ARTICLE

Phytochemical Analysis and Ethanolic Extraction of *Gardenia aqualla* Leaves as Corrosion Inhibitor in 1 M H_2SO_4 Acid

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ABSTRACT

The main objective of this study is to investigate the corrosion inhibition properties of *Gardenia aqualla* leaf extract on mild steel using weight loss method. The corrosion of mild steel was investigated at different concentrations of *G. aqualla* and also at different temperatures (303, 313 and 323 K). *G. aqualla* inhibits the corrosion rate of mild steel from 62.4 mm/yr to 6.5mm/yr, 91.6 mm/yr to 16.6 mm/yr and 113.8 mm/yr to 28.4 mm/yr at 303, 313 and 323 K, respectively, which yielded an optimum result in the values of inhibition efficiency from 63.8 to 89.5 %, 52.5 to 81.9 % and 39 to 75 % for the various temperatures after an interval of 3 days after being in contact with its respective environment. The Langmuir isotherm confirmed that physisorption occurred. It was found that inhibition occurred through adsorption of constituents present in the leaf of *G. aqualla* obtained by the phytochemical screening.

KEYWORDS

Adsorption, Phytochemical screening, Mild steel, Corrosion inhibition, *Gardenia aqualla*.

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INTRODUCTION

An impending phenomenon that is widely experienced in our society, which affects the economy and society is called corrosion. Its consequences arise when it damages the exterior surface of metals and most times leading to metallic parts of an equipment or tools not working appropriately as expected. It is not only limited to industries or factories, but this happens in almost all environments [1,2]. The corrosion phenomenon can be attributed to taking place in a number of processes. First, there is a reduction of mass and thickness of metal as a consequence of an attack on its surface. Furthermore, in the place of a whole-surface attack, certain sites on the area of metal could be affected, forming the accustomed localized corrosion. Additionally, it also takes place along grain boundaries or other spots on the metal that are weak because of a change in resistance to corrosive menace.

A substance known as an inhibitor tends to stop a chemical reaction or process that reduces the activity of reactants or catalysts on the surface of mild steel. It enhances the formation of an oxide as a protective film through the effect of oxidation. Hence, a barrier is created between metal surface and selectively adsorbed species, thereby inhibiting corrosion and retarding the process of corrosion or preventing the corrosive agents on the surface of mild steel [3]. Some organic compounds have been studied to know their effective potentials as corrosion inhibitors [4-6].

Most of these studies revealed that the optimum yield in the values of inhibition efficiency is due to the fact that virtually all organic molecules containing heteroatoms (chemical synthetic inhibitors) such as nitrogen, sulphur, phosphorous and oxygen are duly responsible for it [7]. Huge successes have been achieved by the use of these synthetic chemical inhibitors, but they pose some risks to human life and its environment. These dangers include environmental pollution, lack of availability and high cost [8]. It was paramount that these risk sought to be managed; thus, they compelled scientists to search for their replacement.

Gardenia aqualla is a type of flowering plant found amongst the coffee family called Rubiaceae in the tropical and subtropical areas of Africa such Adamawa Sate, Nigeria and other parts of the world. Gardenias are evergreen in nature and grow in heights (2-20 feet) in their natural habitat. In tree form, the branches tend to project horizontally. Studies have shown that the phytochemistry of methanolic extract of stem bark of *G. aqualla* revealed the presence of steroid, carbohydrate, anthraquinones, saponins, triterpenes, tannins, cardiac glycoside and flavonoids, and the antimicrobial activity of this same plant indicates that the plant can be used as traditional medicine. Hence, the leaves, roots, fruits and stem bark are used to treat leprosy, oral infection, ear infection and bowel disorder, respectively, in northern Nigeria. Researchers in the past have studied the inhibition efficiency and corrosion rate reduction of different plants and its parts used as inhibitors for retarding the corrosive processes. These include black pepper extracts, leaves, seeds and root extracts of *Azadirachta indica* seeds and *Foeniculum vulgare* [9-12]. In the present study, an attempt was made to examine the alcoholic extracts of *G. aqualla* leaves as a potential inhibitor of corrosion for mild steel in the 1 M H_2SO_4 medium using the gravimetric technique along with some statistical model to verify efficiency of the inhibitor developed.

