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Corrosion Inhibition of Copper Using African Black Velvet Tamarind (*Dialium indium*) Extract in Sulphuric Acid Environment

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Authors' contributions

This work was carried out in collaboration between both authors. Author AOJ designed the study, wrote the protocol and wrote the first draft of the manuscript. Author EO managed the literature searches; analyses of the study performed the spectroscopy analysis. Author AOJ managed the experimental process. Author EO identified the species of plant. Both authors read and approved the final manuscript.

Short Research Article

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ABSTRACT

Inhibition of corrosion of copper in aerated 0.5M sulphuric acid solutions containing various concentrations of *Dialium indium* extract was studied at a temperature range of 30 - 50ºC using weight loss and gasometric techniques. Results showed that Velvet Tamarind concentration range of 0.05 - 0.25g/500ml exhibited a good corrosion inhibition of 71.76%. Generally, it was observed that the rate of inhibition increased with temperature of the corrosive media and concentration of the inhibitor. This shows that Velvet Tamarind is a good, efficient and eco-friendly corrosion inhibitor for copper in 0.5M H_2SO_4 solution at room temperature and better at higher temperature.

Keywords: Temperature; inhibition; weight loss; hydrogen evolution.

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1. INTRODUCTION

The continued manifestation of corrosion on metal structures is still causing a lot of concern to corrosion scientists and engineers. It is therefore a major industrial problem that has attracted a lot of investigators in recent years as it affects the metallurgical, chemical and oil-industries [1-3]. Copper is considered to be one of the most important metals which are frequently used in different industrial applications [4]. Copper and its alloys are broadly used in heating systems and condensers. However, these systems should be regularly cleaned due to inlays of carbonates and oxides. Dilute acids are normally used to clean these surfaces. In order to prevent the corrosion of copper metals, corrosion inhibitors are generally added to these acids [5]. However, the problem of finding an inhibitor that has no adverse effect on the environment has attracted numerous researchers in recent times [3,6,7]. Investigations have been made into the inhibitive characteristics of some plant extracts which are less toxic and environmentally acceptable [8-10].

Dialium indium commonly known as African Black velvet Tamarind is a large tree found in many parts of Africa such as West Africa, Central African Republic and the Chad. The tree belongs to the family *Fabaceae-caesalpiniodaea*. It is 30meters high, with a densely leafy crown, but often shrubby. The fruits are usually circular and frightened, black in colour with a stalk of 6mm long. The pulp contains high content of vitamin C (Ascorbic acid), moisture, dry matter and ash, organic matter, crude fat, crude fibre, carbohydrate, protein and minerals which include magnesium, sodium, iron, calcium and potassium. The crude lipid contains mainly triacylglycerol, free fatty acid and sterols. The pulp of *Dialium indium* has been used as medicinal remedies, as source of vitamin C and a flavour in snacks and non-alcoholic beverages. It serves as a good source of essential nutrients for human and livestock [11].

This present work investigates the effect of African Black velvet Tamarind extract on the corrosion inhibition of copper in 0.5M sulphuric acid solutionat 30ºC, 40ºC and 50ºC using weight loss and gasometric techniques.

2. MATERIALS AND METHODS

2.1 Metal Preparation

The sheet employed in this work was made of pure copper. Rectangular copper coupons of dimension 4.0 x 4.0 x 3.0 cm were mechanically pressed cut. Each coupon polished and drilled at free desiccators to prevent contamination before use for corrosion studies.

2.2 Preparation of Velvet Tamarind

The additive used in this study is the African black velvet tamarind and was obtained from steel market in Port Harcourt, Nigeria (4º47' N 7º02' E). The pulp of the velvet tamarind was dried and ground into powdered form. The powder obtained was sieved to remove the chaff and then used for the corrosion study. Five different concentrations (0.05g/500ml, 0.10g/500ml, 0.15g/500ml, 0.20g/500ml, and 0.25g/500ml) were prepared in five (5) volumetric flasks.

