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# Corrosion Inhibition of Tin metal by Ethanolic Extract of Tinospora Cordifolia Plant (stem/leaf) in $H_2SO_4$ acid using Additives and its Antibacterial Properties

Vineeta Mandawara[1], Dr. Alok Chaturvedi[2]
[1,2](Synthetic and Surface Science Laboratory, S.P.C., Govt. College, Ajmer, Rajasthan, India)

***Abstract:***
*Corrosion is the natural degradation of metal surfaces in aqueous and atmospheric conditions. It is the progressive, natural deterioration of metal surfaces caused by chemical or electrochemical reactions with their surroundings. The inhibition efficacy of Tinospora Cordifolia plant stem and leaf extracts at different concentrations of $H_2SO_4$ acid (0.5N, 1N, 2N, 3N) in the presence and absence of additive was examined using weight loss and thermometric techniques. It was observed that the inhibitory efficiency rises with increasing concentrations of stem and leaf extract (0.2% to 0.8%) as well as acid strength (0.5N to 3N $H_2SO_4$). The addition of additive ($K_2SO_4$) resulted in further improvement in inhibitory efficiency due to a synergistic effect. Maximum inhibitory efficiency of 92.28 and 88.91% for stem/leaf extract in absence and 95.56 and 92.77% in presence of additive was obtained at maximum strength of stem/leaf extract (0.8%) as well as $H_2SO_4$ acid (3N).The values of log(θ/(1-θ) increase linearly as inhibitor concentrations rise, demonstrating that they follow the chemisorption or Langmuir adsorption isotherm.The weight loss and thermometric method calculations are in good agreement and reveals that stem extract is better corrosion inhibitor.*

***Key Word****: Inhibition Efficiency, Weight Loss, Thermometric Method, Corrosion Rate, Surface Coverage, Inhibitor, Tinospora Cordifolia.*

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## I. Introduction

The damaging attack on a substance caused by an interaction with its environment is known as corrosion[1]. Metal deterioration is caused by chemical and electrochemical processes. The atmosphere, the temperature, the pH of the aqueous solution, the existence of passive layers, and any potential electrochemical processes that could be taking place all affect how susceptible a metal is to corrosion [2,3]. The inevitable deterioration of a metal's surface brought on by chemical reactions is known as corrosion. This procedure converts a pure metal into its chemically more stable form, such as sulphides, oxides, hydroxides, etc. under a corrosive environment. Any type of gas, liquid, or solid might make up the corrosive environment. The majority of individuals think that rusting occurs everywhere [4].

Tin is an amphoteric metal that interacts in both acidic and alkaline environments but is comparatively unaffected by neutral conditions [5]. When applied electrochemically as a coating on steel, copper, or nickel, it exposes very large surface areas to corrosive environments. Tin's behavior shifts from passivity to corrosion at pH 5–4, which is in the acid rain range. Tin also corrodes favorably in alkaline and acidic environments [6]. Tin is utilized extensively in a wide range of sectors, including electronics, coatings, and packaging. It is used in the manufacturing of alloys like as bronze and pewter, as well as a coating on food cans to prevent corrosion and contamination. Tin is also used to make electrical components such as solder and tinplate, which are utilized to make printed circuit boards [7].

The best way to prevent corrosion from the medium in which a metal is put is to utilize corrosion inhibitors. Typically, organic molecules with hetero atoms, conjugate systems, and functional groups may effectively control corrosion in acidic solutions. Most organic compounds have a high capacity for adsorption onto metal surfaces, which results in the creation of a protective organic coating and their ability to prevent corrosion. Organic compounds can indeed have minimal toxicity and may be used sparingly to control and slow down corrosion without affecting the mechanical qualities of the metal, making it an easy, efficient, and environmentally acceptable method of corrosion prevention [8,9].

## II. Plant Description

Tinospora Cordifolia, also known as gurjo, heart-leaved moonseed, guduchi, or giloy, is a Menispermaceae herbaceous vine that is only found in the tropics of the Indian subcontinent [10]. It has been employed in Ayurveda to treat a number of ailments. It is a big, deciduous climbing shrub with multiple long, twining branches that spreads widely. Simple, alternating, exstipulate leaves with long petioles are present.

Due to its scarlet fruit and heart-shaped leaves, the heart-leaved moonseed earns its name. The lamina is broadly oblong or ovate cordate, 10-20 cm (4-8 in) long or 8-15 cm (3-6 in) wide, deeply cordate at the base, seven nerved, membranous, pubescent above, and has a prominent reticulum underneath. Unisexual flowers are tiny, occur on separate plants when the plant is leafless, and are greenish-yellow in color on axillary and terminal racemes. Female flowers often grow alone, whereas male flowers are grouped. Six sepals, in two sets of three each, are present. Smaller than the inner ones are the outside ones. It has six membranous, obovate petals that are smaller than the sepals [11].

Indian medicinal herb guduchi has long been utilized in Ayurveda formulations to treat a variety of illnesses. General weakness, fever, dyspepsia, dysentery, gonorrhea, secondary syphilis, impotence, gout, viral hepatitis, skin conditions, and anemia have all been treated with this plant. Guduchi is therapeutically used to treat diabetes, rheumatoid arthritis, and jaundice in compound formulations. The root is used to treat intestinal blockage and is thought to be a potent emetic. [12-14]

The aerial parts, roots, and whole plant of Tinospora Cordifolia have yielded a considerable variety of isolated chemicals. Major constituents include the alkaloids berberine, tinospporin, palmitine, tembetarine, choline, isocolumbin, and tetrahydropalmatine; the steroids sitosterol, octacosanol, heptacosanol, nonacosan-15-one, hydroxyecdysone, makisterone, giloinsterol, diterpenoid lactones, furanolactones, tinosporon, and columbin; and the glycosides 18-nonderodane glycoside, furanoidditerpene glycosides, tinocordifoliside, tinocordiside, cordiside, cordifoliside, plamatosides, and syringin.[15-19]

## III. Material And Methods

**Preparation of Stem and Leaves Extract:**

The freshly collected stem and leaves of the *Tinospora Cordifolia* plant were air dried at room temperature before being ground to form powder. *Tinospora Cordifolia* powder stem and leaf extract prepared by refluxing the dried stem/leaves in soxhlet unit in ethanol solvent with refluxing by heating for adequate time.

**Metal used:**

Tin coupons were used for all the experiments. Specimens of tin metal were prepared by cutting the sheet of pure tin, in square shaped having dimension of 2.5 cm × 2.5 cm with a small hole of about 2mm diameter near the upper edge.

**Chemicals used:**

Different concentration solutions of $H_2SO_4$ i.e 0.5N, 1N, 2N, 3N were prepared in double distill water using analytical grade reagents and these acid solutions were used for corrosion studies. Inhibitor solutions of varying concentrations i.e. 0.1, 0.2, 0.6 and 0.8 were prepared using ethanol solvent.

**Methods:**

**Weight loss method:**

At room temperature, each specimen was hung by a V-shaped glass hook made of fine capillary and placed into a beaker containing 50 mL of the test solution. Test specimens were cleaned with running tap water and dried with a hot air drier after appropriate exposure. In each case, double trials were carried out, and the mean value of weight reduction or loss was determined. The percentage inhibition efficiency was calculated [20-22] by using this equation:

$$\eta\% = \left[\frac{(\Delta W_u - \Delta W_i)}{\Delta W_u}\right] \times 100$$

Where $\Delta W_u$ and $\Delta W_i$ are the weight loss of the metal in the absence and presence of inhibitorsolution, respectively. The degree of surface coverage (θ) was calculated as [23-24]:

$$\theta = \left[\frac{(\Delta W_u - \Delta W_i)}{\Delta W_u}\right]$$

The corrosion rate (CR) in mm/yr (millimetre per year) was expressed as [25] :

$$\text{Corrosion rate (mm/yr.)} = \frac{(\Delta W \times 87.6)}{(A \times T \times d)}$$

Where ΔW is the weight loss of the specimen in mg, A is the area of exposure of the specimen in square $cm^2$, T is the time of exposure in hours and d is the density of the specimen in $g/cm^3$.