EXPERIMENTAL

Mild steel preparation: The mild steel was composed of many elements which includes their compostion as C = 0.078, Si = 0.05, P = 0.99, Cu = 0.02 and Fe = 98.86. The specimens were of average dimensions 1.2 cm × 0.72 cm × 0.77 cm and used for the gravimetric study. The exterior of specimens was scraped using sand paper, washed thoroughly with acetone and rinsed with distilled water and then placed in a desiccator before immersing them into their respective solutions.

Preparation of *G. aqualla* extract: Leaves of *G. aqualla* were collected from Girei local Government area, North East, Adamawa state. The leaves were shade dried for 3 days, after which the surface area of the leaves was increased by grinding it with an electric blender. The powdered leaves were soaked in ethanol, which was continually stirred for 24 h. The dried alcoholic extracts were prepared by evaporating the filtrate, hence, they are used for the preparation of inhibitor test solutions in the concentrations of 0.2, 0.4, 0.6 and 0.8 g/100 mL solution of 1M H_2SO_4.

Gravimetric analysis: The weighed mild steel specimens of identical sizes were suspended in 100 mL test solutions of different concentrations at various temperatures for an interval of 3 days. At every 3-days interval, the specimens were taken out, washed with distilled water, rinsed with ethyl alcohol, dried manually and finally weighed again to obtain its new mass. The experiments were carried out in duplicate and the average value stated. The weight-loss was calculated. From these data various values of inhibition efficiency (I %), corrosion rate (C_r) and surface coverage (θ) were calculated using the following relationships:

$$I\,(\%) = \frac{(W_1 - W_2)}{W_1} \times 100 \quad (1)$$

$$C_r = \frac{K\Delta W}{\rho A t} \quad (2)$$

$$\theta = \frac{W_1 - W_2}{W_1} \quad (3)$$

where, I (%) is the efficiency of inhibition, W_1 is the weight loss of mild steel in the absence of inhibitor, W_2 is the weight loss of mild steel in the presence of inhibitor, C_r is the corrosion rate in mm/yr^{-1}, W is the weight loss of mild steel in mg, A is the total area of mild steel sample in cm^2, t is the time of exposure of metal sample in the test solution in h, ρ is the density of mild steel (*i.e.* 7.86 g/cm^{-3}), θ is the surface coverage of inhibitor on mild steel surface and K (constant) value is 87.6.

RESULTS AND DISCUSSION

Natural products obtained from phytochemical screening (Table-1) shows the results of *Gardenia aqualla* constituents, which indicates the presence of saponins, tannins, flavonoids, alkaloids and steroids. Terpenoids and glycosides were found to be absent. These natural products present in the extracts block the surface of mild steel through the mechanism of adsorption, thereby inhibiting or retarding the corrosion process. However, the blocking of surface cannot be attributed to a specific or group of constituent(s).

TABLE-1
PHYTOCHEMICAL SCREENING
OF THE *Gardenia aqualla* LEAVES

Saponins	Present	Alkaloids	Present
Tannins	Present	Glycosides	Absent
Terpenoids	Absent	Steroids	Present
Flavonoids	Present	Phenols	Present

Weight loss studies: The gravimetric analysis such as corrosion rates and efficiency of inhibition at different temperatures and concentrations of *G. aqualla* in 1 M H_2SO_4 after a 3 days interval are shown in Figs. 1-3. It can be comprehended that the rate of corrosion reduced significantly on adding the corrosion inhibitor and then reduced progressively with an increase in inhibitor concentration, while the inhibition efficiency also increased with an increase in the concentration of inhibitor until its maximum value of 89.5% was achieved [12,13].