2.3 Methods

Two methods of corrosion tests were used in the work, namely; weight loss and Hydrogen gas evolution (gasometric) techniques. Weight loss technique monitors the variation of weight loss of copper coupon in the corrodent with time while gasometric technique measures the volume of the hydrogen gas evolved during corrosion with time.

3. WEIGHT LOSS DETERMINATION

The weight loss was determined following the methods reported earlier [6]. Three sets of experiments were carried out at 30ºC, 40ºC and 50ºC, consisting of twenty five 250ml beakers, which separately contained the various concentrations of the extract mentioned above in 0.5M H_2SO_4 acid. Previously weighed copper coupons were each suspended in each beaker with the help of glass hooks. Thermostated water bath was used to maintain a constant temperature.

The copper coupons were retrieved from the corrodent solutions at 24hours interval progressively for 168hours (7 days).

Each retrieved coupon was immersed in a solution of 20% sodium hydroxide containing 200g/liter of zinc dust, scrubbed with a bristle brush several times to remove the corrosion product, dried in acetone and then reweighed. The weight loss was calculated in grams as the difference between the initial weight prior to immersion, and weight after removal of the corrosion product (rust).

Each reading reported is an average of two readings recorded to the nearest 0.001g on an AB 54 AR digital analytical weighing balance.

The inhibition efficiencies (%E) were calculated from the equation below:

$$\%\mathrm{E} = \frac{\Delta W_B - \Delta W_i}{\Delta W_B} \quad x \ \frac{100}{1} \tag{1}$$

Where ΔW_B and ΔW_i are the weight loss data of the copper coupons in the absence and presence of the additives respectively [9].

3.1 Gasometric Measurements Experimental Procedure

Gasometer is an instrument used in measuring volumes of gas evolved in a reaction. The gasometric instrument is constructed according to the design of Onuchukwu [12].

Six copper coupons of 1.0cm x 0.5cm x 1.0cm were used in the experiments with test solutions in six separate beakers containing 0.5M sulphuric acid solution only (for the Blank or control experiment) and five different concentrations (0.05g/500ml, 0.10g/500ml, 0.15g/500ml, 0.20g/500ml, and 0.25g/500ml) of African black velvet tamarind in 0.5M sulphuric acid solution. The volume of the test solutions used in each experiment was 50ml. A test solution of 50ml of each was introduced into the reaction vessel connected to a burette through a delivery tube. The initial volume of air in the burette was recorded. One metal coupon was dropped into the test solution and the reaction vessel quickly closed.

Variation in the volume of hydrogen gas evolved with time was recorded every 1minute for 2hours. Each experiment was conducted on a fresh specimen of metal coupon. The hydrogen gas evolved displaced the fluid in the gasometric set-up, which is read directly and recorded.

4. RESULTS AND DISCUSSION

4.1 Inhibitory Action of Extract of Black African Velvet Tamarind (*Dialium indium*) on the Corrosion of Copper in Sulphuric Acid

Fig. 1 shows a wide variation of weight losses between the Blank and various concentrations of Velvet Tamarind extract. This indicates that the presence of the additives reduces the weight loss or corrosion rate of copper in the sulphuric acid solution. It can also be seen from the figure that, increase in concentration of the inhibitor led to a further decrease in the weight loss of copper in the acid solution.

