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Chicken Feather Powder as Corrosion Inhibitor for Aluminium in NaOH Solution

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The effect of chicken feather powder (CFP) on the corrosion of aluminium (Al) in 0.5 M NaOH solution was examined using weight loss method. The inhibition efficiency of chicken feather powder on the corrosion of Al in 0.5 M NaOH solution increased with increasing concentration and immersion time whereas decreases with increasing temperature which shows that the adsorption occurred is physisorption. Inhibition action of chicken feather powder at different concentration and temperature were investigated. The adsorption of chicken feather powder on metal surface obeyed Langmuir adsorption isotherm. Weight loss method showed that the chicken feather powder acted as mixed inhibitor for Al in 0.5 M NaOH solution and follows physical adsorption on the surface of aluminium.

Keywords: Chicken feather, Aluminium, Weight loss, Langmuir adsorption isotherm.

INTRODUCTION

Development of eco-friendly products for environmentally sustainable applications is currently drawn much attention of the researchers[1]. Keratin, a biopolymer which is the main component of chicken feathers[2]. It has extensive applications in cosmetics, food, biodegradable films, activated charcoal and coatings[3,4]. Chicken feathers form the poultry farm and slaughter house are disposed as waste in landfills. Disposal of such solid waste is a severe concern for the environmental problem though these are the source of natural protein[5,6]. Researchers have utilized these chicken feathers to produce activated charcoal for the removal of heavy metals from wastewater[7]. Animal feed have been developed from chicken feathers[8]. Plastic films have also been produced from cyanoethylated chicken feathers[9]. Especially, chicken keratin consists of essential amino acids such as cystine, arginine and threonine[10].

Utilization of organic substance and plant extract as corrosion inhibitor are the common method to protect metal from corrosion any medium[11,12]. Medicinal plant extracts are most widely used as green inhibitors since most of them are non-toxic, environmentally benign, less expensive when compare to organic substances[13-16]. *Jasminum nudiflorum*, Opuntia and leaves of *Gossipium hirsutum L* extract are used as green corrosion inhibitor for Al in mild acid and base medium[17-20]. To the best of our knowledge, chicken feather powders have not yet been exploited as corrosion inhibitor. Hence, the aim of the present work is to test the efficiency of chicken feather powder as corrosion inhibitor. The aim of the present work was to test the chicken feather powder as corrosion inhibitor for aluminium in mild base medium using weight loss method.

EXPERIMENTAL

Sodium hydroxide, sodium sulfide, ammonium sulfate and acetone were purchased from Merck, India. All the chemicals were analytical grade and used without further purification.

Preparation of chicken feather powder: Chicken feathers were collected from chicken processing plants at Namakkal were soaked in diethyl ether for 24 h to remove the stains, oil and dried under sunlight for 2 days. 50 g of dried chicken feathers were dissolved in 2 L of 0.5 M sodium sulfide solution and stirred for 6 h at 30 °C by maintaining the pH between 10-13. The solution was then filtered and centrifuged at 10,000 rpm for 10 min and the supernatant liquid was collected carefully. About 0.5 M of ammonium sulfate solution was prepared and added drop wise to the feather solution with constant stirring until a yellowish white precipitate is occurred. The precipitated particles were filtered and washed with deionized water. The purified chicken feather powder was dried and stored for further study.

FTIR spectrum was recorded with Nicolet 870 Fourier-transform infrared spectrophotometer ranging between 4000 and 400 cm^{-1} using KBr pellets. XRD pattern were recorded with Philips analytical X-ray diffraction meter using CuK_α radiation (λ = 1.5406 Å) operated at 40 kV and 100 mA. Surface morphologies of the chicken feather powder was studied using LEO 1455 VP scanning electron microscope. Elemental composition of the material was determined using LEO 1455 VP energy dispersive X-ray diffraction.

