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Evaluation of vegetable oil of nigel as corrosion inhibitor for iron in NaCl 3% medium

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Abstract

For protecting the metals such as iron in aqueous medium, inhibitors based on vegetable oils show adequate protective powers. They can find numerous applications in various industries due to their environment friendly nature, biodegradability and absence of heavy metals or toxic chemicals in them. The present work concern an evaluation of vegetable oil of Nigel as corrosion inhibitor for iron in a marine environment (The seawater is equivalent to 3% by weight sodium chloride: NaCl 3%, from the point of view of an ionic strength solution). Vegetable oil extract of Nigel is biodegradable and environmentally friendly. The influence of the concentration on the corrosion process in the absence and presence of inhibitor was studied by electrochemical measurements including free and polarization curves potential. The polarization curves showed a decrease in the density of anodic and cathodic currents as a function of the concentration, this extract acts as a mixed inhibitor forming a protective layer on the metal surface. The results on the influence of concentration showed that the maximum efficiency is obtained at a concentration of 6 g / L, with a percentage of 99.84%, and therefore reducing significantly the corrosion rate.

Keywords: Nigel oil, iron, inhibition, Polarization, marine environment

Introduction

The electrochemical corrosion is generally caused by dissymmetry potentials between metal and strong acid and basic solution. The aggressiveness of hydrogen ion is inevitable in uninhibited acid, H^+ and dissolved O_2 are named natural motors of corrosion [1]. Several methods are available to prevent or retard corrosion of metallic materials [2]. 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 process. This will give us anodic, cathodic or mixed type of inhibition. Organic compounds, mainly containing oxygen, nitrogen and sulfur atoms and having multiple bonds, are recognized as effective inhibitors of the corrosion of many metals and alloys. In different media, for a given metal, the efficiency of the inhibitor depends on the stability of the formed complex and the inhibitor molecule should have centres, which are capable of forming bonds with the metal surface via an electron transfer. Generally, a strong coordination bond causes higher inhibition efficiency, the inhibition increases in the sequence O<N<S<P [3-7].

Plant extracts have become important as an environmentally acceptable, readily available and renewable source of materials for wide range of corrosion prevention; therefore, finding naturally occurring substances as corrosion inhibitors is a subject of great practical significance [8–10]. These types of inhibitors do not contain heavy metals no toxic compounds, and they are biodegradable [11-23].

There are various natural products that have been studied, such as the Hibiscus sabdariffa extract [11], cedre oil [12], fenugreek extracts [13], Garcinia kola extract [14], lawsonia extract [15], black pepper [16], Phyllanthus amarus extract [17], Azadiracta indica [18]. The anticorrosion effect of black pepper and its derivative piperine

[19], jojoba oil [20], artemisia oil [21], pennyroyal oil from Mentha pulegium [22], eucalyptus oil [23] and thymus oil [24] have been reported as a good inhibitors for metals. The aim of this paper is to study the inhibiting action of Nigel oil compound. The electrochemical behaviour of iron in NaCl 3% media in the absence and presence of Nigel oil has been studied by electrochemical techniques such as potentiodynamic polarization, and linear polarization. The effect of temperature is also studied.

2. Materials and methods

2.1. Plant material

Fully ripened seeds used in this work were harvested in the year 2012 from the agricultural province of Had-Kort located in the region of Gharb–Chrarda-Bnihssan in the west of Morocco. After harvest, the seeds were stored at 4 °C until extraction.

Oil was obtained by cold-press, also called screw expeller. The nigella seeds are squeezed under high pressure in a single step. Seeds are supplied to the press in a continuous feed. As the raw material is pressed, friction causes it to heat up; the material can exceed temperatures of 50 °C.

Press-extraction was carried out using screwless cold presses (IBG Monforts Oekotec GmbH, Monchengladbach, Germany).

2.2 Determination Oil compositions

Fatty acids (FAs) were converted to fatty acid methyl esters (FAMEs) before analysis by shaking a solution of 60 mg oil and 3 mL of hexane with 0.3 mL of 2 N methanolic potassium hydroxide. They were analysed by gas chromatograph (Varian CP-3800, Varian Inc.) equipped with a FID. The column used was a CP- Wax 52CB column (30 m×0.25 mm i.d.; Varian Inc., Middelburg, The Netherlands). The carrier gas was helium, and the total gas flow rate was 1 mL/min. The initial column temperature was 170 °C, the final temperature 230 °C, and the temperature was increased by steps of 4 °C/min. The injector and detector temperature was 230 °C. Data were processed using Varian Star Workstation v 6.30 (Varian Inc., Walnut Creek, CA, USA). The results were expressed as the relative percentage of each individual fatty acid (FA) presents in the sample.