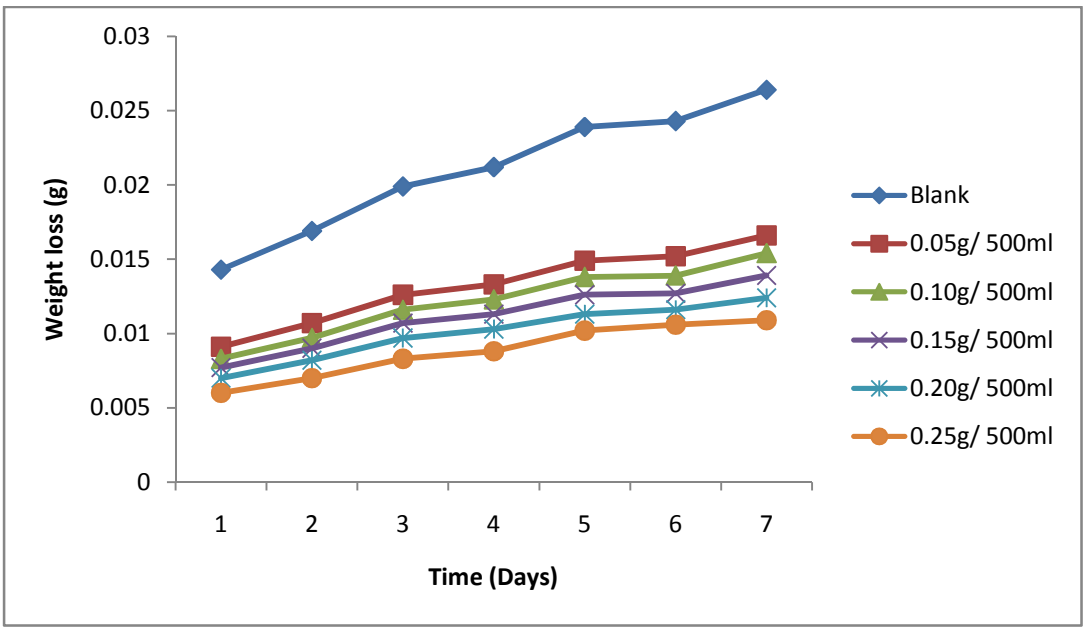

Fig. 1. Variation of weight loss with time for copper coupons in 0.5M H_2SO_4 acid solution containing different concentrations of extract of black African velvet tamarind (*Dialium indium*) at 30ºC

The same observations were found in Figs. 2 and 3, showing that velvet Tamarind is also effective in reducing the corrosion rate of copper in sulphuric acid solution at higher temperatures of 40 and 50ºC.Similar results were obtained by earlier researchers [13-14].

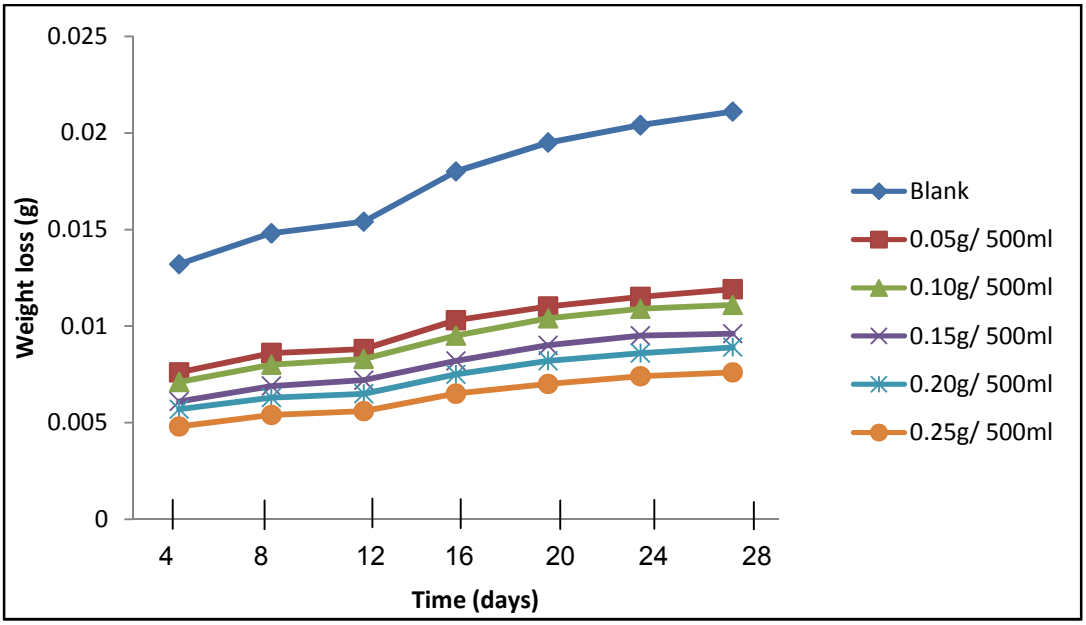

Fig. 2. Variation of weight loss with time for copper coupons in 0.5M H_2SO_4 acid solution containing different concentrations of extract of black African velvet tamarind (*Dialium indium*) at 40ºC

