable process with devastating consequences. While there are several methods of preventing corrosion, corrosion control using extracts of plant seeds, fruits, flowers, leaves, barks and roots has been attracting attentions due to environmental, cost and sustainability concerns. However, some of these plant materials particularly the seeds and fruits have great economic values due to nutritional, medical and socio-cultural usefulness. Hence the need to use extracts from their wastes (peels and pods). In this study the use alligator pepper pods and mango peels extracts as anti-corrosion agents on carbon steel in acidic environment were analysed and compared. Results showed that the alligator pepper pod and mango peel extracts contained phytochemicals capable of inhibiting corrosion. The mango peels contained higher contents of alkaloids, flavonoids, saponins, and terperniods compared to alligator pepper pod extracts. The glycosides, phenols and tannins contents of alligator pepper pod extracts were slightly higher than those in mango peels extracts. Results of the corrosion tests showed that carbon steel is prone to corrosion in acidic medium. Further outcome of the study also showed that both extracts are efficient in inhibiting carbon steel corrosion in HCl solution. The corrosion prevention efficiency of alligator pepper pods and mango peels extracts are comparable, but that of mango peels is slightly better. Results of this study showed that corrosion inhibition efficiency of the extracts decreases with time but increases with concentration.

**Keywords:** Corrosion, Alligator Pepper Pod, Mango Peel, Extracts, Acidic Medium, Phytochemicals, Inhibition Efficiency

## 1. Introduction

Carbon steel enjoys wide usage across many industries and sectors due to the wide extents of its mechanical properties, one of which is the strength. In addition, carbon steels are readily available, ease to fabricate, and usually have lowest initial cost. However, carbon steels are very susceptible to corrosion [1]. Corrosion is an undesirable process. It involves deterioration or degradation of metal by chemical / electrochemical reaction between metal and its environment [2].

The consequences of corrosion are numerous. However, the major consequences of corrosion are economic costs; structural failures; life-threatening accidents, loss of lives; threats to the ecosystem and environmental damages [2].

There are several ways of preventing corrosion. These include material selection, coatings, inhibitors, cathodic protection, and design among others. Corrosion inhibitors such as silicates, phosphates, nitrites, and organic amines etc. are commonly used to reduce the rate of corrosion of carbon steel in corrosive environment [3]. However, some of these conventional inhibitors are known to exert toxic effect to human and the environment [4]. Thus, effort is being directed to develop bio-based inhibitors commonly obtain from plant extracts and other natural products [5-9]. These materials have many benefits such as eco-friendly, low cost, highly sustainable and available, and highly renewable. In addition, these plant materials contain substances and phytochemicals known for anticorrosive activities [10, 4, 11]. These substances and phytochemicals include phenols, tannins, oils and fats, etc. They have been effectively used inhibit metallic corrosion [12].

Therefore, current researches focus on the utilization of plant extracts as a source of green corrosion inhibitor that might effectively replace convectional anticorrosive chemicals as well as eliminate their negative impacts. [13-15, 3].

Several extracts of plant materials (seeds, fruits, flowers, leaves, barks and even the roots) are known to inhibit corrosion [16-21, 1]. However, some of plant materials particularly the seeds and fruits are known to have great economic values; some are edible and some are trado-medically or socio-culturally useful [22-23, 20, 24]. It is therefore imperative to evaluate the suitability of using the extracts obtain from parts of seeds and fruits that are not useful or considered as wastes (such as the peels and pods) as corrosion inhibitors. Thus in this study, the use alligator pepper (*Aframomum melegueta*) pods and mango (*Mangifera indica*) peels extracts as anti-corrosion agents on carbon steel in an acidic medium were analysed and compared.

## 2. Materials and Methods

### 2.1. Materials and Apparatus

The major materials that were used in the study were alligator pepper pods, mango peels and carbon steel (A-285-GR) samples. The alligator pepper pods and mango peels were obtained from the local community (Okada town, Ovia North East Local Government, Edo State, Nigeria). Carbon steel (A-285-GR) samples were obtained from the oil refinery. All reagents (analytical grades) and apparatus used were provided by Chemical Engineering Laboratory of the Igbinedion University, Okada. The materials, reagents and apparatus are shown in Table 1 and Table 2.