Weight loss method: The rectangular Al specimens of 4 cm length, 2 cm width and 0.2 cm breadth were used and abraded using 800, 1000 and 1200 grit emery sheets. The Al specimens were washed thoroughly with double distilled water, degreased with acetone, dried at room temperature and weighed. The stock solution was prepared using 50 g of chicken feather powder in 0.5 M NaOH solution and diluted 1000 mL of 0.5 M NaOH and diluted to get 100, 200, 300, 400 and 500 ppm. Various concentration of inhibitor solution (100-500 ppm) was prepared for experimental work. The experiments were performed at room temperature using different concentrations of the inhibitor. The aluminium specimens in triplicate were immersed in 100 mL of corrosion medium (0.5 M NaOH). After the specified time, the coupons were removed from test solution and thoroughly washed with double distilled water, dried well and then weighed. The weights of the specimens were noted before and after the mass loss measurements. The experiments were repeated three times and the average values were considered for calculation. The effect of temperature on the corrosion inhibition of CPF for 0.5 M NaOH at 30, 30 and 50 °C were studied with different concentration of the inhibitor.

RESULTS AND DISCUSSION

FT-IR Spectrum: The FT-IR spectrum of chicken feather powder is displayed in Fig. 1 to study the functional moieties of chicken feather powder. The peaks at 3147 and 1580 cm^{-1} can be assigned to the presence N-H stretching and bending vibrations due to amino acids. The intense peak at 1560 cm^{-1} attributed to C-O stretching vibration of carbonyls. The peaks at 1280 and 1020 cm^{-1} indicate the presence of the C-N stretching and bending vibrations which is an additional evidence for the constituent of amino acids in chicken feather powder. The unassigned peaks can be due to the presence of various bio-organic materials in chicken feather powder.

Scanning electron microscope and EDAX analysis: The morphological images of chicken feather powder from the SEM studies are depicted in Fig. 2. Scanning electron microscope images reveal the morphology of flakes with bigger sized particles. The chicken feather powder particles formed are lumps and not separated properly due to hygroscopic in nature. Elemental compositions of chicken feather powder were studied using EDAX. The EDAX spectrum in Fig. 3 shows presence of oxygen, sulphur, chlorine and carbon atoms. It confirms the presence of heteroatom in chicken feather powder which could act as a corrosion inhibitor.

Weight loss measurements: The effect of inhibitor concentration on weight loss of Al in base solution containing different concentrations of chicken feather powder at different temperatures, 30, 40 and 50 ºC are shown in Fig. 4. From the Fig. 4, it is clear that the weight loss decreases with the increase of concentration and reached maximum inhibition at 500 ppm. At the same time, increase in temperature caused the higher weight loss and lower inhibition value. The percentage inhibition efficiency (IE) can calculated using the following equation:

$$IE\ (\%) = (M_0 - M) \times 100/M_0$$

where, M_0 and M are the weight loss of Al in the absence and presence of inhibitor, respectively.