**Thermometric method:**

Inhibition efficiencies were also assessed using this technique, which entailed submerging a single specimen with a surface area of 13 $cm^2$ in a reaction chamber containing a 50 mL acid solution at a starting temperature of $301^o$ K. With 0.5N $H_2SO_4$, however, there was no appreciable temperature changes noted. Experiments were conducted in acid solutions of 1N, 2N, and 3N as well as in the absence and presence of inhibitors at varying concentrations of 0.2, 0.4, 0.6, and 0.8. The specimen and thermometer bulb were submerged entirely in the test solution in the beaker. The beaker was stored in a room with thermal insulation. A thermometer with a resolution of $0.1^o$k was used to measure temperature changes at intervals of 5 minutes. The temperature rose gradually at first, then quickly until it reached its maximum value. The highest temperature was then recorded.

Reaction Number, RN ($Kmin^{-1}$) is calculated as [26]:

$$RN = \frac{T_m - T_i}{t}$$

Where $T_m$ = Maximum temperature of the solution.

$T_i$ = Initial temperature of the solution.

t= time required (in minutes) to attain maximum temperature.

The percentage inhibition efficiency was calculated as [27-29]:

$$\eta\% = \frac{(RN_f - RN_i)}{RN_f} \times 100$$

Where $RN_f$=Reaction Number in uninhibited solution.

$RN_i$= Reaction Number in the inhibited solution.

## IV. Results and Discussion

The corrosion rate of tin in sulphuric acid ($H_2SO_4$) solutions of various strengths was studied using weight loss and thermometric methods in the absence and presence of Tinospora Cordifolia plant stem and leaf extracts as well as additive ($K_2SO_4$) at $301^o$K temperature, and percentage inhibition efficiencies were calculated using both methods. The information for weight loss, percentage inhibition efficiency, corrosion rate, and surface coverage for tin metal in 0.5 N, 1 N, 2 N, and 3 N sulphuric acid solutions with varying inhibitor concentrations (0.2% to 0.8%) in both the absence and presence of an additive ($K_2SO_4$) is provided in Tables 1, 3, 5, 7, 2, 4, 6 and 8, respectively. Inhibition effectiveness and the Langmuir adsorption isotherm are depicted in the corresponding graphs in Figures 1a–b, 2a–b, 3a–b, 4a–b, 5a–b, 6a–b, 7a–b, and 8a–b. The data in tables 9 and 10 were used to calculate the reaction number and percentage of inhibition efficiency for stem and leaf extracts at various concentrations (0.2% to 0.8%) in 1N, 2N, and 3N $H_2SO_4$ acid solutions, and the relevant graphs are presented in Figs 9 and 10, respectively. Nevertheless, no significant temperature changes were seen for 0.5N $H_2SO_4$.

**Table 1: Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage(θ) and Corrosion rate for tin in 0.5 N $H_2SO_4$with inhibitor of stem and leaves extract**

Temperature : 301°K ± 0.1°K Area of Specimen : 13 $cm^2$ Time of Exposure : 242 hrs

| Inhibitors Concentration | Δw | Surface Coverage (θ) | Corrosion Rate (mm/yr) | I.E. (η%) | $\log\left(\frac{\theta}{1-\theta}\right)$ |
|---|---|---|---|---|---|
| **Stem** | | | | | |
| **Uninhibited** | **0.428** | | **0.00163** | | |
| **0.2** | 0.106 | 0.7523 | 0.00040 | 75.23 | 0.48246 |
| **0.4** | 0.092 | 0.7850 | 0.00035 | 78.50 | 0.56243 |
| **0.6** | 0.078 | 0.8177 | 0.00029 | 81.77 | 0.65180 |
| **0.8** | 0.062 | 0.8551 | 0.00023 | 85.51 | 0.77094 |
| **Leaves** | | | | | |
| **0.2** | 0.116 | 0.7289 | 0.00044 | 72.89 | 0.42953 |
| **0.4** | 0.105 | 0.7546 | 0.00039 | 75.46 | 0.48784 |
| **0.6** | 0.093 | 0.7827 | 0.00035 | 78.27 | 0.55653 |
| **0.8** | 0.074 | 0.8271 | 0.00028 | 82.71 | 0.67976 |

**Table 2: Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage(θ) and Corrosion rate for tin in 0.5 N $H_2SO_4$with inhibitor of stem and leaves extract in presence of Additive $K_2SO_4$**

Temperature : 301°K ± 0.1°K Area of Specimen : 13 $cm^2$

Time of Exposure : 242hrs Additive : 0.5N $K_2SO_4$

| Inhibitors Concentration | Δw | Surface Coverage (θ) | Corrosion Rate (mm/yr) | I.E. (η%) | $\log\left(\frac{\theta}{1-\theta}\right)$ |
|---|---|---|---|---|---|
| **Stem** | | | | | |
| **Uninhibited** | **0.428** | | **0.00163** | | |
| **0.2** | 0.091 | 0.7873 | 0.00034 | 78.73 | 0.568372 |
| **0.4** | 0.076 | 0.8224 | 0.00028 | 82.24 | 0.665640 |
| **0.6** | 0.058 | 0.8644 | 0.00022 | 86.44 | 0.804455 |
| **0.8** | 0.042 | 0.9018 | 0.00015 | 90.18 | 0.962998 |
| **Leaves** | | | | | |
| **0.2** | 0.101 | 0.7640 | 0.00038 | 76.40 | 0.510181 |
| **0.4** | 0.084 | 0.8037 | 0.00031 | 80.37 | 0.618188 |
| **0.6** | 0.070 | 0.8364 | 0.00026 | 83.64 | 0.708630 |
| **0.8** | 0.059 | 0.8621 | 0.00022 | 86.21 | 0.795993 |

**Table 3: Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage($\theta$) and Corrosion rate for tin in 1 N $H_2SO_4$with inhibitor of stem and leaves extract**

Temperature : 301°K ± 0.1°K Area of Specimen : 13 $cm^2$ Time of Exposure : 192 hrs

| Inhibitors Concentration | Δw | Surface Coverage (θ) | Corrosion Rate (mm/yr) | I.E. (η%) | $\log\left(\frac{\theta}{1-\theta}\right)$ |
|---|---|---|---|---|---|
| **Stem** | | | | | |
| **Uninhibited** | **0.430** | | **0.00206** | | |
| **0.2** | 0.088 | 0.7953 | 0.00042 | 79.53 | 0.58941 |
| **0.4** | 0.080 | 0.8139 | 0.00038 | 81.39 | 0.64082 |
| **0.6** | 0.067 | 0.8441 | 0.00032 | 84.41 | 0.73354 |
| **0.8** | 0.050 | 0.8837 | 0.00024 | 88.37 | 0.88072 |
| **Leaves** | | | | | |
| **0.2** | 0.105 | 0.7558 | 0.00050 | 75.58 | 0.49066 |
| **0.4** | 0.093 | 0.7837 | 0.00044 | 78.37 | 0.55909 |
| **0.6** | 0.081 | 0.8116 | 0.00038 | 81.16 | 0.63426 |
| **0.8** | 0.063 | 0.8534 | 0.00030 | 85.34 | 0.76501 |

**Table 4: Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage(θ) and Corrosion rate for tin in 1 N $H_2SO_4$with inhibitor of stem and leaves extract in presence of Additive $K_2SO_4$**

Temperature : 301°K ± 0.1°K Area of Specimen : 13 $cm^2$

Time of Exposure :192 hrs Additive : 1N $K_2SO_4$

| Inhibitors Concentration | Δw | Surface Coverage (θ) | Corrosion Rate (mm/yr) | I.E. (η%) | $\log\left(\frac{\theta}{1-\theta}\right)$ |
|---|---|---|---|---|---|
| **Stem** | | | | | |
| **Uninhibited** | **0.430** | | **0.00206** | | |
| **0.2** | 0.076 | 0.8232 | 0.00036 | 82.32 | 0.668023 |

| | | | | | |
|---|---|---|---|---|---|
| **0.4** | 0.062 | 0.8558 | 0.00029 | 85.58 | 0.773407 |
| **0.6** | 0.050 | 0.8837 | 0.00024 | 88.37 | 0.880725 |
| **0.8** | 0.037 | 0.9139 | 0.00017 | 91.39 | 1.025895 |
| **Leaves** | | | | | |
| **0.2** | 0.092 | 0.7860 | 0.00044 | 78.60 | 0.565008 |
| **0.4** | 0.075 | 0.8255 | 0.00036 | 82.55 | 0.674921 |
| **0.6** | 0.061 | 0.8581 | 0.00029 | 85.81 | 0.781555 |
| **0.8** | 0.045 | 0.8953 | 0.00021 | 89.53 | 0.932021 |