***Table 1.*** *Materials Used.*

| Materials | Remarks |
|---|---|
| Alligator Pepper Pods | For formulation of corrosion inhibitor |
| Mango Peels | For formulation of corrosion inhibitor |
| Carbon Steel (A-285-GR) | Carbon steel sample |
| Hydrochloric Acid | Source of corrodent |
| Distilled water | Washing |
| Acetone | Cleaning of specimen |
| Ethanol | Solvent for extraction |
| Carbon steel | Specimen for corrosion analysis |
| Soft brush | For cleaning |

***Table 2.*** *Apparatus.*

| Materials | Remarks |
|---|---|
| Beaker | This was used for holding and measuring liquids |
| Conical flask | This was used for mixing and preparing solutions |
| Measuring cylinder | This was used for measuring quantities of liquid samples |
| Heating mantle | Used in during heating. |
| Weighing balance | This was used to measure the weight of samples. |

(a) (b)

***Figure 1.*** *(a) Alligator Peppers (b) Mangoes.*

### 2.2. Methods

#### 2.2.1. Preliminary Preparation of Carbon Steel Specimen

A carbon steel sample (A-285-GR) was obtained from the oil refinery. Each carbon steel sample was cleaned and dried with tissues before each test. The sample was polished with grit abrasive sandpaper, washed with tap water and then distilled water, and then degreased with acetone and dried again.

#### 2.2.2. Preparation of Plant Samples

Unwanted materials in the alligator pepper pods and mango peels were removed by thoroughly washing the pods and the peels with running water. After being cleaned, the samples were cut into little pieces and dried in an oven at 45°C separately and grinded into fine small particles. The samples were stored in different containers before use.

#### 2.2.3. Solvent Extraction

The pulverized alligator pepper pods and mango peels extract were separately extracted with the use of soxhlet extractor available in the Chemical Engineering Laboatory, Igbinedion University, Okada. Mango peel powder and alligator pepper pods powder weighing 25g each were separately added to different 500mL round-bottom flask filled with 300mL of 70% ethanol. To reduce solvent losses, a reflux condenser was attached to the flask and cold water was allowed to pass through it. The apparatus was set up in a heating mantle, and the pulverized alligator pepper pods and mango peels were extracted individually and thoroughly by heating the solution under reflux at 78°C.

The refluxed solutions were filtered using filter paper after being allowed to cool overnight. A rotary evaporator was used to purified the extracts.

#### 2.2.4. Phytochemical Analysis

*Qualitative phytochemical analysis*

The phytochemical screenings of the extracts were conducted to determine the major groups of active chemical constituents present in the extracts. The presence of alkaloids, flavonoids, glycosides, phenols, reducing sugars, saponins, tannins, terpenes etc. were determined following the standard qualitative phytochemical screening procedures described by these authors [25-30].

*Quantitative phytochemical analysis*

Standard quantitative phytochemical analysis procedures as described by [25-30] were adopted.

### *2.2.5. Corrosion Tests (Weight Loss / Gravimetric Test)*

The weight loss or gravimetric approach was used. Rectangular coupons of dimensions of 40mm x 20mm x 2mm were cut from the carbon steel using a rotary metal cutter. A hole of about 0.35cm was then drilled on each coupon using twist drill bits. The coupons were the physically cleaned, ethanol-degreased, washed with distilled water, acetone-dried and then weighed.

As shown in Figure 3, the coupons were suspended using nylon thread in a 100ml beaker containing 100ml of HCl (hydrochloric acid) that contain various inhibitors at varied concentrations for periods of 48, 96, 144, 192, and 240 hours at a temperature of 30°C. The samples were retrieved at designated intervals, dipped in distilled water, scrubbed gently to remove any remaining acid and inhibitors, dried in acetone, and then reweighed [31].

*Effect of inhibitor concentration*

The effect of the inhibitor's concentration was examined by increasing its concentration from 2500ppm to 22,500 ppm with a step size of 5000ppm at the specified temperature.

*Effect of immersion time*

The effect of the exposure time was also examined by varying the exposure time from 48 hours to 240 hours with a step size of 48 hours at the specified temperature.