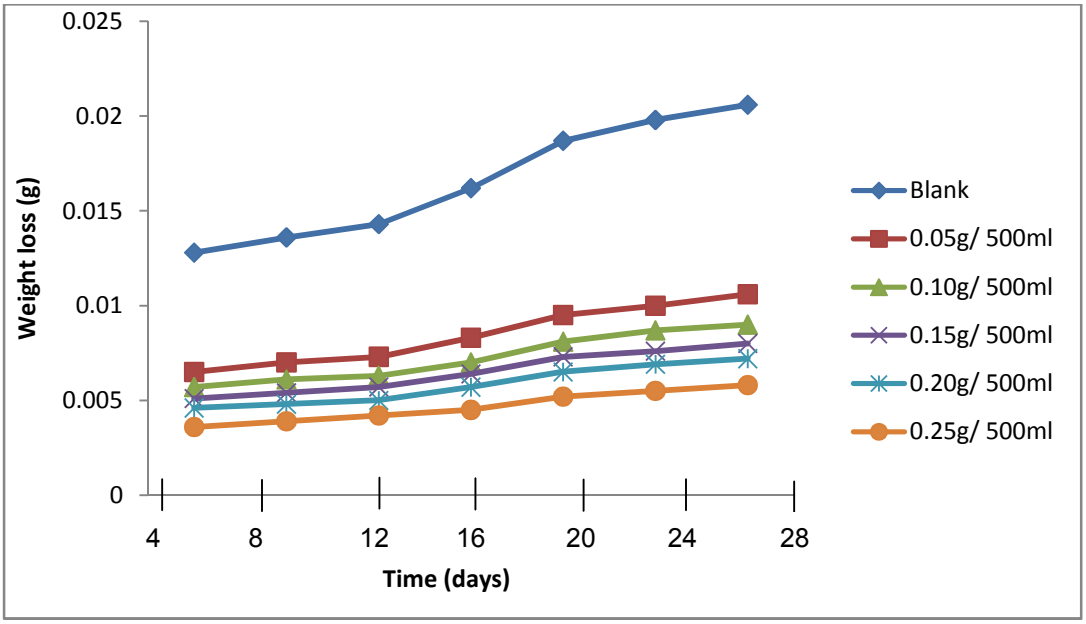

Fig. 3. Variation of weight loss with time for copper coupons in 0.5M H_2SO_4 acid solution containing different concentrations of extract of black African velvet tamarind (*Dialium indium*) at 50ºC

4.2 Hydrogen Evolution Results via the Gasometer

The results show that there was a general decrease in hydrogen gas evolution with time, as the concentration of the additive increased from 0.05g/500ml to 0.25g/500ml (Fig. 4) which confirm that the inhibition efficiency of the African Black velvet tamarind increases with its concentration.