**Table 5: Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage($\theta$) and Corrosion rate for tin in 2 N $H_2SO_4$with inhibitor of stem and leaves extract**

Temperature : 301$^o$K ± 0.1$^o$K Area of Specimen : 13 cm$^2$ Time of Exposure : 164 hrs

| Inhibitors Concentration | Δw | Surface Coverage (θ) | Corrosion Rate (mm/yr) | I.E. (η%) | $\log\left(\frac{\theta}{1-\theta}\right)$ |
|---|---|---|---|---|---|
| **Stem** | | | | | |
| **Uninhibited** | **0.425** | | **0.00238** | | |
| **0.2** | 0.074 | 0.8258 | 0.00041 | 82.58 | 0.67582 |
| **0.4** | 0.061 | 0.8564 | 0.00034 | 85.64 | 0.77552 |
| **0.6** | 0.053 | 0.8752 | 0.00029 | 87.52 | 0.84589 |
| **0.8** | 0.040 | 0.9058 | 0.00022 | 90.58 | 0.98298 |
| **Leaves** | | | | | |
| **0.2** | 0.090 | 0.7882 | 0.00050 | 78.82 | 0.57071 |
| **0.4** | 0.081 | 0.8094 | 0.00045 | 80.94 | 0.62804 |
| **0.6** | 0.075 | 0.8235 | 0.00042 | 82.35 | 0.66891 |
| **0.8** | 0.057 | 0.8658 | 0.00032 | 86.58 | 0.80966 |

**Table 6: Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage($\theta$) and Corrosion rate for tin in 2 N $H_2SO_4$with inhibitor of stem and leaves extract in presence of Additive $K_2SO_4$**

Temperature : 301$^o$K ± 0.1$^o$K Area of Specimen : 13 cm$^2$

Time of Exposure : 164 hrs Additive : 2N $K_2SO_4$

| Inhibitors Concentration | Δw | Surface Coverage (θ) | Corrosion Rate (mm/yr) | I.E. (η%) | $\log\left(\frac{\theta}{1-\theta}\right)$ |
|---|---|---|---|---|---|
| **Stem** | | | | | |
| **Uninhibited** | **0.425** | | **0.00238** | | |
| **0.2** | 0.062 | 0.8541 | 0.00034 | 85.41 | 0.767453 |
| **0.4** | 0.050 | 0.8823 | 0.00028 | 88.23 | 0.874839 |
| **0.6** | 0.042 | 0.9011 | 0.00023 | 90.11 | 0.959576 |
| **0.8** | 0.029 | 0.9317 | 0.00016 | 93.17 | 1.134855 |
| **Leaves** | | | | | |
| **0.2** | 0.078 | 0.8164 | 0.00043 | 81.64 | 0.648030 |
| **0.4** | 0.066 | 0.8447 | 0.00037 | 84.47 | 0.735531 |
| **0.6** | 0.054 | 0.8729 | 0.00030 | 87.29 | 0.836818 |
| **0.8** | 0.041 | 0.9035 | 0.00023 | 90.35 | 0.9714008 |

**Table 7: Weight Loss (Δw), Percentage inhibition efficiency (η%), Surface coverage($\theta$) and Corrosion rate for tin in 3N $H_2SO_4$with inhibitor of stem and leaves extract**

Temperature : 301$^o$K ± 0.1$^o$K Area of Specimen : 13 cm$^2$ Time of Exposure : 142 hrs

| Inhibitors Concentration | Δw | Surface Coverage (θ) | Corrosion Rate (mm/yr) | I.E. (η%) | $\log\left(\frac{\theta}{1-\theta}\right)$ |
|---|---|---|---|---|---|
| **Stem** | | | | | |
| **Uninhibited** | **0.415** | | **0.00269** | | |
| **0.2** | 0.060 | 0.8554 | 0.00038 | 85.54 | 0.77200 |
| **0.4** | 0.052 | 0.8746 | 0.00033 | 87.46 | 0.84351 |
| **0.6** | 0.042 | 0.8987 | 0.00027 | 89.87 | 0.94800 |
| **0.8** | 0.032 | 0.9228 | 0.00020 | 92.28 | 1.07749 |
| **Leaves** | | | | | |
| **0.2** | 0.073 | 0.8240 | 0.00047 | 82.40 | 0.67041 |
| **0.4** | 0.064 | 0.8457 | 0.00041 | 84.57 | 0.73885 |
| **0.6** | 0.056 | 0.8650 | 0.00036 | 86.50 | 0.80668 |
| **0.8** | 0.046 | 0.8891 | 0.00029 | 88.91 | 0.90401 |

**Table 8: Weight Loss (Δw), Percentage inhibition efficiency (η%)Surface coverage($\theta$) and Corrosion rate for tin in 3N $H_2SO_4$with inhibitor of stem and leaves extract in presence of Additive $K_2SO_4$**

Temperature : 301°K ± 0.1°K Area of Specimen : 13 $cm^2$

Time of Exposure :142hrs Additive : 3N $K_2SO_4$

| Inhibitors Concentration | Δw | Surface Coverage (θ) | Corrosion Rate (mm/yr) | I.E. (η%) | $\log\left(\frac{\theta}{1-\theta}\right)$ |
|---|---|---|---|---|---|
| **Stem** | | | | | |
| **Uninhibited** | **0.415** | | **0.00269** | | |
| **0.2** | 0.048 | 0.8843 | 0.00031 | 88.43 | 0.883266 |
| **0.4** | 0.039 | 0.9060 | 0.00025 | 90.60 | 0.984000 |
| **0.6** | 0.031 | 0.9253 | 0.00020 | 92.53 | 1.092961 |
| **0.8** | 0.018 | 0.9556 | 0.00011 | 95.56 | 1.332893 |
| **Leaves** | | | | | |
| **0.2** | 0.061 | 0.8530 | 0.00039 | 85.30 | 0.763631 |
| **0.4** | 0.051 | 0.8771 | 0.00033 | 87.71 | 0.853497 |
| **0.6** | 0.043 | 0.8963 | 0.00027 | 89.63 | 0.936674 |
| **0.8** | 0.030 | 0.9277 | 0.00019 | 92.77 | 1.108269 |

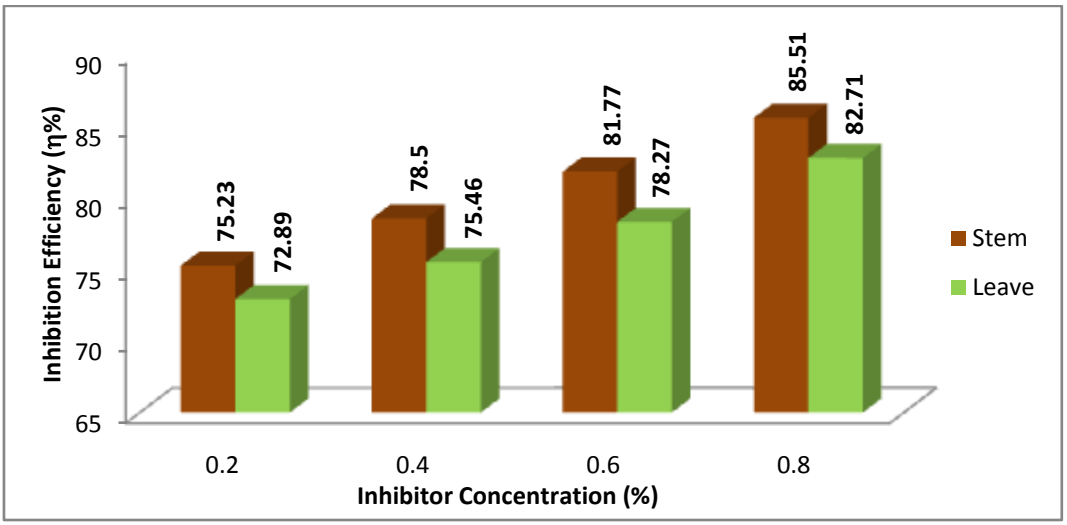


**Figure 1(a): Variation of Inhibition Efficiency (η%) for tin in 0.5N $H_2SO_4$ with inhibitor concentration of stem and leaves extract.**

