Journal of Saudi Chemical Society (2014) **18**, 19–25

King Saud University

Journal of Saudi Chemical Society

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ORIGINAL ARTICLE

Anti-corrosive properties of Argan oil on C38 steel in molar HCl solution

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Received 3 April 2011; accepted 20 May 2011
Available online 13 June 2011

KEYWORDS

Corrosion;
Inhibition;
Argan oil;
Steel;
Adsorption

Abstract Corrosion inhibition effect of Argan oil (AO) on corrosion of C38 steel in 1 M HCl solution was investigated using weight loss measurements, electrochemical polarization and EIS methods. Results obtained reveal that Argan oil acts as a mixed inhibitor without modifying the hydrogen reduction mechanism. The inhibition efficiency increases with increased Argan oil concentration to attain a maximum value of 81% at 3 g/L. The inhibition efficiency of Argan oil decreases with the rise of temperature. Argan oil is adsorbed on the steel surface according to Langmuir isotherm model. The parameters (E_a^*, ΔH_a^*, ΔG^* and ΔS_a^*) were estimated and discussed. The fundamental thermodynamic functions were used to glean important information about Argan oil's inhibitory behavior.

1. Introduction

Steel is widely used in most industries because of its low cost and availability for the manufacture of reaction vessels such as cooling tower reservoirs, pipelines, etc. (Ramesh et al., 2003). Acid solutions are generally used for the removal of undesirable scale and rust in several industrial processes. Hydrochloric and sulfuric acids are widely used in the pickling processes of metals (Chauhan and Gunasekaran, 2007). Corrosion affects most of the industrial sector and may cost billions of dollars each year for preventing, replacement and maintenance (Roberge, 2008).

The electrochemical corrosion is generally caused by dissymmetry potentials between metal and strong acid. The aggressiveness of hydrogen ion is inevitable in uninhibited acid. H^+ and dissolved O_2 are named natural motors of corrosion

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Peer review under responsibility of King Saud University.
doi:10.1016/j.jscs.2011.05.008

Production and hosting by Elsevier

(Amin et al., 2007). The use of inhibitors is one of the most effective ways to prevent corrosion. Corrosion inhibitors will reduce the rate of either anodic oxidation or cathodic reduction or both. This will give us anodic, cathodic or mixed type of inhibition.

Organic adsorption compounds are effective as corrosion inhibitors for corrosion of different metals in acidic medium because of the functional group containing hetero-atoms such as nitrogen, sulfur and oxygen (Ivanov, 1986; Ammar and El Khorafi, 1973; Abed et al., 2002, 2004; Putilova et al., 1960). However, there is increasing concern about the toxicity of most corrosion inhibitors. The toxic effect does not only affect living organisms but also poisons the environment (Eddy and Ebenso, 2008). Owing to increasing ecological awareness and strict environmental regulations and the need to develop environmentally friendly processes, attention is now focused on the development of substitute nontoxic alternatives to inorganic inhibitors applied earlier. Among the various natural products, such as the *lawsonia* extract (El-Etre et al., 2005), *black pepper* (Bothi and Sethuraman, 2008) *Phyllanthus amarus* extract (Okafor et al., 2008), *fenugreek* extracts (Noor, 2008), *Hibiscus sabdariffa* extract (Oguzie, 2008), *Azadiracta indica* (Oguzie, 2008), *Garcinia kola* extract (Oguzie et al., 2006). The anticorrosion effect of *black pepper* and its derivative *piperine* (Dahmani et al., 2010), *cedre oil* (Bouyanzer et al., 2007), *jojoba oil* (Chetouani et al., 2004), *artemisia oil* (Benabdellah et al., 2006), *pennyroyal oil* from *Mentha pulegium* (Bouyanzer et al., 2006a), *eucalyptus oil* (Bouyanzer et al., 2006b) and *thymus oil* (Bammou et al., 2010) have been reported from our laboratories. All of these have been reported to be good inhibitors for metals and alloys in acidic solutions. The encouraging results obtained by natural oils as corrosion inhibitor of steel in acid solutions permit to test more substance oils. There is no report to our knowledge on the effect of the addition of Argan oil (AO) on the corrosion of C38 steel alloy in hydrochloride solution.