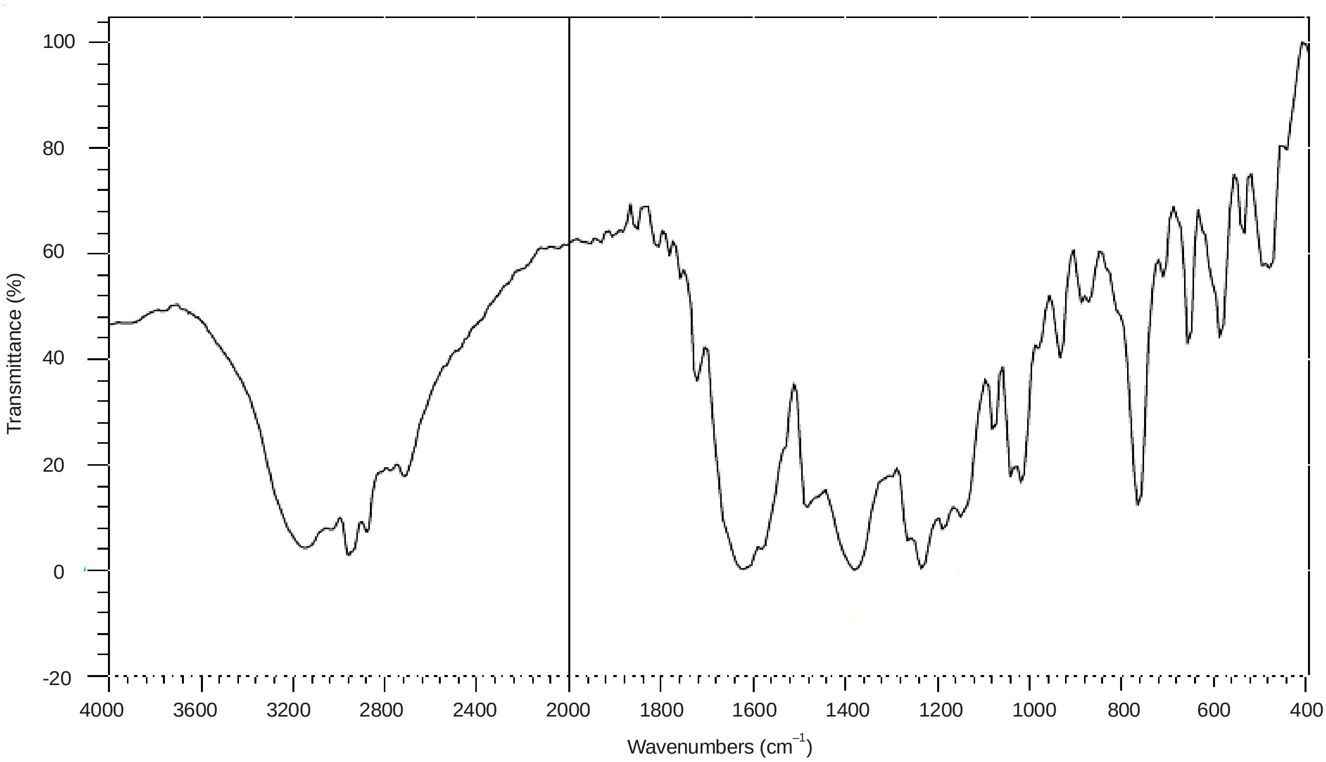

Fig. 1. FT-IR spectrum of chicken feather powder

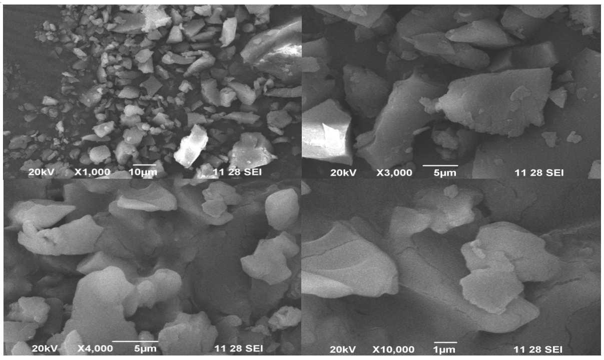

Fig. 2. SEM images of chicken feather powder at various magnification

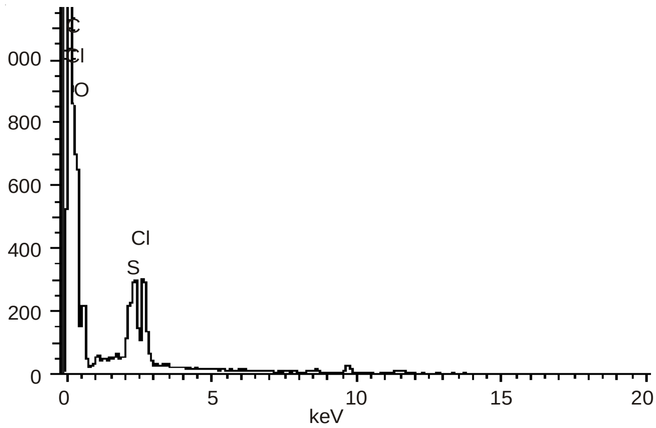

Fig. 3. EDAX spectrum of chicken feather powder

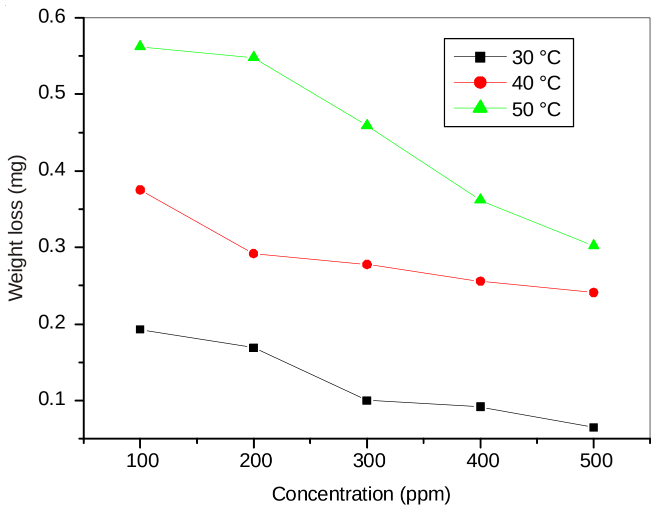

Fig. 4. Effect of inhibitor concentration on weight loss

The values of inhibition efficiency obtained from weight loss measurements for Al in base solutions containing different concentrations of chicken feather powder at different temperatures, 30 and 50 °C are presented in Table-1. It is predictable from the Fig. 5 that inhibition efficiency increases with the increase of concentration and reached the maximum value at higher concentration (500 ppm). This suggests that chicken feather powder adsorbed strongly on the surface of Al by forming a protective layer and shield the metal from corrosion. Further, the increase of temperature decreases the inhibition efficiency. From the above discussion it follows that the percentage inhibition increases with increasing concentration of the inhibitor, decreases with the extension of immersion time and decreases with increasing temperature. It reveals that the highest value of percentage inhibition efficiency is occurred at 30 °C for 500 ppm concentration of the inhibitor.

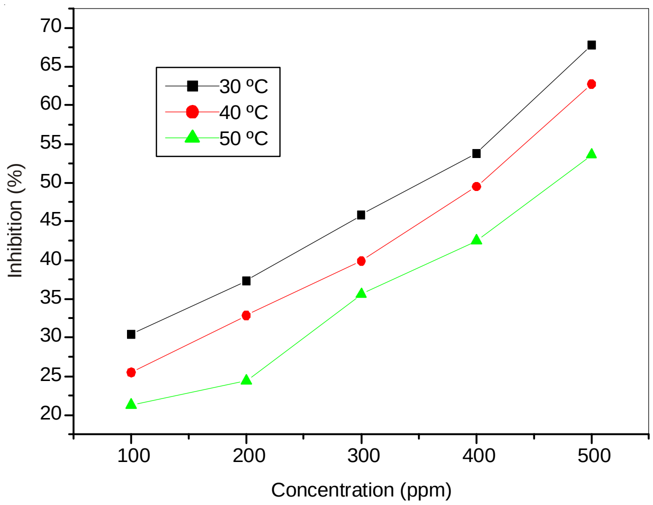

Fig. 5. Plot of inhibitor efficiency *vs.* concentration