Adsorption mechanism: Basically, two adsorption processes could be considered as follows: (a) whole process of creating a barrier with the inhibitor or inhibiting the corrosion of mild steel can be said to occur through either adsorption of *Gardenia*

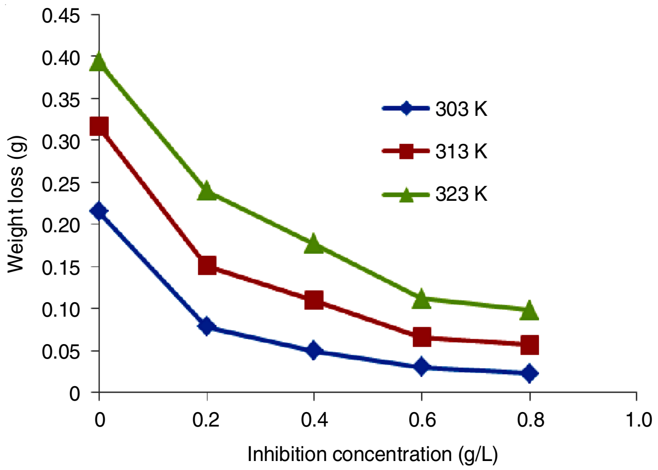

Fig. 1. Weight loss of mild steel with and without *Gardenia aqualla* extract

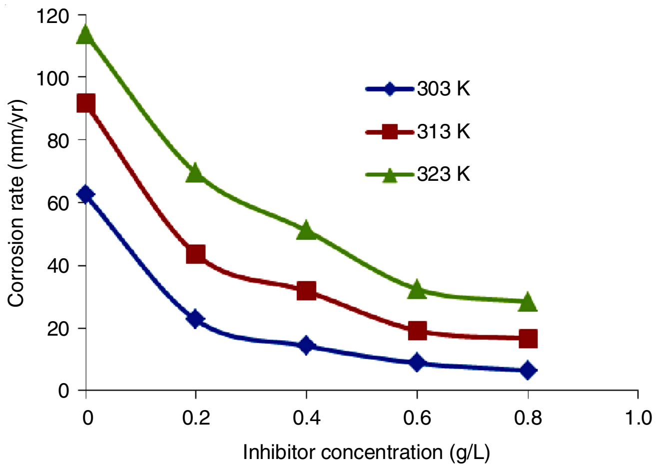

Fig. 2. Corrosion rate of mild steel with and without the *Gardenia aqualla* extract

aqualla molecules or the formation of a layer of insoluble metal complex on the surface, which acts as a barrier between metal surface and corrosive medium (process is termed as physisorption mechanism); (b) neutral *Gardenia aqualla* may be adsorbed on the surface of metal through the process of chemisorption involving the displacement of molecules of water from

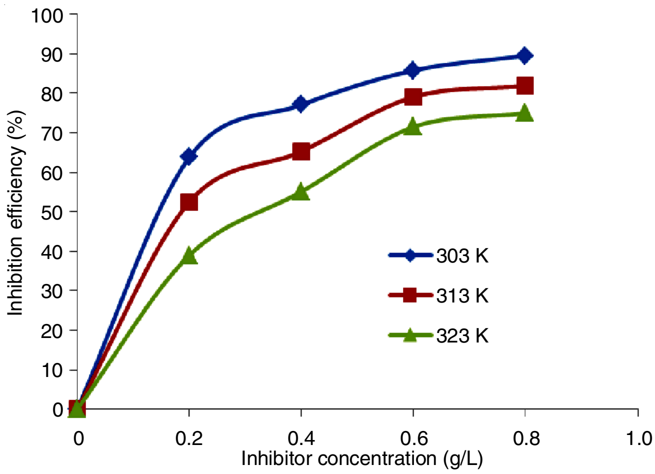

Fig. 3. Inhibition efficiency of the *Gardenia aqualla* extract on mild steel corrosion in 1.0 M H_2SO_4

the metal surface and sharing of electrons between iron and oxygen atoms [14,15]. As a result, Langmuir adsorption mechanism was used to control the inhibition reaction.