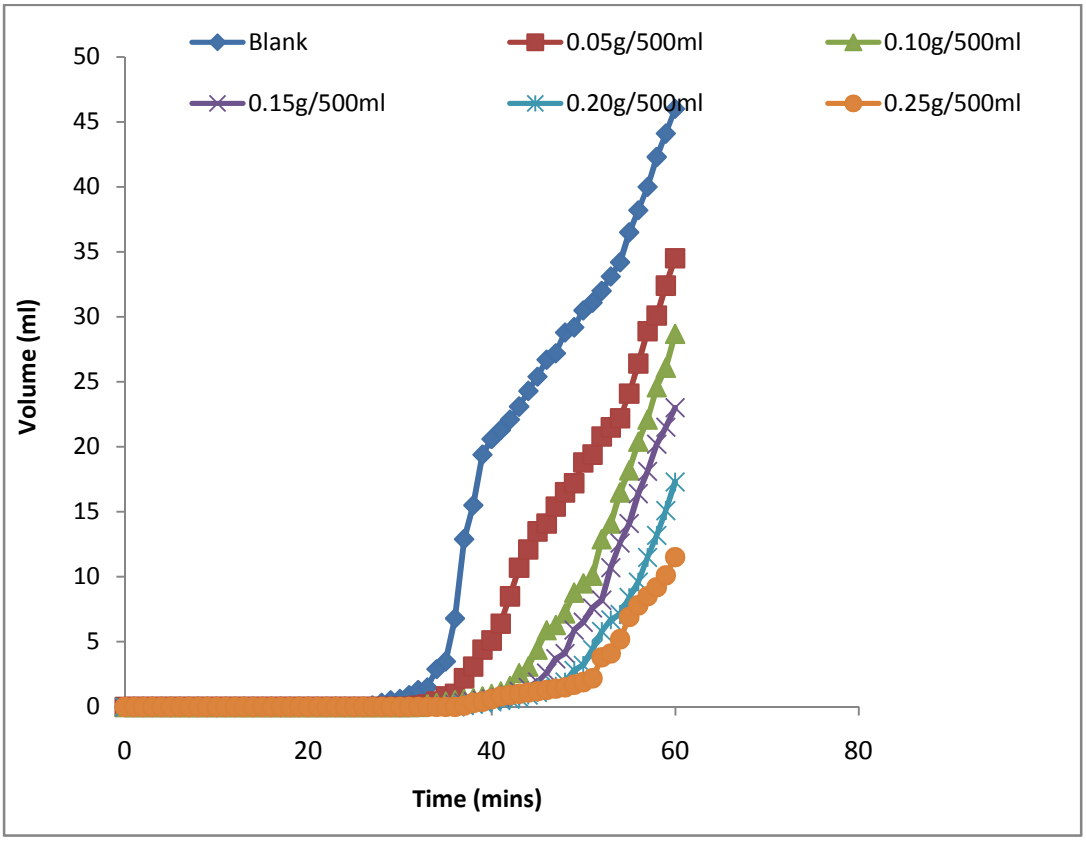

Fig. 4. Variation of volume of hydrogen gas evolved with time (minutes) for the inhibition of copper in 0.5M H_2SO_4 solutions by African black velvet tamarind at 303K

5. EFFECT OF CONCENTRATION INCREASE ON THE INHIBITION EFFICIENCY OF EXTRACT OF BLACK AFRICAN VELVET TAMARIND (*Dialium indium*)

From Table 1, it was observed that the percentage inhibition efficiency increases with the concentration of the inhibitor and temperature. Hence at the highest temperature and concentration of 50ºC and 0.25g/500ml respectively, the highest value for Percentage inhibition efficiency was obtained. This observation can also be seen in Fig. 4.

Table 1. Influence of concentration of velvet tamarind extract on its percentage inhibition efficiency at different temperatures

Velvet tamarind concentration	Percentage inhibition efficiency		
	30ºC	40ºC	50ºC
Blank (0.5M H_2SO_4 acid)	0.00	0.00	0.00
0.05g/500ml	37.03	42.97	48.96
0.10g/500ml	42.14	46.58	56.14
0.15g/500ml	46.89	53.81	60.69
0.20g/500ml	51.89	57.71	64.86
0.25g/500ml	57.97	63.78	71.76

6. EFFECT OF TEMPERATURE ON THE INHIBITION EFFICIENCY OF EXTRACT OF BLACK AFRICAN VELVET TAMARIND (*Dialium indium*)

Fig. 5 shows that with increase in the temperature, there is a corresponding increase in the inhibition efficiency. This means that the higher the temperature of the acidic medium, the higher the inhibition efficiency of velvet tamarind in sulphuric acid solution.

