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Original Research Article

Inhibitory Potentials of *Bamboosa vulgaris* Leaves Extract on Corrosion Inhibition of Mild Steel in 1M HCl Solution

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Abstract: The corrosion inhibitory potentials of *Bamboosa vulgaris* leaves extract in 1M HCl solution was studied using gravimetric and gasometric techniques. The results obtained from both gasometrical and gravimetric analysis showed decrease in corrosion rate of mild steel immersed in the 1M HCl solution containing *Bamboosa vulgaris* leaves extract from the corrosion of the mild steel immersed in the blank uninhibited 1M HCl solution. There was a more pronounced decrease in corrosion rate as the concentration of the plant extract was increased from 200mg/l to 1000mg/l. The decrease in corrosion rate is attributed to inhibition of plant extract on the corrosion of mild steel. Inhibition efficiency of *Bamboosa vulgaris* leaves extract increased with increase in the concentration of its extract. However the corrosion inhibition properties of *Bamboosa vulgaris* leaves extract is suggested to be as a result of the formation of a protective shielding layer which might have developed around the metal surface under the corrosive medium conditions owing to the organic nature of the *Bamboosa vulgaris* leaves extract. The formation of the shielding layer is as a result of *Bamboosa vulgaris* phytochemical molecules adsorption to the metal surface, forming iron (11) complexes with the metal. The adsorption of the plant extract on the metal surface fitted into Langmuir adsorption isotherm, Freundlich adsorption isotherm, and Temkim adsorption isotherm, but best fitted into Langmuir adsorption isotherm. The calculated values of apparent free energy of adsorption are all negative indicating spontaneous adsorption of *Bamboosa vulgaris* leaves extract on the metal surface.
Keywords: *Bamboosa vulgaris,* inhibitory potentials, phytochemical molecules, corrosion and adsorption isotherm.

INTRODUCTION

Metallic materials are still the most widely used group of materials particularly in both mechanical engineering and transportation industry [9]. The usefulness of metals and alloys is faced with a major challenge know as corrosion. Corrosion is the deterioration of a metal as a result of chemical reactions between it and the surrounding environment. [5, 9] This chemical reaction is a natural process, which converts refined metal to more chemically stable form such as metal oxides, hydroxides, or sulphides. The reaction is spontaneous because the energy content of the metals and alloys in pure state is greater than that of their ores, so chemical combination of the metals to form ore-like compounds becomes a natural process [1, 2, 8].

Corrosion can cause disastrous damage to metal and alloy structures which results to economic consequences in term of repair, replacement of products, subsequent safety and environmental concerns [8]. Due to these undesirable effects corrosion ought to be prevented. There are several ways corrosion can be prevented or controlled with a view of improving the lifetime of metallic and alloy materials. These include:

Use of protective metallic or organic coatings
Change to more suitable material [12]. Design modifications to the system or component [13]. Modification to the environment with the use of inhibitors [18].

Amongst these preventive measures, the use of inhibitors proffers better and sustainable solution to the problem of corrosion [2]. Corrosion inhibitors are chemicals that react with the metal surface or the environmental gasses that cause corrosion, thereby, interrupting the chemical reaction that causes corrosion. Inhibitors can work by adsorbing themselves on the metal surface, forming a protective film [2]. These chemicals can be applied as a solution or as a protective coating via dispersion techniques.

Extensive work on corrosion control by inhibition, has covered areas such as microbial inhibition, chemical inhibition, petrochemical inhibition and other synthetic or artificial forms of inhibition. Although these micro acids are of effective inhibition measures, they have adverse effects, for example lead compounds present in paint formulations are well known for their toxic carcinogenic effect, other corrosion inhibitors such as benzene nitrates and phosphorus, exhibit toxic and adverse environmental effects. However, the need to develop effective non toxic environmentally friendly features is the common jingle in science today [8, 11, 14]. In this regard, many researchers have embarked on the use of organic inhibitor of plant source to prevent corrosion of metals, of which their research results proved effective, and efficient. The expanded interest on organic inhibitors of plant source otherwise called green inhibitors is attributed to the fact that they are cheap, ecologically friendly and posses no environmental threat, and the fact that they are readily available, renewable source of materials and sustainable [15]. The corrosion inhibition properties in many plant extracts is due their heterocyclic constituents like alkaloids, flavonoids, tannins etc. Again, it is suggested that medicinal plants posses good corrosion inhibition properties, since they are constituted of compounds containing hetero-atoms like N, S, O and P which are reported to have corrosion inhibiting properties [1-9,16, 17]. The above reasons lead to our interest in *Bamboosa vulgaris* leaves.