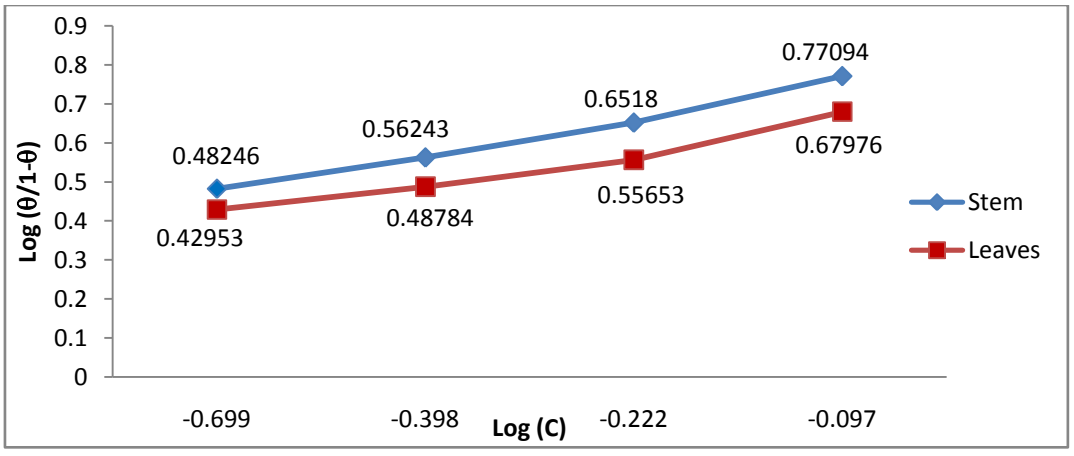


**Figure 1(b): Langmuir Adsorption Isotherm for tin in 0.5N $H_2SO_4$**

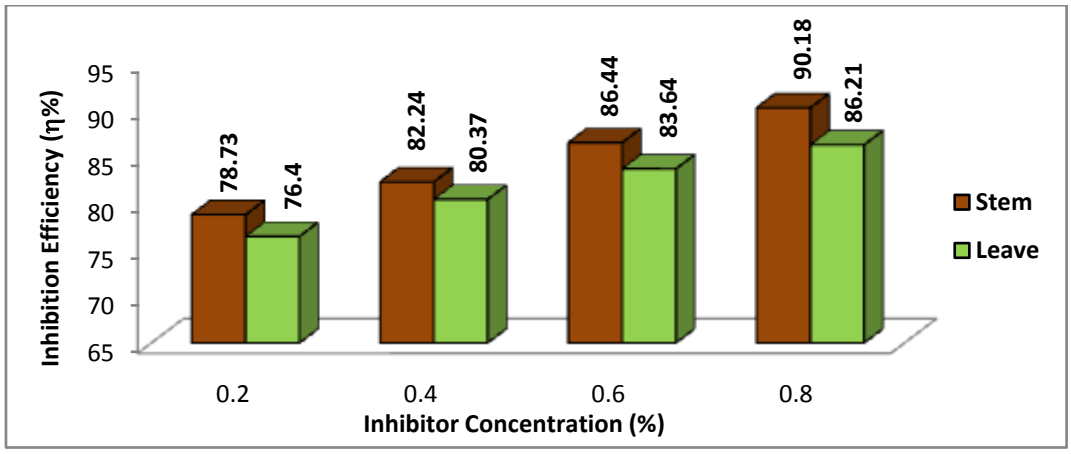


**Figure 2(a): Variation of Inhibition Efficiency (η%) for tin in 0.5 N $H_2SO_4$ with inhibitor concentration of stem and leaves extract in presence of additive 0.5 N $K_2SO_4$**

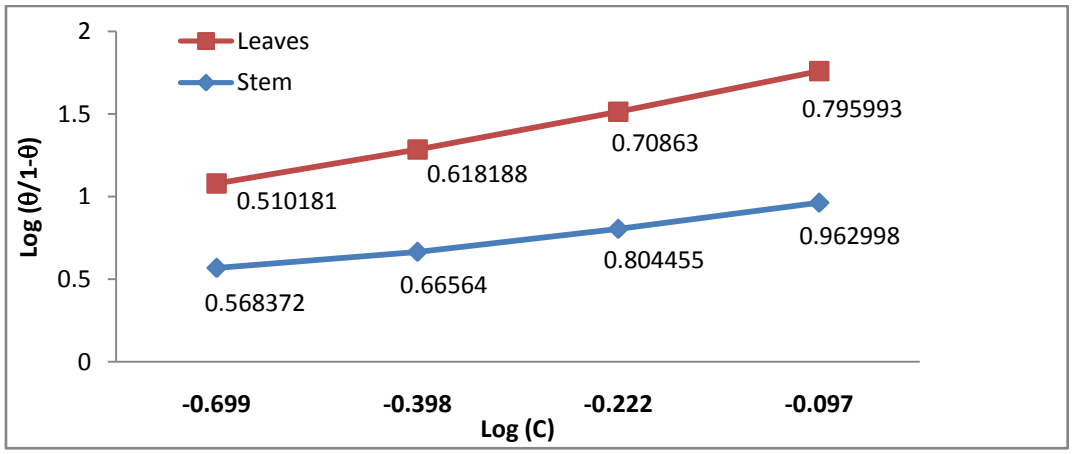


**Figure 2(b): Langmuir Adsorption Isotherm for tin in 0.5N $H_2SO_4$ in presence of additive 0.5 N $K_2SO_4$**

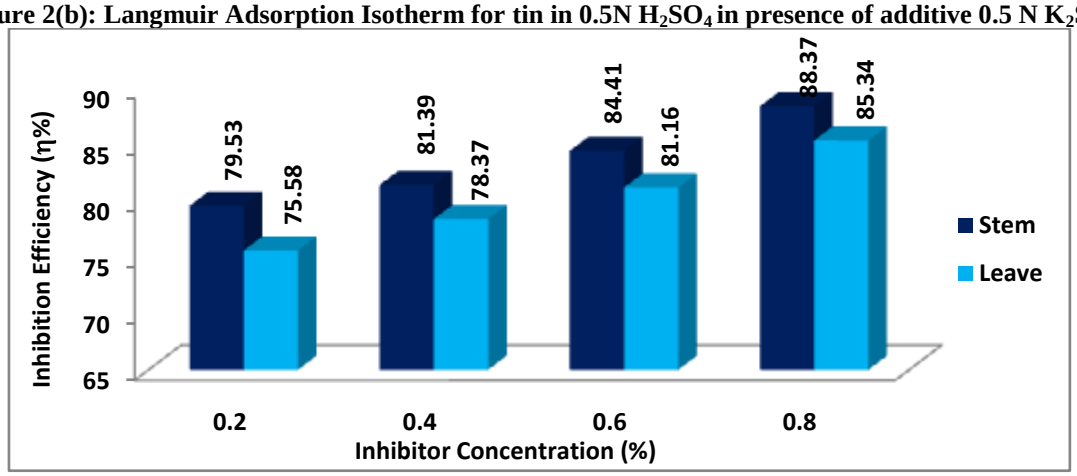


**Figure 3(a): Variation of Inhibition Efficiency (η%) for tin in 1N $H_2SO_4$ with inhibitor concentration of stem and leaves extract.**

