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FULL LENGTH ARTICLE

Evaluation of *Dryopteris cochleata* leaf extracts as green inhibitor for corrosion of aluminium in 1 M H_2SO_4

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Abstract Corrosion inhibition of aluminium in 1 M H_2SO_4 by two different solvent extracts of *Dryopteris cochleata* leaves was studied using weight loss, electrochemical measurements, X-ray diffraction and scanning electron microscopy. Characterization of plant extract was carried out using Fourier transform infrared spectroscopy. X-ray diffraction and SEM analysis have confirmed the molecular adsorption of the DCLME and DCLWE extracts on the aluminium surface. The methanol extract of *D. cochleata* leaves is a better inhibitor than water extract. Polarization studies showed that the extracts act as a mixed type inhibitor.

1. Introduction

Aluminium is one of the most utilized metals for numerous engineering and industrial applications due to its cost effectiveness and excellent functional properties. Aluminium and its alloys exhibit corrosion resistance in many environments and for this reason it finds more important industrial values, due to its low density, high strength, favourable mechanical properties, good finishing surface and relatively good corrosion resistance. Aluminium depends on the presence of surface oxide film for its high corrosion resistance in several media, but alkaline solutions are known to form the oxide film non-protective; because hydroxide ion dissolves the protective oxide and the aluminium surface establishes a negative potential, with the formation of aluminate ion [1,2]. The study of aluminium corrosion phenomena has become very important particularly in acidic media because of the increased industrial applications of acid solutions. Therefore, it's necessary to seek inhibitors for the corrosion of aluminium in H_2SO_4 solution. The protection of metals against sulfuric acid corrosion has been the subject much of study because it is used in number of the industrial processes. Much research was devoted to study the corrosion of aluminium and its alloys in different aqueous and acidic solutions using organic and inorganic compounds.

Most of the organic inhibitors contain in their structures mostly N, S, and O atoms. The organic inhibitors form a protective film on the metal surface while inorganic inhibitors act as anodic inhibitors [3–5]. Unfortunately, uses of some organic and inorganic chemical inhibitors are limited because of reasons: their synthesis compounds are very costly, poor

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biodegradability, toxic and hazardous for human beings and the environment as well. So it has been focused on the corrosion inhibition properties of plant extracts [6–11] because plant extracts serve as an incredibly rich sources of natural chemical compounds present (e.g. amino acids, terpenoids, flavonoids, alkaloids, polyphenols, tannins, etc.,) that are environmentally acceptable, of low cost, easily available and renewable sources of materials and extracted by simple procedures. The natural products as corrosion inhibitors for different metals in different media have been reported by several authors [12–15]. The extract of various plants has been used successfully for the corrosion process prevention of mild steel in HCl and H_2SO_4, and it has been found to be very effective [16,17]. In the present research, we have worked on the problem of aluminium protection in two frequently encountered environments in the industries. Hence, investigations are focused towards the development of naturally occurring eco-friendly inhibitors of corrosion.

Plants in the *Dryopteris cochleata* family (Dryopteridaceae) are well known for the chemical diversity of their alkaloids, phenolics, flavonoids, amino acids, carbohydrates, saponins, terpenoids, cardiac glycoside, anthraquinones and steroids constituents. The Dryopteridaceae is the largest in this family. Moreover, *D. cochleata* has great medicinal value, antioxidant and biological activities. It has been reported to possess wide ethanomedical, antifungal property and used as an antidote. It also has been applied as medicine for epilepsy, leprosy, cuts, wounds, ulcers, swelling, pains, snake and dog bites. The Dryopteridaceae decoction of dried rhizome, stem and stripe is used for blood purification and as tonic for strength. [18]. The juice of fronds is used to treat muscular and rheumatic pain [19]. The leaf extract has been reported to have antibacterial activity [20]. The molecules are rich in heteroatoms which are present in DCLME and DCLWE an effective corrosion inhibitor.

The aim of this study is to evaluate the inhibition effect of the water and methanol extracts of *D. cochleata* leaves on the corrosion of aluminium in 1 M H_2SO_4. In this paper the anti-corrosion potential of *D. cochleata* leaf extracts was evaluated using weight loss, Tafel polarization, electrochemical impedance spectroscopy, XRD, scanning electron microscopy (SEM) and FTIR spectroscopy techniques. We have also investigated the effect of immersion time, temperature and acid concentration on inhibition efficiency of the extract using weight loss measurements. Our investigation shows great potential of the *D. cochleata* leaf extract for corrosion inhibition of aluminium in an acidic environment.

2. Experimental

2.1. Extraction

Healthy *D. cochleata* leaves were collected from Kolli hills, Namakkal District, Tamil Nadu, India. The *D. cochleata* leaves were dried at room temperature for two weeks and powdered for extraction. *D. cochleata* leaf methanol extract (DCME) was prepared by adding powder of plant leaves (100 g) in methanol (500 ml) and allowed to stirring for 3 h. The extract was filtered using cheese cloth and Whatmann No. 1 filter paper. After filtration, the filtrate was evaporated using rotary evaporator and finally a solid residue was obtained. The *D. cochleata* leaf water extract (DCLWE) was obtained by the same method using the plant in deionized water with stirring for 6 h. It was then filtered and evaporated to dryness on a steam bath to obtain a solid residue. It was stored in a refrigerator for further use. The test solutions were prepared by dissolving a particular amount of *D. cochleata* leaf extract in 1 M H_2SO_4 solution and used for corrosion study.

2.2. Materials

The following composition of the aluminium was used for all of the experiments:

(wt%): C (0.277), Si (0.739), O (0.525) and rest Al. Weight loss and electrochemical studies were performed on aluminium coupons of dimensions 2.5 cm × 1.0 cm × 1.0 mm. For preparation, the aluminium samples were abraded with different grades of emery, washed with double distilled water and acetone, dried at room temperature, and stored in a moisture free desiccator.

2.3. Test solutions

For weight loss and electrochemical studies, the test solutions (1 M H_2SO_4) were prepared by dilution of analytical grade, 98% H_2SO_4 (Merck) with double distilled water. The extract concentration range used for the corrosion studies was 400–2400 ppm in methanol and water.

2.4. Weight loss measurements

The weight loss of pre cleaned and dried aluminium specimens were determined by weighing the aluminium samples before and after immersing in 1 M H_2SO_4 in the absence and presence of various concentrations of DCLME and DCLWE at different temperatures (303, 313, 323 and 333 K). The weight loss experiments were performed in triplicate and the mean value is reported. After exposure, test coupons were washed with distilled water and then dried in a vacuum oven. The inhibition efficiency (I.E. %) and surface coverage (θ) were determined by the following equations:

$$\text{I.E. } (\%) = \frac{w_o - w_i}{w_o} \times 100 \tag{1}$$

$$\theta = \frac{\text{I.E. } (\%)}{100} \tag{2}$$

where w_o and w_i represent the weight loss value in the absence and presence of inhibitor. Corrosion rate (C_r) at different concentrations was calculated using the formula below:

$$\text{Corrosion rate } (C_r) \text{ (mpy)} = \frac{534\ W}{DAT} \tag{3}$$

where W is the weight loss of aluminium (gms), D is the density of aluminium, T is the time of immersion, and A is the area of the specimen exposed to the corrosive solution.

2.5. Electrochemical measurements

Tafel polarization and Ac impedance were performed using a CHI 760C electrochemical analyzer. It consists of a conventional three-electrode cell with a platinum electrode, saturated