Bamboosa vulgaris is commonly known as golden bamboo and it is taxonomically a grass, but its habit is tree-like. It occurs throughout India in areas up to 2100 m elevation. Bamboo leaves have been claimed to be used as astringent, ophthalmic solution, sudorific and febrifuge. In Nigerian folklore medicine, bamboo is claimed to be used as an emmenagogue, abortifacient, appetizer and for managing respiratory diseases as well as gonorrhea. Bamboo Leaves are used in ayurvedic medicine in ptosis and paralytic complaints. The leaves have been used in Indian folk medicine to treat various inflammatory conditions. [21] It is reported in Owolabi and Lajide that *Bamboosa vulgaris* leaves contain phytochemicals like, alkaloids, flavonoids, tannins and terpenoids [20]. Owing to the phytochemical constituents of *Bamboosa vulgaris* and its medicinal properties we suggest it will possess good corrosion inhibiting properties. This study investigates the corrosion inhibiting potentials of *Bamboosa vulgaris* leaves extract.

MATERIALS AND METHODS

Materials

The materials used for the study were mild steel sheet. The weight composition of the mild steel is recorded in table 1 blow.

Table1: Weight composition of mild steel

Element	C	M n	P	S i	F e
Weight (%)	0.15	0. 6	0.36	0.03	98.86

The mild steel sheet was obtained from metallurgical department federal university of technology Owerri Imo state Nigeria. For the purpose of this study the mild steel sheet was prepared into coupons following the procedure previously described in Ibisi *et al* [2].

Extract Preparation

Bamboosa vulgaris leaves were collected from plants around Michael Okpara University of Agriculture Umudike Abia State Nigeria. The leaves were cut into pieces to increase the surface area for easy drying. The leaves were then oven dried with laboratory oven at 50^{o}C. The drying and every other analysis were carried out in chemistry Lab, College of physical and applied sciences, Michael Okpara University of Agriculture Umudike. The dried leaves samples were ground to powdery form, and refluxed in ethanol for 72hrs using soxhlet extractor. Then the extract was evaporated to dryness, then from the resultant dried concentrate extract test solutions of 200mg/l, 400mg/l, 600mg/l, 800mg/l and 1000mg/l were prepared in 1M HCl solutions.

Gravimetric Analysis (weight loss)

Weight loss experiment was conducted under total immersion conditions in 250ml of test solutions maintained at 30^{0}C. The pre-weighed test coupons were retrieved at the end of immersion period, scrubbed with bristle brush under running water until clean. The clean test coupons were then dried in acetone and reweighed. The weight loss therefore was obtained as the difference between weight of coupons before and after immersion, from the weight loss data corrosion rate of the mild steel was calculated using equation 2 .1

$$CR = \frac{\Delta wt}{At} \qquad (2.1)$$

Where CR represents corrosion rate, A is surface area of the coupon,

t is the time of immersion and Δwt is change in weight (weight loss)

With the calculated values of corrosion rate of the mild steel in test solutions containing *Bamboosa vulgaris* leaves extract and corrosion rate of the coupon in uninhibited system (blank), the inhibition efficiency and degree of surface coverage of the plant extract molecules were calculated using equation 2.2 and 2.3 respectively.

$$\theta = 1 - \frac{CR_{in}}{CR_{bl}} \quad (2.2)$$

$$IE(\%) = \left(1 - \frac{CR_{in}}{CR_{bl}}\right) X\ 100 \quad (2.3)$$

Where CR_{in} and CR_{bl} are corrosion rates in inhibited test solution and uninhibited system (blank) respectively, θ is degree of surface coverage while *IE* is inhibition efficiency.

Gasometrical Method

Gasometrical analysis was carried out at 30°C for 3hrs. From the volume of hydrogen gas evolved per minute, degree of surface coverage *(θ)* and inhibition efficiency were calculated using equation 2.4 & 2.5 [1-4].

$$\theta = [1 - \frac{V_{Ht}^1}{V_{Ht}^0}] \quad (2.4)$$

$$IE\ (\%) = [1 - \frac{V_{Ht}^1}{V_{Ht}^0}]\quad X\ 100 \quad (2.5)$$

Where, V_{Ht}^1 is the volume of hydrogen evolved at time *t* for inhibited solution and V_{Ht}^o is the volume of hydrogen gas evolved in uninhibited solution, *IE* and θ retain their previous definitions.