The degree of surface coverage (θ) can be expressed by the following equation:

$$\theta = IE/100$$

The values of θ are given in Table-1. Data indicates that the degree of surface coverage increases with increasing the chicken feather powder concentration. This implies that the chicken feather powder increases the adsorption on the surface of the Al and reduces the corrosion rate by decreasing the surface available for the corrosion medium. Corrosion rate (CR) can be calculated by the following equation:

$$CR = \Delta W/At$$

where, ΔW is weight loss of Al, A is the area of Al specimen and t is the immersion time. The values of corrosion rates are given in Table-1. It is concluded that the corrosion rate is directly proportional to the temperature and inversely proportional to the concentration of chicken feather powder.

TABLE-1
WEIGHT LOSS, INHIBITION EFFICIENCY, SURFACE COVERAGE AND CORROSION RATE OF ALUMINIUM IN THE PRESENCE OF INHIBITOR

Concentration (ppm)	Weight loss (mg)			IE (%)			θ			CR		
	30 °C	40 °C	50 °C	30 °C	40 °C	50 °C	30 °C	40 °C	50 °C	30 °C	40 °C	50 °C
100	0.193	0.375	0.562	30.4	25.5	21.3	0.304	0.255	0.213	0.0603	0.1171	0.1756
200	0.169	0.292	0.548	37.3	32.8	24.4	0.373	0.328	0.244	0.0528	0.0912	0.1712
300	0.1	0.278	0.459	45.8	39.9	35.6	0.458	0.399	0.356	0.0312	0.0868	0.1434
400	0.092	0.256	0.362	53.8	49.5	42.5	0.538	0.495	0.425	0.0278	0.08	0.1131
500	0.065	0.241	0.302	67.8	62.7	53.6	0.678	0.627	0.536	0.0203	0.0753	0.0943