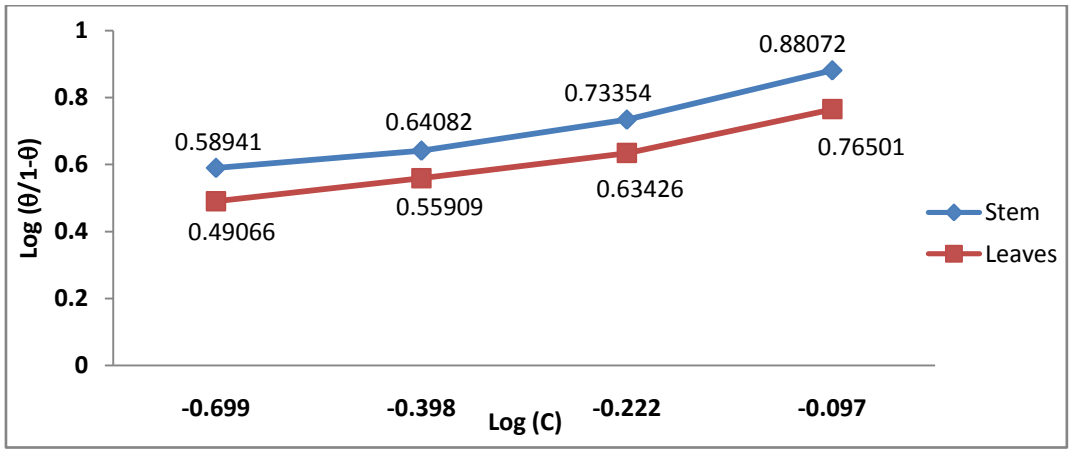


**Figure 3(b): Langmuir Adsorption Isotherm for tin in 1N $H_2SO_4$**

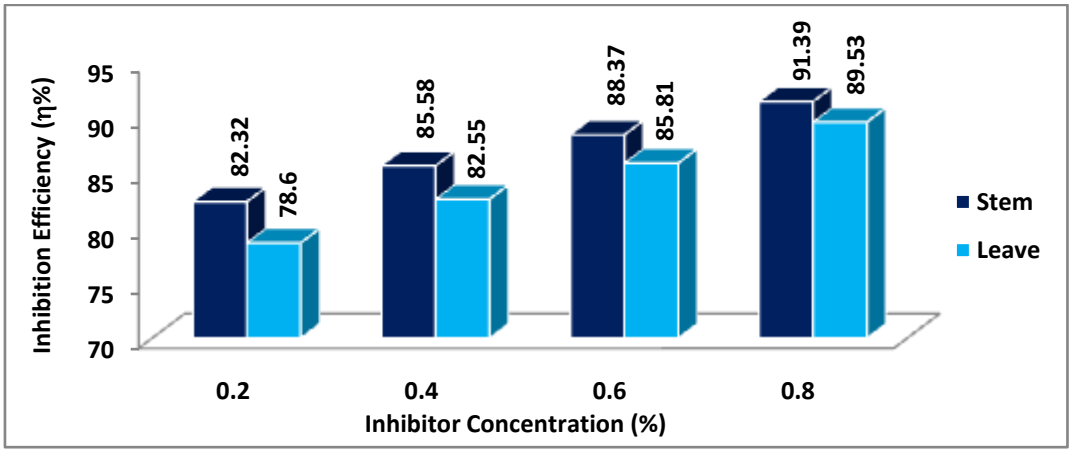


**Figure 4(a): Variation of Inhibition Efficiency (η%) for tin in 1 N $H_2SO_4$ with inhibitor concentration of stem and leaves extract in presence of additive 1 N $K_2SO_4$**

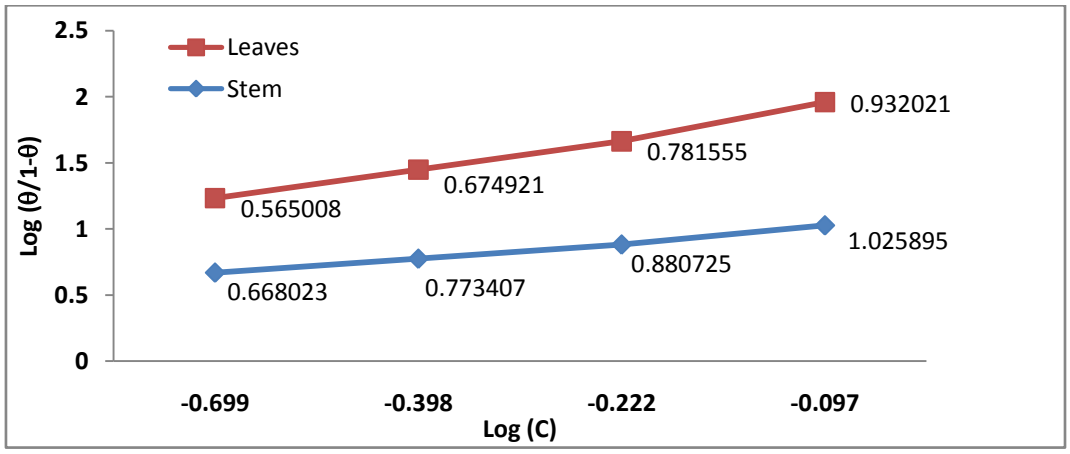


**Figure 4(b): Langmuir Adsorption Isotherm for tin in 1N $H_2SO_4$ in presence of additive 1 N $K_2SO_4$**

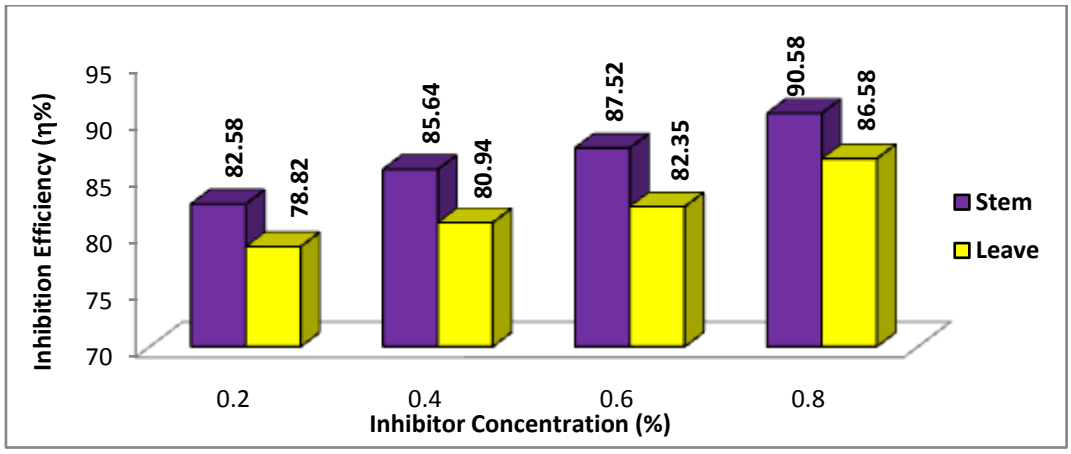


**Figure 5(a): Variation of Inhibition Efficiency (η%) for tin in 2N $H_2SO_4$ with inhibitor concentration of stem and leaves extract.**