RESULTS AND DISCUSSION

Gravimetric Results

The gravimetrical examined corrosion rate results, of mild steel coupons immersed in 1M HCl solution containing *Bamboosa vulgaris* leaves extract and blank 1M HCl solution without the plant extract are graphically represented in figure 1.

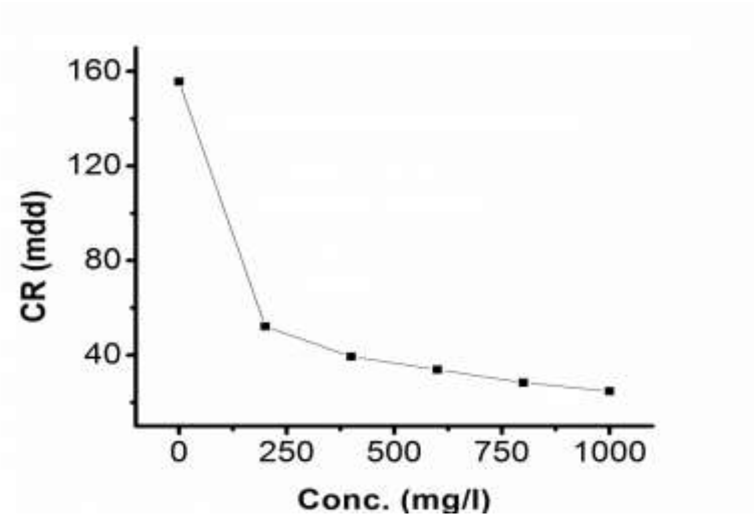

Fig-1: Gravimetric graph of corrosion rate against concentration of the system studied

Observations from the graph show decrease in corrosion rate of the mild steel coupon immersed in 1M HCl solution containing *Bamboosa vulgaris* leaves extract from the result of the coupon immersed in the blank solution. The decrease in corrosion rate became more pronounced as the concentration of the plant extract increased from 200mg/l to 1000mg/l. This indicates corrosion inhibition of *Bamboosa vulgaris* leaves extract. The corrosion inhibition efficiency results of the test extract are graphically presented in figure 2.

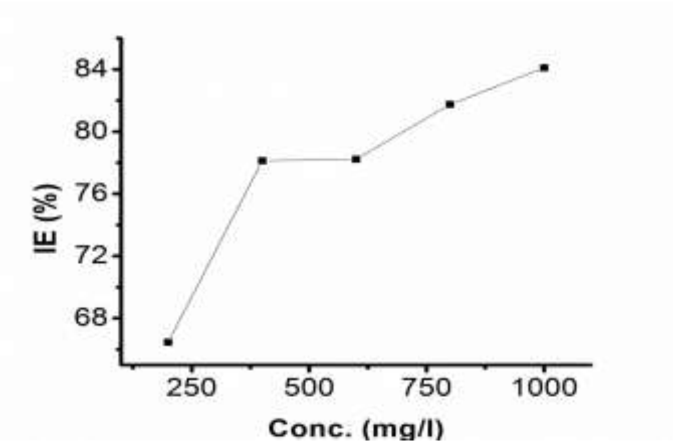

Fig-2: gravimetrical results of Inhibition efficiency against concentration of the extract

It can be observed from the graph that, inhibition efficiency of the plant extract increased as the concentration of *Bamboosa vulgaris* leaves extract increased. From the observations it can be deduced that the more *Bamboosa vulgaris* leaves extract molecules are introduced into the system the more corrosion of mild steel is inhibited.

Gasometrical Results

A graphical representation of gasometrical determined corrosion rates of mild steel coupons in the corrosive medium studied is shown in figure 3.