***Figure 2.*** *Carbon steel coupons.*

***Figure 3.*** *Corrosion Tests Setup.*

The area of the coupon is given by:

$$A = 2(xy + yz + xz) \quad (1)$$

Where:
A = total area of carbon steel coupon ($cm^2$)
x = breadth of carbon steel coupon (cm)
y = length of carbon steel coupon (cm)
z = thickness of carbon steel coupon (cm)
Weight loss is calculated as follows:

$$Weight\ Loss = Weight\ before\ Immersion - Weight\ after\ Immersion \quad (2)$$

The corrosion rate (CR) and metal loss (ML) were calculated as follows:

$$Corrosion\ Rate\ (CR) = \frac{Weight\ Loss\ (g) \times K_1}{Alloy\ Density\ (g/cm^3) \times Exposed\ Area\ (cm^2) \times Exposed\ Time\ (hr)} \quad (3)$$

$$Metal\ Loss\ (ML) = \frac{Weight\ Loss\ (g) \times K_2}{Alloy\ Density\ (g/cm^3) \times Exposed\ Area\ (cm^2)} \quad (4)$$

Where $K_1$ and $K_2$ are 8.75 x $10^4$ and 10 respectively.
The inhibitor Efficiency was calculated by:

$$Inhibitor\ efficiency\ (\%) = \left(\frac{CR_{\text{uninhibited}} - CR_{\text{inhibited}}}{CR_{\text{uninhibited}}}\right) \times 100 \quad (5)$$

Where:
$CR_{uninhibited}$ is the corrosion rate of the uninhibited system
$CR_{inhibited}$ is the corrosion rate of the inhibited system

## 3. Result and Discussion

### *3.1. Result of Phytochemical Analysis*

Results of the qualitative phytochemical analysis (Table 3) showed that the alligator pepper pod and mango peel extracts contained alkaloids, flavonoids, glycosides, phenols, saponins, tannins, and terperniods. Plant materials are known to contain different substances and organic compounds (e.g. alkaloids, flavonoids, glycosides, phenols, pigments, organic and amino acids, reducing sugars, saponins, tannins, terpenes etc.) that inhibit corrosion [32-36].

Results of the quantitative phytochemical analysis (Table 4) showed that extracts of mango peels contained higher contents of alkaloids, flavonoids, saponins, and terperniods compared to alligator pepper pod extracts. The glycosides, phenols and tannins contents of alligator pepper pod extracts were slightly higher than those in mango peels extracts.

***Table 3.*** *Apparatus. Phytochemical Constituents of Alligator pepper pod and Mango extracts.*

| Constituent | Alligator pepper pod Extract | Mango peel extract |
|---|---|---|
| Alkaloids | ++ | +++ |
| Flavonoids | ++ | +++ |
| Glycosides | + | + |
| Phenols | +++ | ++ |
| Saponins | + | +++ |
| Steroids | - | - |
| Tannins | ++ | + |
| Terperniods | + | + |

Keys: +++ indicate highly present, ++ indicate moderately present, + indicate slightly present and – indicate absent

***Table 4.*** *Phytochemical Composition of alligator pepper pod and mango peel extracts on dry weight basis expressed as mg/100g.*

| Constituent | Alligator pepper pod Extract | Mango peel extract |
|---|---|---|
| Alkaloids | 3.60±0.20 | 6.25±0.10 |
| Flavonoids | 3.60±0.10 | 5.37±0.40 |
| Glycosides | 0.016±0.10 | 0.01±0.10 |
| Phenols | 2.24±0.10 | 1.90±0.10 |
| Saponins | 3.47±0.30 | 9.35±0.20 |
| Steroids | - | - |
| Tannins | 1.50±0.20 | 1.20±0.10 |
| Terperniods | 0.18±0.10 | 0.19±0.10 |

### *3.2. Results of Corrosion Tests*

The results of the comparative analyses of the weight loss, metal loss, rates of corrosion and the efficiency of the inhibitor at different concentrations of alligator pods and mango peels extracts are shown in Figure 4, Figure 5, Figure 6 and Figure 7 respectively. The figures showed that carbon steel is highly corroded in acid solutions. Results of the investigation further revealed that Alligator pepper pods and Mango peels extracts exhibited efficient ability in inhibiting corrosion on carbon steel in HCl medium. This buttress that fact that Mango peels extracts is good corrosion inhibitor [7].

Results of the study also showed that weight loss, metal loss and the rate of corrosion decreases with increasing concentration of the inhibitors. Results further showed that the corrosion inhibition efficiency of the extracts decreases with time but increases with concentration.

The corrosion inhibition efficiency of alligator pepper pod extracts and mango peels extracts are comparable, however, the Mango peels extracts exhibited slightly higher results. For example, the best results are 92.86% and 85.71% for Mango peels and Alligator pepper extracts respectively at 22500 ppm concentration. The performances of the extracts as corrosion inhibitors are related to the nature and the amount of phytochemicals they contained. Alkaloids, flavonoids, Glycosides, polyphenols, saponins, steroids, tannins, terpenoids etc. have proven to efficient corrosion inhibitors [37-39, 13, 40-42, 15].