2.3 Materials preparation

The material used in this study is iron. Prior to all measurements, the iron samples were polished with different emery paper up to 2000 grade for removing metal oxides, rinsed with distilled water, and dried at room temperature before introducing it directly into the cell.

The aggressive solution (NaCl 3%) was prepared by dilution of 30 g of NaCl (solid) with distilled water. The corrosion inhibition solution was prepared by dissolving natural Nigel oil in NaCl 3% solution.

2.4 Electrochemical Methods

The electrochemical study was done with a potentiostat PGZ 301 controlled by a PC and supported by Voltamaster 4.0 software. This potentiostat connected to a cell with three electrodes. The working electrode was carbon steel with the surface area of 1 cm^2. A saturated calomel electrode (SCE) was used as a reference. All potentials were given with reference to this electrode. The counter electrode was a platinum plate of surface area of 1 cm^2.

For polarization curves, the working electrode was immersed in a test solution without and with different concentrations of Nigel oil during 60 min until a steady state opens circuit-potential (Eocp) was obtained. The chronoamperometry measurements were carried out at 0.1V/SCE. The electrochemical measurements were recorded from -1000 to 500 mV/SCE.

The inhibition efficiency E (%) is calculated according to equation (1):

$$E\% = \frac{i^0_{corr} - i_{corr}}{i^0_{corr}} \times 100 \qquad (1)$$

Where i^0_{corr} and i_{corr} are the uninhibited and inhibited corrosion current densities, respectively.

3. Results and discussion

3.1 Nigella oil analysis

Data regarding fatty acid composition of Nigella sativa (NS) oil is presented in Table 1 that shows that linoleic, oleic and linolenic acids account for more than 80% of the total fatty acids. They represent the main unsaturated fatty acids. The ratio of linoleic acid to oleic acid was more than 2:1. The ratio of saturated to unsaturated fatty acids (S/U%) was 49%. These ratios were higher than those reported by Ramadan and Mösel [25] for black cumin seed oil (26%). In this study, saturated fatty acids accounted for 17 % of total fatty acids. Among them, the main saturated normal chain fatty acids were palmitic, stearic, myristic and arachidic

Table 1. Fatty acid composition of the Moroccan Nigella sativa seeds oil.

Fatty Acid (%)	% of total fatty acids		Fatty Acid (%)	% of total fatty acids
Myristic Acid (C14 :0)	1 ± 0.1		Linolenic Acid (C18 :3)	0.4 ± 0.1
Palmitic Acid (C16:0)	13.1 ± 0.1		Arachidic Acid (C20:0)	0.5 ± 0.1
Palmitolic Acid (C16:1)	0.2 ± 0.1		Gadoleic Acid (C20 :1)	ND
Stearic Acid (C18 :0)	2.3 ± 0.1		Total saturated fatty acids (TSFA)	16.8 ± 0.5
Oleic Acid (C18:1)	23.8 ± 0.1		Total unsaturated fatty acids (TUFA)	82.9± 0.5
Linoleic Acid (C18:2)	58.5 ± 0.1		----------------	----------------

Values are given as means of three replicates ± SD.

3.2 Electrochemical measurements

The effect of Nigel oil concentration on the anodic and cathodic polarization curves of iron in NaCl 3% solution has been studied and the obtained results are shown in Fig. 1. Relevant data deduced from figure 1 are given in Table 2. The addition of different concentrations of the Nigel oil induces a displacement of the corrosion potential to more anodic values, leads to reduction of anodic and cathodic current densities of corrosion. It acts as mixt inhibitor.

The corrosion current density decreases with the increase of Nigel oil concentration in NaCl 3%. The examination of these results shows a good efficacy at 5g / L that reaches up to 99% (table 2 and figure 2).