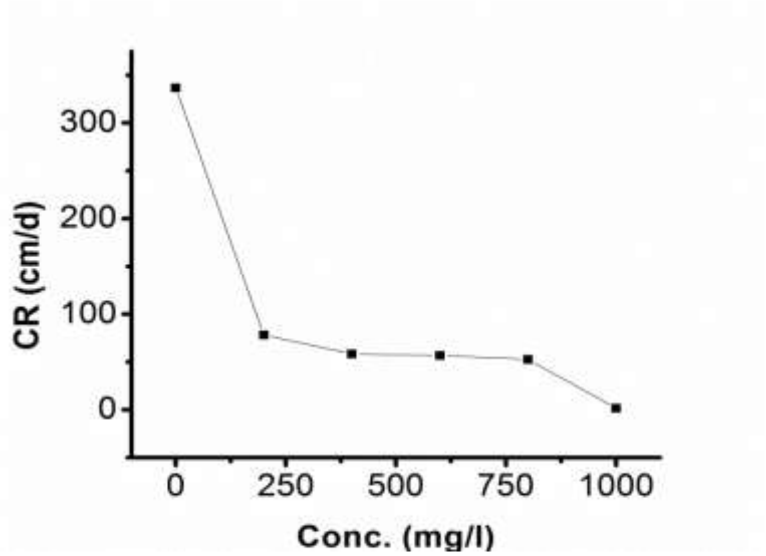

Fig-3: Gasometrical results of corrosion rate against concentration of the system

The graphical result shows decrease in corrosion rate of the mild steel coupon as the plant extract is introduced into the corrosive system. This result was similar to what was observed from the gravimetric results. The decrease in corrosion rate became more pronounced as the concentration of the plant extract increased from 200mg/l to 1000mg/l exactly as observed in gravimetric analysis. The extent of inhibition is displayed in the graphical representation of inhibition efficiency against concentration of *Bamboosa vulgaris* leaves extract shown in figure 4.

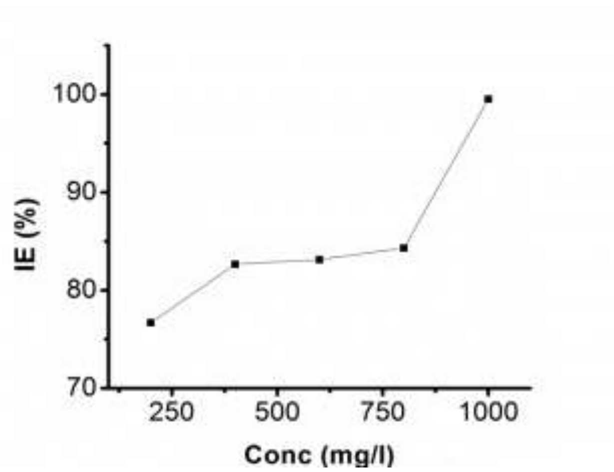

Fig-4: Gasometrical results of inhibition efficiency against concentration of the extract

The graph shows increase in inhibition efficiency as concentration *Bamboos vulgaris* leaves extract increases. A close study of the graph reveals that the inhibition efficiency was almost 100% at 1000mg/l concentration of the plant extract. However the corrosion inhibition properties of *Bamboosa vulgaris* leaves extract is suggested to be as a result of the formation of a protective shielding layer which might have developed around the metal surface under the corrosive medium conditions owing to the organic nature of the *Bamboosa vulgaris* leaves extract. The test plant extract is said to be constituted of phytochemical compounds like alkaloids, flavonoids, tannins and terpernoids, [20] which are composed of ligan molecules with lone pairs of electrons that can be donated to the empty d-orbitals of the metal to form complexes on the metal surface. This results to the adsorption of the extract molecules on the surface of the mild steel to form a shielding layer which prevents direct contact between the metal and the corredent [22].

Adsorption Studies

The relationship between the degree of surface coverage of *(θ)* and Bamboosa vugaris extract can be represented by the Langmuir adsorption isotherm. According to equation 3.1

$$\frac{C}{\theta} = C + \frac{1}{K_{ad}} \qquad (3.1)$$

Where K is the constant for adsorption related to the free energy (ΔG^{O}_{ad}) by relation in equation 3.2

$$K = \frac{1}{55.5} exp\left(\frac{\Delta G_{ad}}{RT}\right) \qquad (3.2)$$

C is concentration of the plant extract, R is gas constant, T is temperature while θ retain its initial meaning. Figure 5 shows a plot of $\frac{C}{\theta}$ against concentration of *Bamboosa vulgaris* leaves, extract in 1M HCl gravimetrically and gasometrically studied to be linear, with intercept $\frac{1}{K}$ which suggest that the experiment fits into Langmuir adsorption isotherm. Other adsorption isotherms shown in figures 6 and 7 which are Freundlich and Temkim adsorption isotherms were used to access the absorptiveness of *Bamboosa vulgaris* leaves extract on mild steel surface. The plant extract molecules adsorption fitted into all the adsorption isotherms but best fitted into Langmuir adsorption isotherm. Table 2 contains calculated values apparent free energy of adsorption (ΔG_{ad}) which are all observed to be negative. The negative sign indicates that *Bamboosa vulgaris* leaves extract was spontaneously adsorbed to the surface of the mild steel in acidic medium studied.