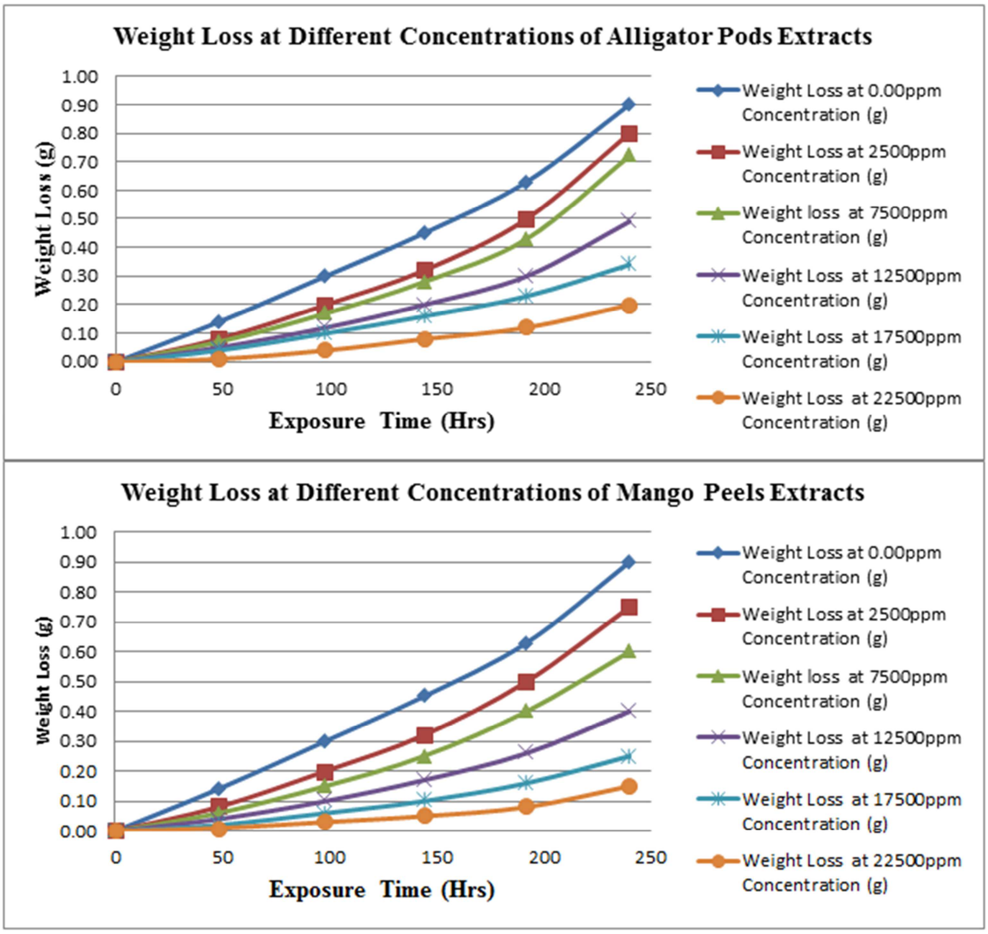


***Figure 4.*** *A comparative analysis of weight loss at different concentrations of alligator pods and mango peels extracts with respect to time of exposure.*