IE-Inhibition efficiency; θ-Surface area coverage; CR-Corrosion rate

Kinetics analysis: The data observed from the weight loss method were used to study the kinetic order by various reaction rate equations. A plot of -log (weight loss) and time gives the straight line which confirms that the adsorption process on the aluminium surface follows the pseudo-first order reaction kinetics whose equation is:

$$-\log\text{ (weight loss)} = \frac{k_1 t}{2.303}$$

where, k_1 is the rate constant, t is the immersion time. The plots of -log (weight loss) *vs* immersion time is given in Fig. 6. The heat of adsorption (Q_{ads}) was calculated using the following equation,

$$Q_{ads} = 2.303R\left[\log\left(\frac{\theta_2}{1-\theta_2}\right) - \log\left(\frac{\theta_1}{1-\theta_1}\right)\right] \times \left(\frac{T_1 T_2}{T_2 - T_1}\right)$$

where, θ_1 and θ_2 are the surface coverage angle at temperatures T_1 and T_2, respectively. The values of E_a and Q_{ads} presented in Table-2 confirm that the adsorption process is exothermic in nature.

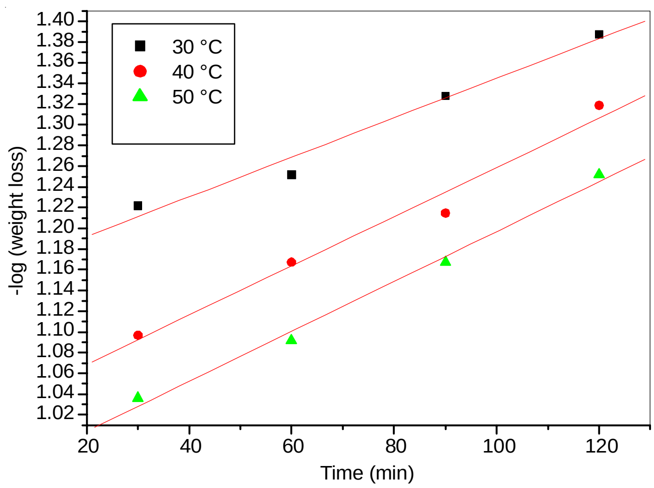

Fig. 6. Plots of -log (weight loss) *vs* time

The free energy for the adsorption of chicken feather powder on aluminium was calculated using the following equation,

$$G_{ads} = -2.303RT \log (55.5\, K_{ads})$$

where, $K_{ads} = \theta/(1-\theta) \times C$, T is the temperature, R is gas constant, θ is degree of surface coverage and K_{ads} is the equilibrium constant. The values of ΔG_{ads} are given in Table-2.

Activation energy for the adsorption of chicken feather powder on the Al surface was calculated using Arrhenius equation. The activation energy was calculated using the following equation,

$$\log\frac{CR_2}{CR_1} = \frac{Ea}{2.303R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

where, T_1 and T_2 are 30 and 50 °C respectively, CR_1 and CR_2 are the corrosion rates at temperatures 30 and 50 °C respectively. The activation energy calculated from the Arrhenius equation is given in Table-2. Increasing the concentration of chicken feather powder increases the activation energy of the adsorption process and decrease the rate of the reaction (Table-2). Hence, it supports the physical adsorption mechanism instead of chemical one. The increase in activation energy and heat of adsorption in the presence of inhibitor suggests that the physical adsorption increases on Al surface with increasing the concentration of inhibitor. The negative values of the heat of adsorption indicate the exothermic nature of the process.

Adsorption models: In order to evaluate the adsorption process of chicken feather powder on the Al surface, Temkin, Langmuir and Frumkin adsorption isotherms also were studied according to the following equations:

Temkin: $\log (\theta/C) = \log K - g\theta$

Langmuir: $\theta/(1-\theta) = KC$

Frumkin: $\log \theta/(1-\theta)\, C = \log K + g\theta$

where, θ is the surface coverage, K is the adsorption-desorption equilibrium constant, C is the inhibitor concentration and g is the adsorbate interaction parameter.

The adsorption process is confirmed by the straight lines obtained when C/θ was plotted against C for Langmuir isotherm, log θ/(1-θ)C plotted against θ for Frumkin isotherm and log (θ/C) plotted against θ for Temkin isotherm. The linear correlation coefficient of the data is close to 1, indicates that the adsorption of inhibitor molecule obeys the Langmuir's adsorption isotherm. The values for Langmuir, Frumkin and Temkin isotherms are shown in Figs. 7-9, respectively. The adsorption models suggest that increase in the inhibitor concentration increases the number of molecules adsorbed over