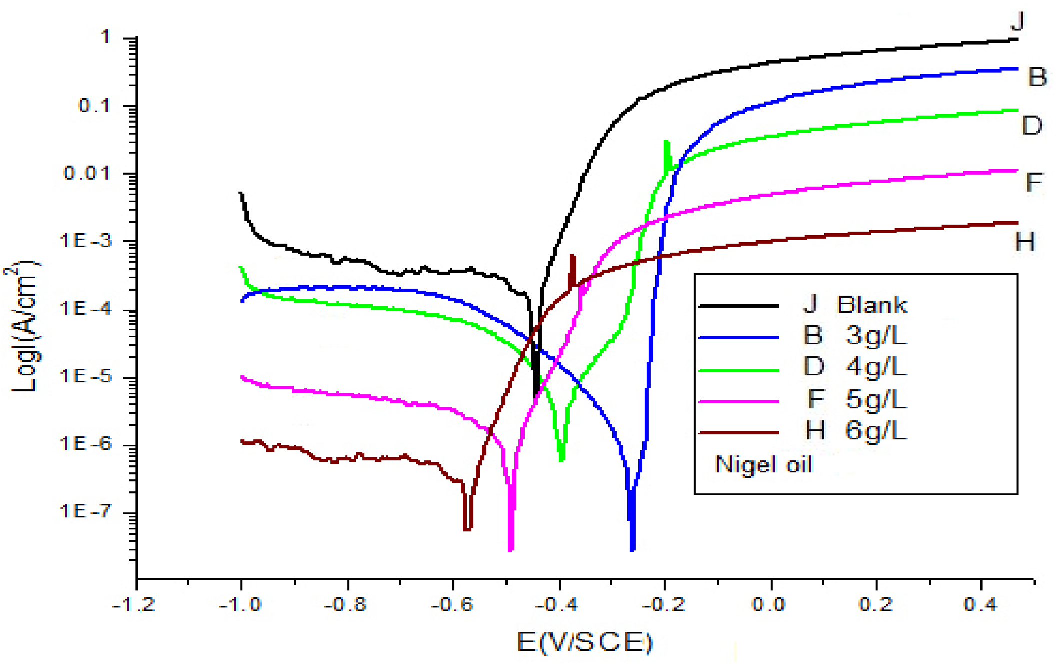

Figure 1: Polarization curves for iron in NaCl 3% at various concentrations of Nigel oil

The inhibitory action of the Nigel oil may be due to its adsorption of molecules on the surface of the material (iron), providing a barrier between the metal and the environment. When the concentration of the extract increases, the recovery rate also increases and hence also the inhibitory efficiency. For maximum studied concentration (6g / L), efficiency Reach 99.8%.

Table 2: Electrochemical parameters and inhibitory efficiencies iron corrosion in NaCl 3% without and with various concentrations of inhibitors.

C (g/L)	E_{corr} (mV/ECS)	I_{corr} (A/cm^2)	V_{corr} (cm/an)	EI %
0	-450	$3.02.10^{-4}$	$7.98.10^{-5}$	-
3	-264	$7.01.10^{-5}$	$1.85.10^{-5}$	76.7
4	-388	$4.88.10^{-5}$	$1.29.10^{-5}$	83.8
5	-494	$2.87.10^{-6}$	$7.59.10^{-7}$	99.4
6	-572	$4.75.10^{-7}$	$1.25.10^{-7}$	99.8

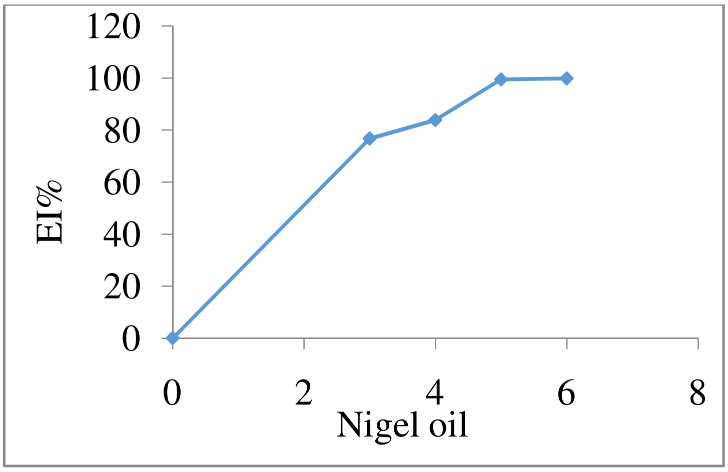

Figure 2: Efficiency depending on concentration of Nigel oil

Conclusion

The polarization curves showed a decrease in the density of the anodic and cathodic currents as a function of the concentration, which allowed to establish that this extract acts as a mixed inhibitor, forming a protective layer on the metal surface. The obtained results on the influence of concentration showed that a maximum efficiency is obtained for a concentration of 6 g / L with a significant reduction in the corrosion rate.

For the protection of metals such as iron in an aqueous medium, based inhibitors of vegetable oils exhibit satisfactory protective powers. Therefore, they can be widely used in various industries.

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