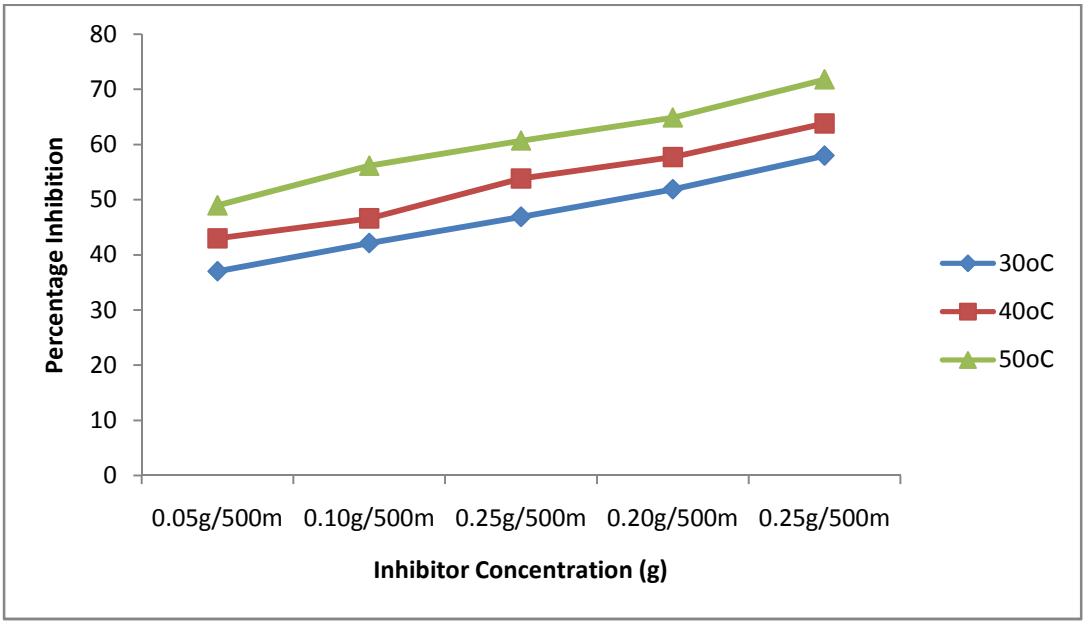

Fig. 5. Variation of inhibition efficiency with inhibitor concentration for copper coupons in 0.5M H_2SO_4 acid solution containing different concentrations of extract of black African velvet tamarind (*Dialium indium*) at three different temperatures

7. THE ACTIVE COMPONENT RESPONSIBLE FOR THE INHIBITORY ACTION OF BLACK AFRICAN VELVET TAMARIND (*Dialium indium*)

The active component responsible for the inhibitory action of African Black velvet Tamarind (*Dialium indium*) is Ascorbic acid (Vitamin C). The inhibitive mechanism at the metal/solution interface may be explained by considering the adsorption of the Ascorbic acid molecule

through the available electron-rich oxygen atoms in the molecule (Fig. 6) and complex formation on the corroding metal surface. These may be responsible for the formation of an oriented film layer, which eventually blocks discharge of H^+ and consequently the dissolution of the copper ions.

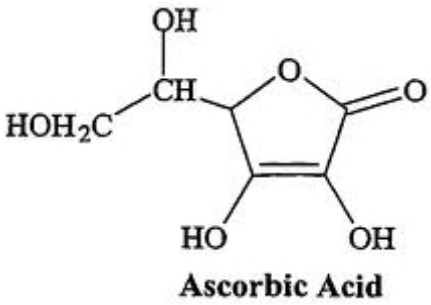

Fig. 6. Chemical structure of ascorbic acid (Vitamin C)

8. CONCLUSION

The present study shows that African Black velvet Tamarind (*Dialium indium*) is a good corrosion inhibitor of copper in 0.5M sulphuric acid solution to a remarkable extent particularly at increased temperature and inhibitor concentration. On the basis of the observed increase in inhibition efficiency with temperatures, a chemisorptions process is proposed for the inhibition action of the additive. This observation could assist corrosion scientist and engineers in solving corrosion problems without a negative impact on the environment as African Black velvet Tamarind (*Dialium indium*) is ecologically friendly.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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