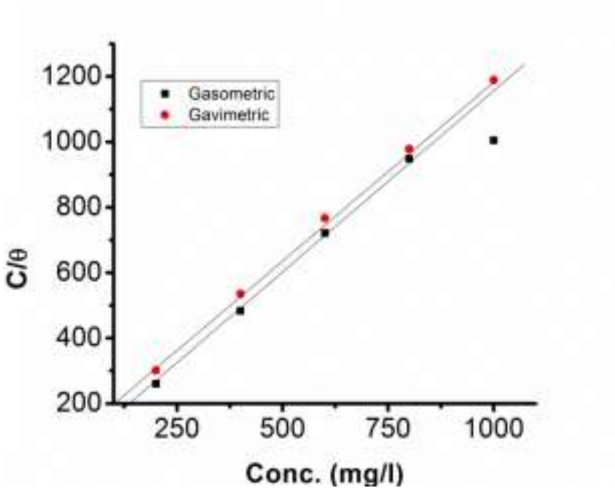

Fig-5: Langmuir adsorption isotherm

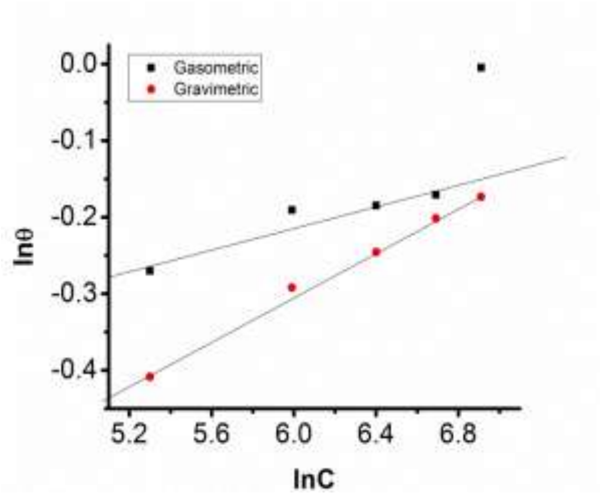

Fig-6: Freundlich adsorption isotherm

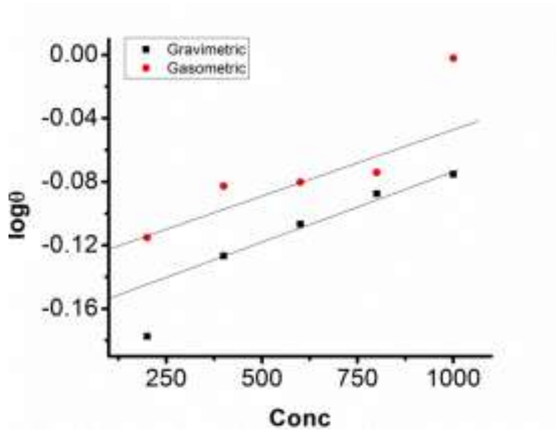

Fig-7: Temkim adsorption isotherm

Table 2: Calculated values of apparent free energy of adsorption of *Bamboosa vulgaris* leaves extract on the mild steel studied

Concentration of the extract (mg/l)	Free energy of adsorption ($KJmol^{-1}$) gravimetrically determined	Free energy of adsorption ($KJmol^{-1}$) gasometrically determined
200	-1.5055	-0.2251
400	-2.2481	-1.0413
600	-2.7746	-1.9774
800	-2.9425	-2.4839
1000	-3.0858	-3.2074

CONCLUSIONS

From the results of the study, the following conclusion were made,

1. Extracts of *Bamboosa vulgaris* leaves extract effectively inhibited corrosion of mild steel in 1M HCl solution.
2. The inhibitive effect resulted from adsorption of *Bamboosa vulgaris* leaves extract on mild steel surface fitting into Langmuir adsorption isotherm, Freundlich adsorption isotherm, and Temkim adsorption isotherm, but best fitted into Langmuir adsorption isotherm
3. The inhibition efficiency of the plant extract increased with extract concentration
4. The apparent free energy of adsorption values of the extract are all negative suggesting spontaneous adsorption

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