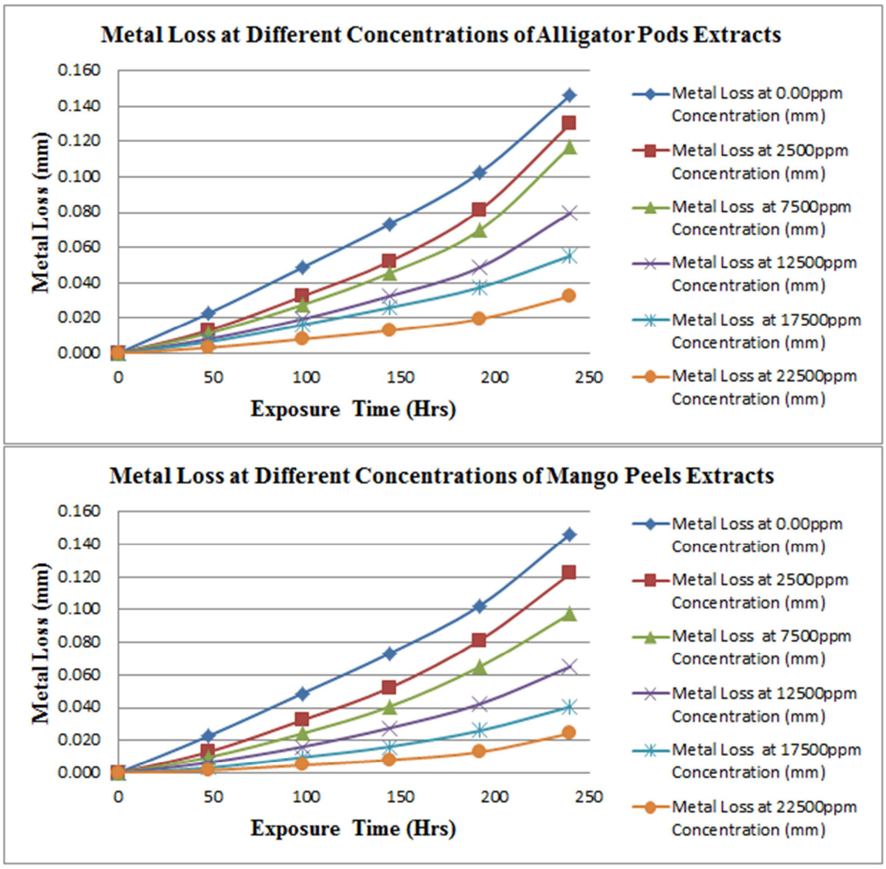


***Figure 5.*** *A comparative analysis of metal loss at different concentrations of alligator pods and mango peels extracts with respect to time of exposure.*

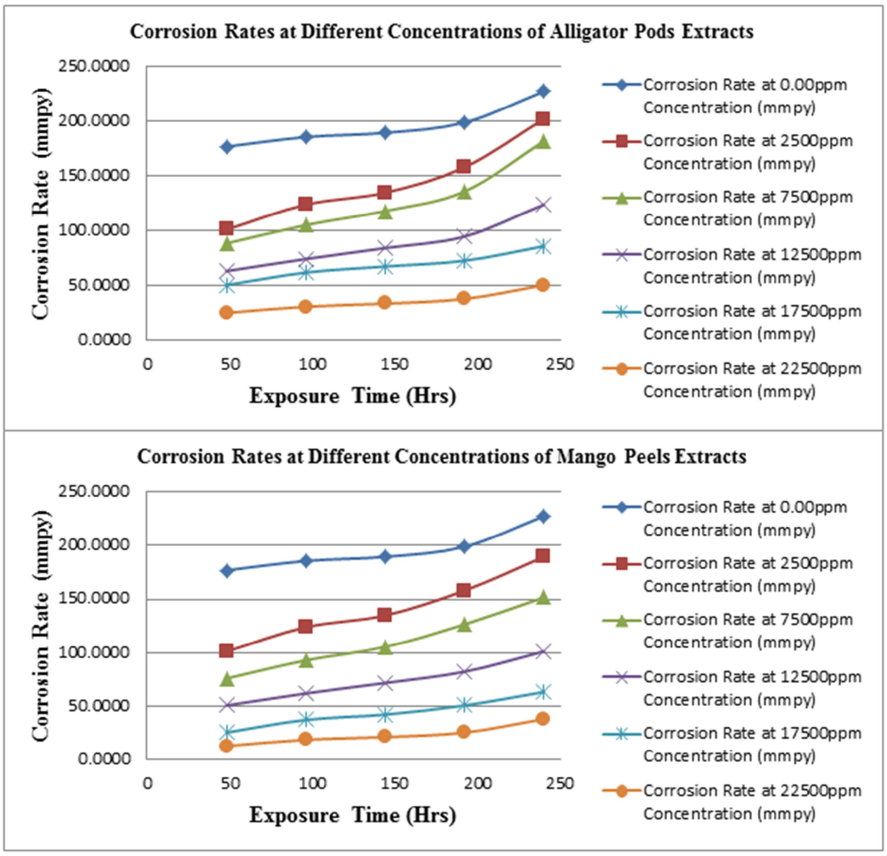


***Figure 6.*** *A comparative analysis of corrosion rates at different concentrations of alligator pods and mango peels extracts with respect to time of exposure.*