The Argan tree, called *Argania spinosa* (L.) Skeels, is a tropical plant, which belongs to the Sapotaceae family. Moroccans traditionally use the fruits of *Argania Spinosa* to prepare edible oil (Khallouki et al., 2005). It represents the only endemic species of the *genus Argania*. As an important traditional alimentary medicine, *A. Spinosa* is a valuable potential for Moroccan. Traditionally, the Argan tree is used for many purposes. In cosmetics, Argan oil is advocated as moisturizing oil, against acne juvenile and flaking of the skin as well as for nourishment of the hair, thanks to its high content of vitamin E (Henry et al., 2004).

The aim of this paper is to study the inhibiting action of Argan oil compound. The electrochemical behavior of C38 steel in HCl media in the absence and presence of Argan oil has been studied by gravimetric method and electrochemical techniques such as potentiodynamic polarization, linear polarization and impedance spectroscopy (EIS). The effect of temperature is also studied.

2. Materials and methods

2.1. Argan oil solution

Argan oil comes from the kernels of the argan, Sample of Argan oil was collected from cooperative size in the area of Biougra located at Chtouka Ait Baha (Morocco).

2.2. Fatty acid methyl esters composition

The analyses performed for the purpose of this study were carried out in the laboratory of the Autonomous Establishment of Control and Coordination of Export which applies to the official methods of analysis for the determination of fatty acid methyl esters (FAME) in oil (OJECCR, 1991; Bligh and Dyer, 1959; DGF, 2008).

The fatty acid methyl esters were analyzed with an Agilent Technologies 6890N gas chromatograph equipped with a capillary column (30 m × 0.32 mm; Supelco, Bellefonte, PA, USA) and flame ionization detection. The column was programmed to increase from 135 to 160 °C at 2 °C/min and from 160 to 205 °C at 1.5 °C/min; the detection temperature was maintained at 220 °C, injector temperature 220 °C. The vector gas was helium at a pressure of 5520 Pa. Peaks were identified by comparing retention times with those of standard fatty acid methyl esters.

2.3. Sterols composition

Sterol was determined by the method DGF (DGF, 2008). Sterol composition was evaluated by GLC-FID/capillary column. Briefly, sterols purified from the unsaponifiable matters by HPLC were transformed into their trimethylsilyl ethers counterparts using pyridine, hexamethyldisilazane, and trimethylchlorosilane 9:3:1 (v/v/v). The sterol profile was analyzed using a gas-phase chromatograph fitted with a chroma pack CP SIL 8 C B column (30 m × 0.32 mm i.d.) and a flame ionisation detector. The temperature of the injector and detector were both 300 °C. The column temperature was 200 °C and programmed to increase at the rate of 10 °C/min to 270 °C. The carrier gas was dry oxygen-free nitrogen, and the internal pressure was 8.6 bars. Sterol quantification was achieved by use of an internal 0.2% chloroform solution of α-cholestanol.

2.4. Tocopherols composition

For the determination of tocopherols compounds a solution of 250 mg oil in 25 mL n-heptane was used for HPLC analysis. The analysis was conducted using a Agilent low pressure gradient system, fitted with a 1100 pump, Agilent 1100 Fluorescence Spectrophotometer (detector wavelengths for excitation 290 nm, for emission 330 nm). The sample (20 μL) was injected by a Agilent LC-1100 autosampler onto a phase HPLC column 25 cm × 4 mm ID (Merck, Darmstadt, Germany) used with a flow rate of 1 mL/min and hexane/tetrahydrofuran (98:2, v/v) as mobile phase (Balz et al., 1992).

2.5. Electrochemical tests

The electrochemical study was carried out using a potentiostat PGZ100 piloted by Voltamaster software. This potentiostat is connected to a cell with three electrode thermostats with double wall (Tacussel Standard CEC/TH). A saturated calomel electrode (SCE) and platinum electrode were used as reference and auxiliary electrodes, respectively. The working electrode is in the form of a disc from mild steel of the surface 1 cm^2. Anodic and cathodic potentiodynamic polarization curves were plotted separately at a polarization scan rate of 0.5 mV/s. Before all experiments, the potential was stabilized at free potential during 30 min.