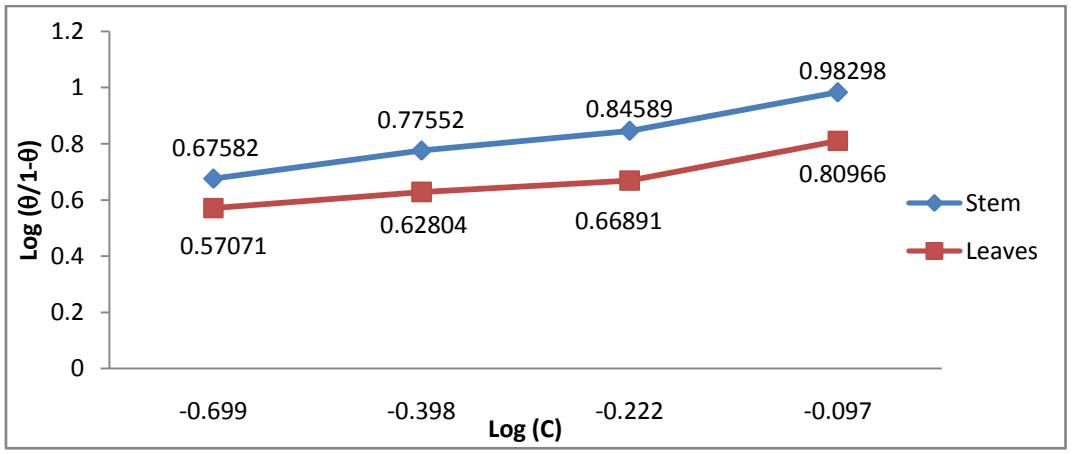


**Figure 5(b): Langmuir Adsorption Isotherm for tin in 2N $H_2SO_4$**

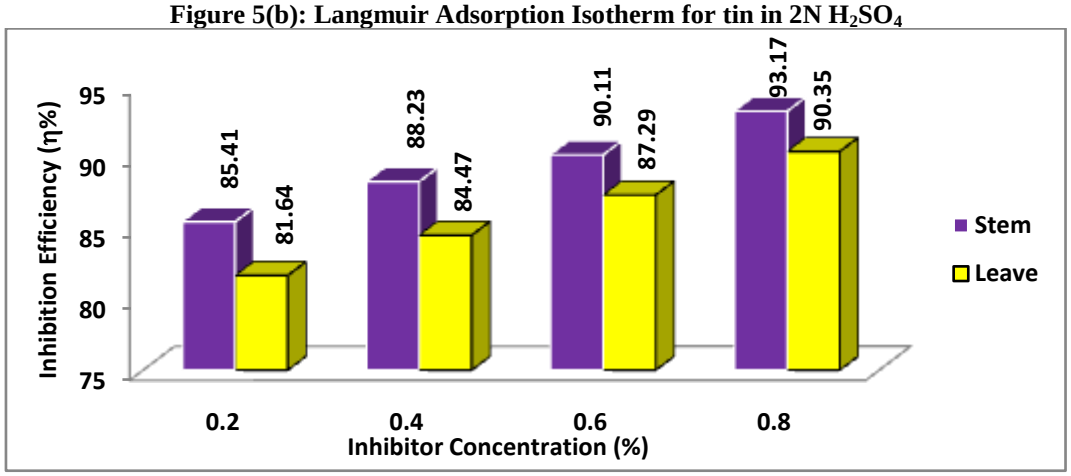


**Figure 6(a): Variation of Inhibition Efficiency (η%) for tin in 2 N $H_2SO_4$ with inhibitor concentration of stem and leaves extract in presence of additive 2 N $K_2SO_4$**

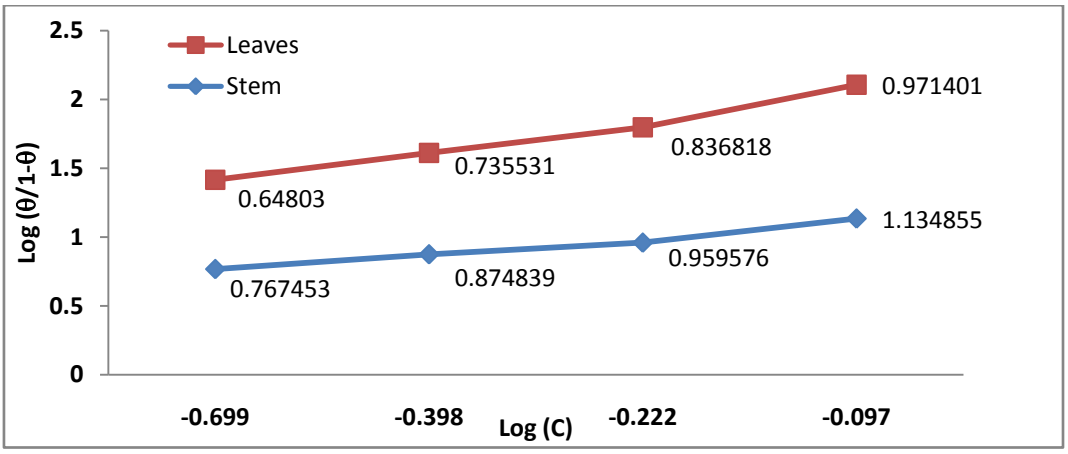


**Figure 6(b): Langmuir Adsorption Isotherm for tin in 2N $H_2SO_4$in presence of additive 2 N $K_2SO_4$**

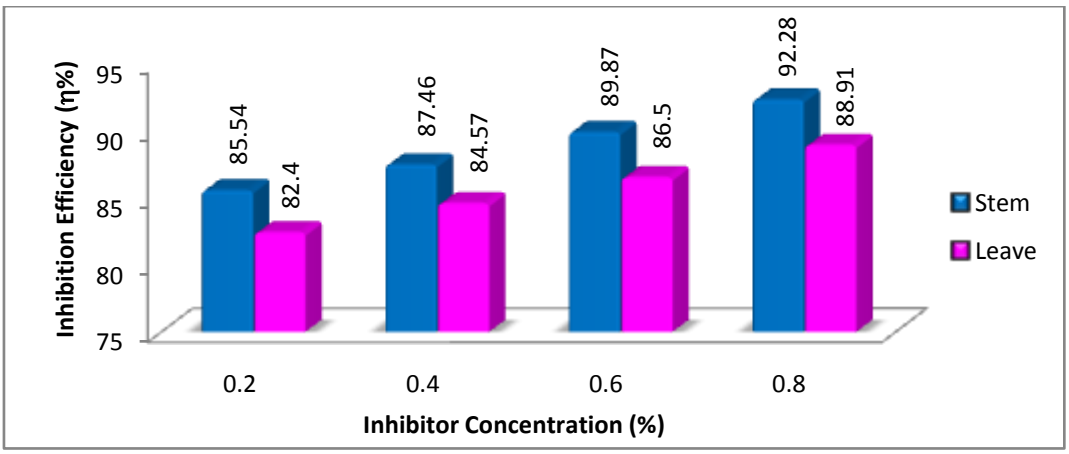


**Figure 7(a): Variation of Inhibition Efficiency (η%) for tin in 3N $H_2SO_4$ with inhibitor concentration of stem and leaves extract.**