The concern of mathematical relationship between surface coverage and concentration of inhibitor is expressed by Langmuir equation as shown in eqn. 4:

$$\frac{C}{\theta}=\frac{1}{K}+C \qquad (4)$$

where K is the equilibrium constant and C is the concentration of inhibitor. The graph plot in Fig. 4 illustrates the Langmuir adsorption plot of C/θ *versus* C, which shows a straight line graph with slope and R^2 values are presented in Table-2.

The Langmuir adsorption plot has linearity and its correlation coefficient is also good (degree of fit between the experimental data and isotherm equation) at different intervals of exposure. The values of R^2 are very close to unity, showing that Langmuir adsorption isotherm was adhered strongly [16,17].

Conclusion

This study has illustrated that *Gardenia aqualla* extract prevented the corrosion of mild steel in 1.0 M H_2SO_4 solution at different temperatures. The efficiency of inhibition at different

TABLE-2
SUMMARY OF AVERAGE WEIGHT LOSS (mg), CORROSION RATE (mm/yr), INHIBITION EFFICIENCY (%), SURFACE COVERAGE (θ) AND CONCENTRATION/SURFACE COVERAGE C/θ

Temperature (K)	Concentration (g/100 mL)	Weight loss (mg)	Inhibition efficiency (%)	Corrosion rate (mm/yr)	Surface coverage (θ)	Concentration/surface coverage C/θ
303	Blank	215.4	–	62.4	–	0
	0.2	77.9	63.8	22.6	0.64	0.313
	0.4	49.3	77.1	14.3	0.77	0.519
	0.6	30.5	85.8	8.80	0.86	0.698
	0.8	22.6	89.5	6.50	0.90	0.889
313	Blank	316.3	–	91.6	–	0
	0.2	150.4	52.5	43.5	0.52	0.385
	0.4	109.8	65.3	31.8	0.65	0.615
	0.6	66.2	79.1	19.2	0.79	0.759
	0.8	57.2	81.9	16.6	0.82	0.976
323	Blank	393.2	–	113.8	–	0
	0.2	239.8	39.0	69.4	0.39	0.513
	0.4	176.6	55.1	51.1	0.55	0.727
	0.6	112.0	71.5	32.4	0.72	0.833
	0.8	98.2	75.0	28.4	0.75	1.067

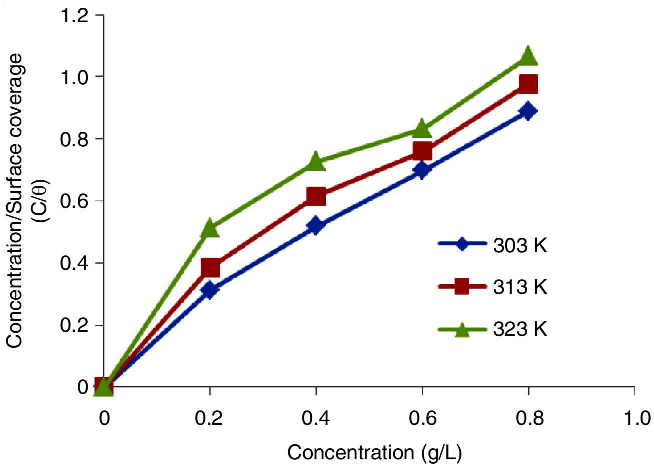

Fig. 4. Langmuir isotherm plot of corrosion of mild steel in the presence of *Gardenia aqualla* extract

concentrations verified an optimum value of about 89.5%, which increases on increasing the concentration of inhibitor and decreases with the rise in temperature. The Langmuir isotherm was obeyed, which confirms the mechanism of physisorption as the process that aided corrosion inhibition of mild steel. *Gardenia aqualla* acted as a potential inhibitor for the corrosion of mild steel in 1M H_2SO_4 solution.

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