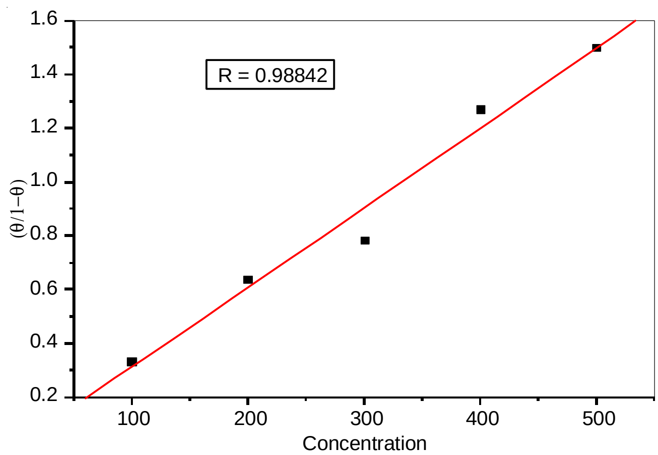

Fig. 7. Langmuir adsorption isotherm

TABLE-2
KINETIC PARAMETERS ON VARIOUS CONCENTRATIONS OF CHICKEN FEATHER POWDER

S. No	Concentration (ppm)	Q_{ads} (KJ/mol)	ΔG_{ads} (KJ/mol)	E_a (KJ/mol)
1	100	-105.647	-19.63	0.6682
2	200	-189.924	-22.16	0.7354
3	300	-385.587	-24.06	0.7527
4	400	-536.75	-25.59	0.8564
5	500	-643.69	-27.65	0.9603

Q_{ads} -Heat of adsorption; ΔG_{ads} -Free energy change of adsorption; Ea-Energy of activation

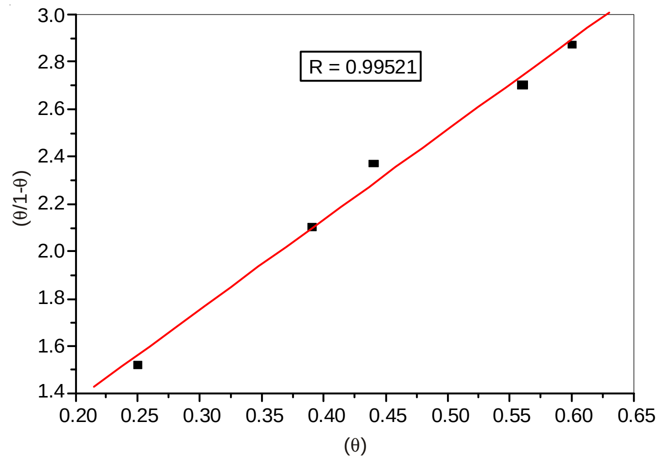

Fig. 8. Frumkin adsorption isotherm

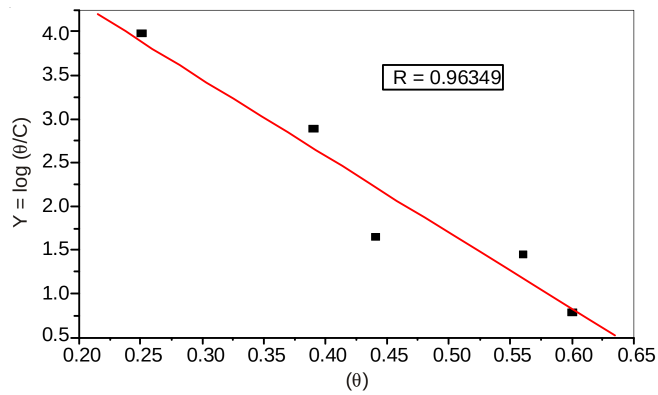

Fig. 9. Temkin adsorption isotherm

the surface of Al which blocks the active sites of base attack and thereby protects the metal from corrosion by reducing the available corrosion surface of aluminium.

Conclusion

The results observed from weight loss method shows that the NaOH soluble chicken feather powder is an effective inhibitor for Al in base medium. The adsorption process obeys the Langmuir, Frumkin and Temkin adsorption isotherm models. The kinetic studies demonstrate that the adsorption process is exothermic and spontaneous in nature. The presence of amino acid which contains heteroatom in chicken feather powder adsorbed physically on the Al surface. The adsorbed amino acid molecules can influence the inhibition behaviour of corrosion processes by reducing the sites available for corrosion.

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