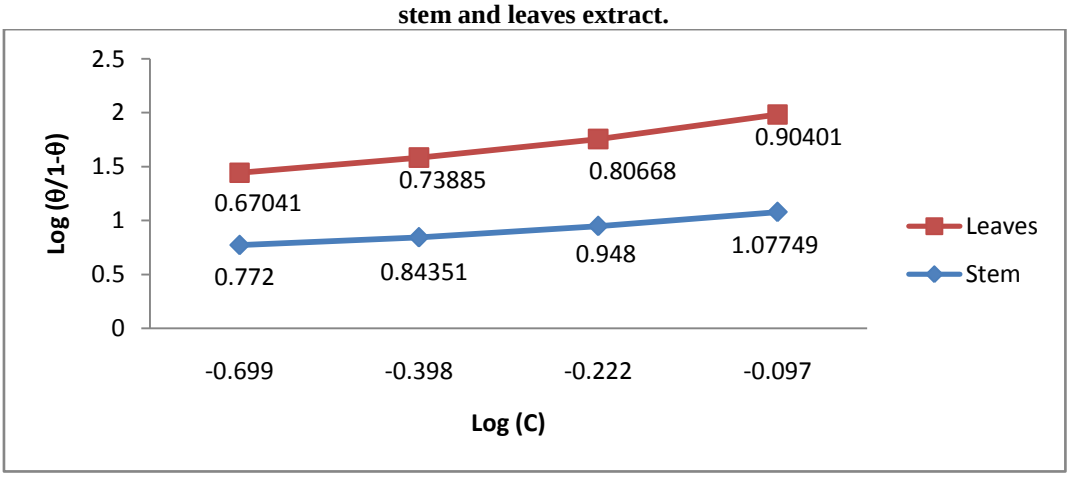


**Figure 7(b): Langmuir Adsorption Isotherm for tin in 3N $H_2SO_4$**

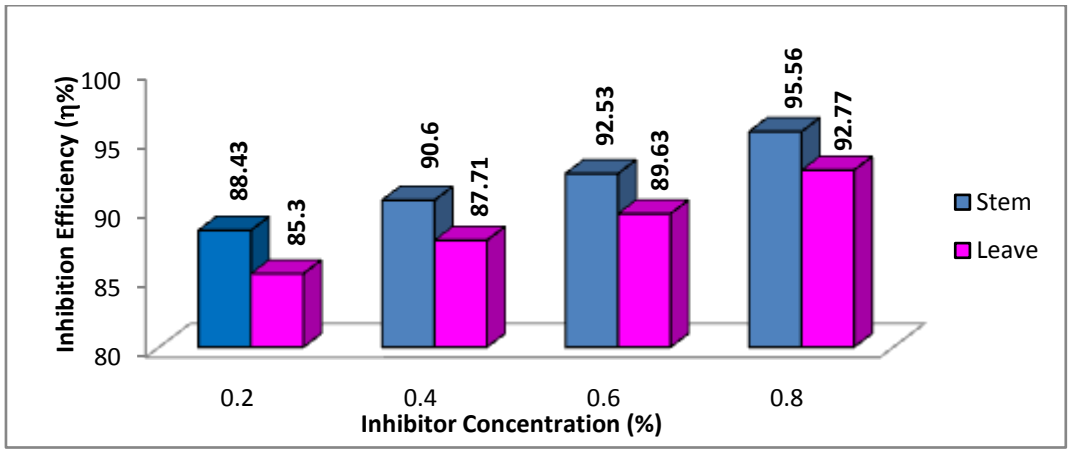


**Figure 8(a): Variation of Inhibition Efficiency (η%) for tin in 3N $H_2SO_4$ with inhibitor concentration of stem and leaves extract in presence of additive 3N $K_2SO_4$**

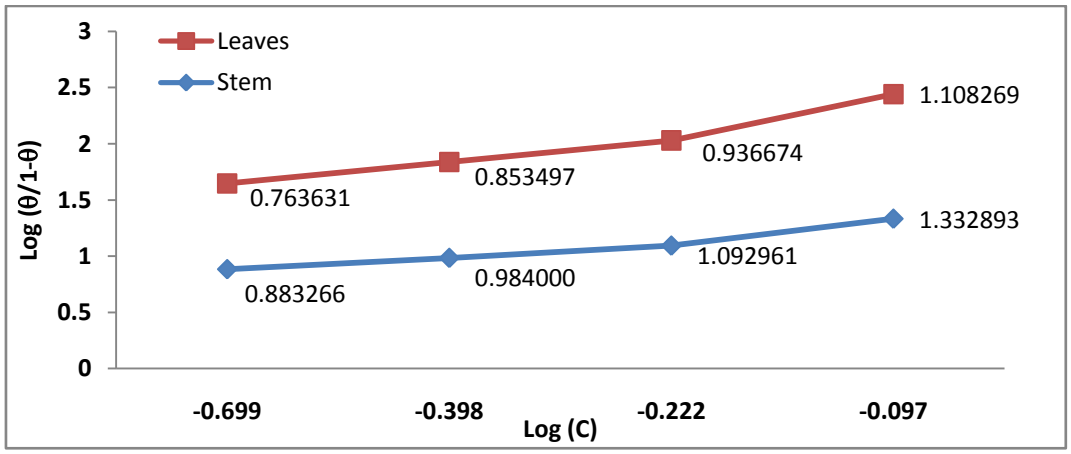


**Figure 8(b): Langmuir Adsorption Isotherm for tin in 3N $H_2SO_4$ in presence of additive 3N $K_2SO_4$**

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**Table 9: Reaction Number (RN) and Inhibition Efficiency (η%) for tin in 1N, 2N and 3N $H_2SO_4$ with inhibitor of stem and leaves extract**

Temperature : 301°K ± 0.1°K Area of Specimen : 13 $cm^2$

| Inhibitor Concentration | 3N $H_2SO_4$ | | 2N $H_2SO_4$ | | 1N $H_2SO_4$ | |
|---|---|---|---|---|---|---|
| | RN | I.E.(η%) | RN | I.E.(η%) | RN | I.E.(η%) |
| **Stem** | | | | | | |
| **Uninhibited** | 0.8656 | | 0.5826 | | 0.3845 | |
| **0.2** | 0.3056 | 64.69 | 0.2240 | 61.55 | 0.1630 | 57.60 |
| **0.4** | 0.2723 | 68.59 | 0.2012 | 65.46 | 0.1525 | 60.33 |
| **0.6** | 0.2455 | 71.63 | 0.1845 | 68.33 | 0.1415 | 63.19 |
| **0.8** | 0.2189 | 74.71 | 0.1670 | 71.33 | 0.1258 | 67.28 |
| **Leaves** | | | | | | |
| **0.2** | 0.3240 | 62.56 | 0.2430 | 58.29 | 0.1745 | 54.61 |
| **0.4** | 0.2956 | 65.85 | 0.2256 | 61.27 | 0.1590 | 58.64 |
| **0.6** | 0.2722 | 68.55 | 0.2020 | 65.32 | 0.1440 | 62.54 |
| **0.8** | 0.2415 | 72.10 | 0.1854 | 68.17 | 0.1328 | 65.46 |

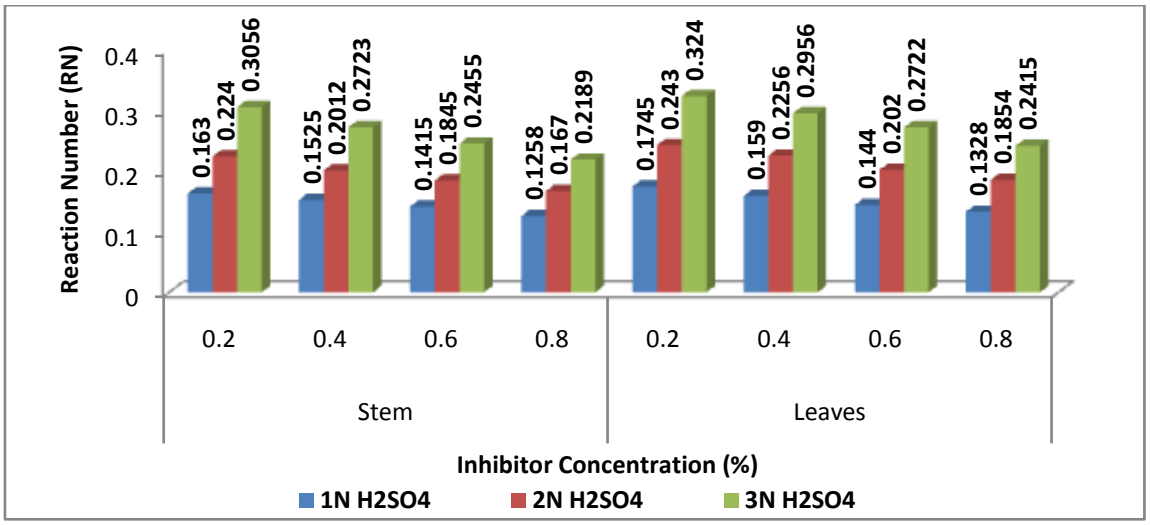


**Figure 9: Variation of Reaction Number (RN) with Inhibitor Concentration of Stem and Leaves extracts for Tin in 1N, 2N and 3N $H_2SO_4$**

**Table 10: Reaction Number (RN) and Inhibition Efficiency (η%) for tin in 1N, 2N and 3N $H_2SO_4$ with inhibitor of stem and leaves extract in presence of Additive**