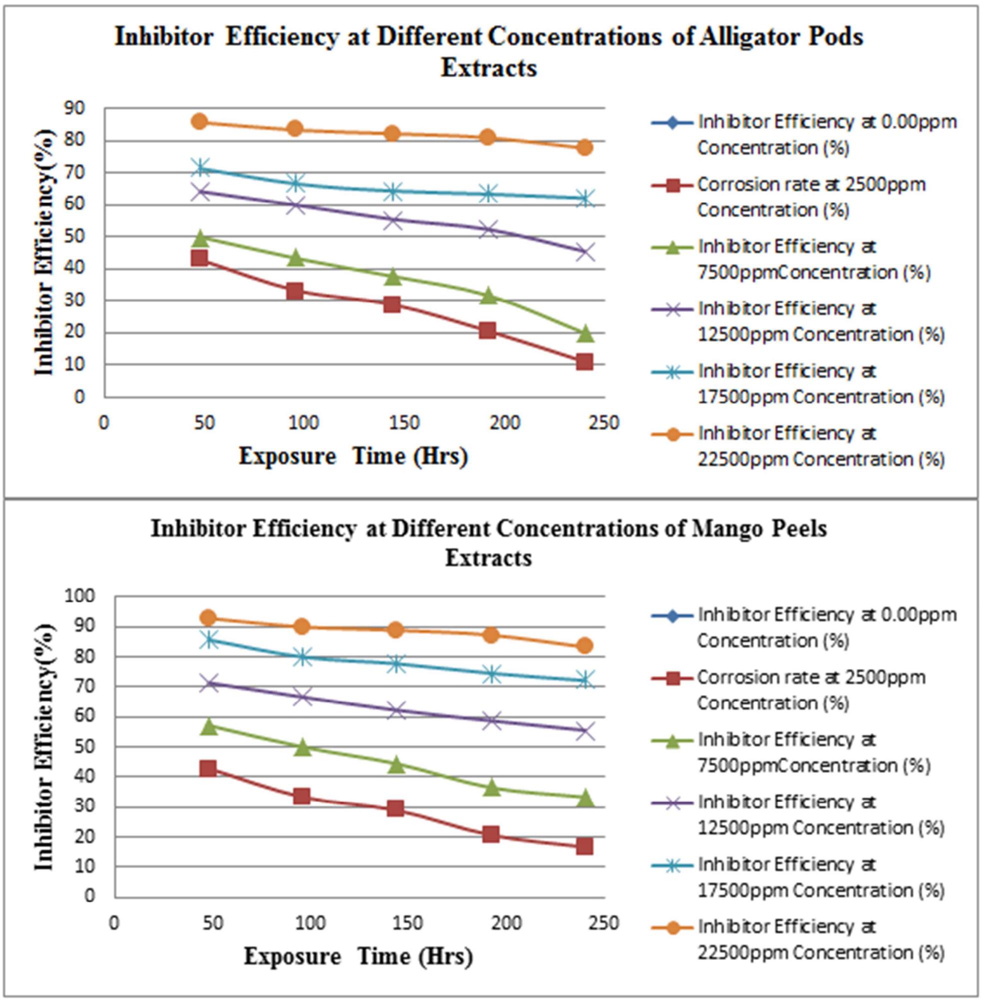


***Figure 7.*** *A comparative analysis of inhibitor efficiency at different concentrations of alligator pods and mango peels extracts with respect to time of exposure.*

## 4. Conclusion

Corrosion control using extracts of plant materials such as seeds, fruits, flowers, leaves, barks and roots has been attracting attentions due to environmental, cost and sustainability concerns. However, due to the usefulness and economic importance of some of these plant materials, there is a need to use extracts from their wastes (e.g. peels and pods). In this study the use alligator pepper pod and mango peels extracts as anti-corrosion agents on carbon steel in acidic solutions were analysed and compared.

Results of the qualitative phytochemical analysis showed that the alligator pepper pod and mango peel extracts contained phytochemicals (alkaloids, flavonoids, glycosides, phenols, saponins, tannins, and terperniods) capable of inhibiting corrosion. Results of the quantitative phytochemical analysis showed that extracts of mango peels contained higher contents of alkaloids, flavonoids, saponins, and terperniods compared to alligator pepper pod extracts. The glycosides, phenols and tannins contents of alligator pepper pod extracts were slightly higher than those in mango peels extracts.

Results of the corrosion tests showed that carbon steel is highly susceptible to corrosion in acidic medium. The outcome of the study also showed that both extracts are efficient in inhibiting corrosion of carbon steel in HCl medium. The corrosion inhibition efficiency of alligator pepper pods and mango peels extracts are comparable, but that of mango peels is slightly higher. Results of this study showed that corrosion inhibition efficiency of both extracts decreases with time but increases with concentration.

## Acknowledgements

Special thanks to the Department of Chemical and Petroleum Engineering. Igbinedion University, Okada for supports.

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