Temperature : 301°K ± 0.1°K Area of Specimen : 13 $cm^2$

| Inhibitor Concentration | 3N $H_2SO_4$ + 3N $K_2SO_4$ | | 2N $H_2SO_4$ + 2N $K_2SO_4$ | | 1N $H_2SO_4$ + 1N $K_2SO_4$ | |
|---|---|---|---|---|---|---|
| | RN | I.E.(η%) | RN | I.E.(η%) | RN | I.E.(η%) |
| **Stem** | | | | | | |
| **Uninhibited** | 0.8656 | | 0.5826 | | 0.3845 | |
| **0.2** | 0.2825 | 67.36 | 0.2020 | 65.32 | 0.1505 | 60.85 |
| **0.4** | 0.2628 | 69.63 | 0.1837 | 68.46 | 0.1410 | 63.32 |
| **0.6** | 0.2262 | 73.86 | 0.1666 | 71.40 | 0.1288 | 66.50 |
| **0.8** | 0.1865 | 78.45 | 0.1448 | 75.14 | 0.1142 | 70.29 |
| **Leaves** | | | | | | |
| **0.2** | 0.2988 | 65.48 | 0.2240 | 61.55 | 0.1635 | 57.47 |
| **0.4** | 0.2748 | 68.25 | 0.2070 | 64.46 | 0.1508 | 60.78 |
| **0.6** | 0.2522 | 70.86 | 0.1908 | 67.25 | 0.1339 | 65.35 |
| **0.8** | 0.2050 | 76.31 | 0.1672 | 71.30 | 0.1198 | 68.84 |

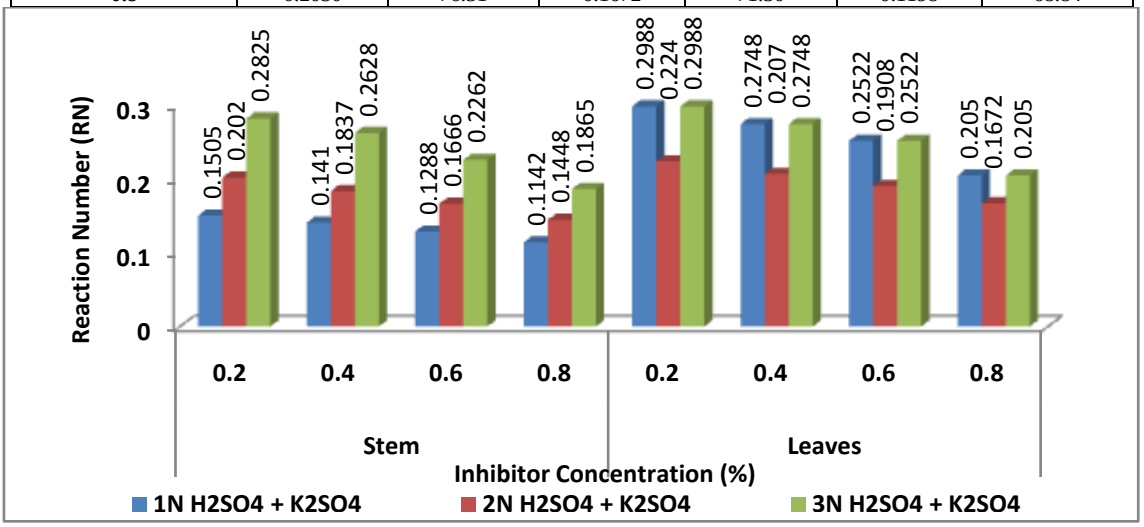


**Figure 10: Variation of Reaction Number (RN) with Inhibitor Concentration of Stem and Leaves extracts for Tin in 1N, 2N and 3N $H_2SO_4$ in presence of additive $K_2SO_4$**

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.ables show that the inhibition effectiveness of the inhibitor rises as the concentration of the inhibitor increases. In the absence and presence of additives ($K_2SO_4$), the maximum inhibition effectiveness for stem extract was 92.28% and 95.56% in 3N $H_2SO_4$ at maximum inhibitor concentrations of 0.8%. Similarly, the inhibition efficiency of leaf extract was 88.91% and 92.77% in 3N $H_2SO_4$ at a maximum inhibitor concentration of 0.8% in the absence and presence of additives ($K_2SO_4$), respectively. The results reveal that stem extract inhibits $H_2SO_4$ more effectively than leaf extract. Surface coverage increases with increasing inhibitor concentration (from 0.2 to 0.8%). The values of $\log(\theta/(1-\theta))$ increase linearly as inhibitor concentrations rise, demonstrating that they follow the chemisorption or Langmuir adsorption isotherm. The current study found that when an additive ($K_2SO_4$) was present, the inhibitors (stem/leaf) were more efficient in inhibiting the metal Tin in $H_2SO_4$ acid solution than when the inhibitors (stem/leaf) were present alone. This is due to synergistic effects. On a metal surface, the combined action of the two chemicals is greater than the combined effects of the two chemicals working independently or simultaneously.

**Antibacterial Activity of Stem/Leaf extract of *Tinospora Cordifolia*:**

Tinospora Cordifolia stem and leaf (aerial portions) extract was tested in vitro for antibacterial activity against gram positive (Staphylococcus aureus) and gram negative (Escherichia coli) bacteria strains using the disc diffusion technique. The effect of ethanol solvent on bacterial strains was also investigated. The antibacterial activity of different aerial parts (stem / leaf) of Tinospora Cordifolia was tested using a liquid inhibition test, and the inhibition zone was determined for each sample. Higher concentrations of plant extract (stem/leaf) were utilized since the inhibitory zone at low concentrations was too narrow to assess. Figures 11a and 11b display the observed results. Table 11 includes results summaries as well. It was discovered throughout the investigation that all plant extracts had effective inhibitory action at 1000 g/mL.

Data in table 11 displays the zone of inhibition for stem and leaf extract against both gram positive and gram negative bacteria. In the presence of stem extract, the zones of inhibition against gram positive and gram negative bacteria were measured to be 25 mm and 18 mm, respectively. Similarly 18 mm and 15 mm, zone of inhibition was obtained against gram positive and gram negative bacteria, for leaf extract. The antibacterial activity findings demonstrated that Tinospora Cordifolia's various aerial components (Stem and Leaf) have effective bacterial inhibition properties.

**Table 11 : Antibacterial Activity For Stem/Leaf Extract of Tinospora Cordifolia On Gram Positive And Gram Negative Bacteria**

| S.No. | Compound/Plant extract | Gram positive bacteria (Inhibition zone in mm) | Gram negative bacteria (Inhibition zone in mm) |
|---|---|---|---|
| 1. | Ethanol solvent | 0 | 0 |
| 2. | Stem extract | 25 | 20 |
| 3. | Leaf extract | 18 | 15 |

**Figure 11a: Effect on gram positive bacteria**

**Figure 11b: Effect on gram negative bacteria**

## V. Conclusion

The stem and leaf extract of Tinospora Cordifolia have been demonstrated to be effective corrosion inhibitors on the metal tin in the absence and presence of additives ($K_2SO_4$) at various concentrations of sulphuric acid ($H_2SO_4$). Both weight loss and thermometric methods demonstrated that the inhibition efficacy of stem and leaf inhibitors increased with increasing inhibitor concentrations from 0.2% to 0.8%, as well as with increasing acid strength from 0.5N to 3N for $H_2SO_4$. The results of this investigation show that stem extract is a more effective corrosion inhibitor in $H_2SO_4$ than leaf extract. The findings of thermometric and weight loss strategies correlate quite well. The adsorption process in this phenomenon depends on the heterocyclic chemicals found in the inhibitors, such as alkaloids, flavonoids, steroids, and tannins, which have higher

electronegative atoms like O, N, and S and possess lone pair electrons. These atoms join with the metal to create a coordinate link that prevents the release of H+ ions and the dissolution of metal ions in acidic environments. Hence, the presence of inhibitors inhibits metal corrosion. Tinospora Cordifolia has better antibacterial activity against gram positive bacteria than gram negative bacteria, according to a research evaluating the antibacterial activity of stem and leaf extract. The best antibacterial activity of the stem extract was against gram positive bacteria (25 mm) and gram negative bacteria (18 mm). Thus, it may also be inferred from the current study that the Tinospora Cordifolia plant exhibited strong antibacterial activity and might be employed as a substitute food preservative in the food industry.

## Acknowledgment

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