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Cynodon dactylon L. extract as an eco-friendly corrosion inhibitor of mild steel in saline solution

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Abstract
Corrosion-induced loss of metal integrity is a serious industrial concern. One of the most reliable and cost-effective corrosion reduction solutions is corrosion inhibitor innovation. The aim of this investigation therefore, is to study the corrosion inhibition of *Cynodon dactylon* L (Bermuda grass) extract on mild steel in a 3.5% NaCl solution. The plant was extracted with 80% ethanol and different concentrations were tested at a temperature range of 30 to 60^{O}C and for various immersion time ranging from 4 to 72 hours using gravimetric (Weight Loss) method. The results showed that *Cynodon dactylon* extract exhibited strong corrosion inhibition efficiency (97.78%.). The inhibition efficiency of the *Cynodon dactylon* extract increased with an increase of extract concentration and through the immersion periods but decreased with an increase of the temperature. The inhibitive effect could be attributed to the presence of some phytochemical compounds in the plant which were adsorbed on the surface of the mild steel.

Keywords: *Cynodon dactylon;* Adsorption; Green corrosion inhibition; Mild steel; Weight loss

INTRODUCTION

Corrosion-induced loss of metal integrity is a serious industrial concern. One of the most reliable and cost-effective corrosion reduction solutions is corrosion inhibitor innovation. However, the great majority of synthetic inhibitors are expensive, toxic, and unfriendly to the environment [1-4]. Because of their cost-effectiveness and easy access, plant extracts are a very popular class as corrosion inhibitors. Mild steel corrosion inhibition is possible through the use of the plant extract's phytochemical constituents such as phenolics, tannins, alkaloids, proteins, flavonoids, and polysaccharides [5]. Herbal products have been studied lately to see how successful they are at inhibiting corrosion and results of investigations have indicated that they work well as corrosion inhibitors. The need to obtain inhibitors that are environmentally benign, non-toxic, and available in large amounts, as well as the desire to mitigate the highly toxic effects of some synthetic inhibitors on both the environment and humans, prompted interest in this area of research. The inhibition effect of the herbal products has been proved by several researchers in both acidic and nearly neutral media. In the acidic conditions, Juniperus plants act as inhibitors. This was detected by

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Saedah [6]. Authors found that *Jatropha curcas* has strong inhibition in acidic media, as shown by Odusote & Ajayi [7]. Moreover, Al-Otaibi and co-authors [8] discovered that the following species have anti-corrosive effects on mild steel: *Lycium shawii*, *Carthamus tinctorius*, *Teucrium oliverianum*, *Ochradenus baccatus*, *Anvillea garcinii*, *Cassia italica*, *Artemisia sieberi*, and *Tripleurospermum auriculatum* [8].

Additionally, Murthy and co-workers [9] showed that *Hibiscus sabdariffa* has an inhibiting property for mild steel corrosion in 1.2N H_2SO_4 than 1.2N HCl [9]. Many other plants were investigated for their inhibition capability in acidic media such as Ginkgo leaf [10], *Wrightia tinctoria*, *Cleroden drumphlomidis*, and *Ipomoea triloba* [11], kola and tobacco plants [12], *Phyllanthus fraternus* [131], *Chlomolaena odorata* L. [14], Roasted coffee extract [15], *Piper guinensis* [16], *Spirulina platensis* [17], *Eriobotrya japonica* [18], *Andrographis paniculata*, *Strychnos nux-vomica*, *Moringa oleifera* and *Bacopa monnieri* [19], *Lantana camara* [20].

Other research works concerned with the study of inhibition of mild steel corrosion in nearly neutral media include reports such as the good inhibition effect exhibited by capsaicin extract in sodium chloride aqueous solution [21], and the report by Akbarzadeh and colleagues reported that Kraft and Soda lignins extracted from oil palm empty fruit bunch can perform as good inhibitors [22]. Challouf and colleagues found that *Origanum majorana* can be used as an inhibitor for mild steel corrosion in neutral 0.5 M chloride medium [23] while Abd-El-Khalek and coauthors found Nicotiana leaves to be more effective in controlling the corrosion of steel in acidic solution than in neutral medium [24].

Researches on plants as eco-friendly inhibitors have all shown how successful they are. In continuation of the evaluation of the prospects plants as inhibitors, this research attempts to find other plants that may work as an eco-friendly agents. This investigation is focused on *Cynodon dactylon*. *Cynodon dactylon* (L.) Pers. also called Bermuda grass, which is a perennial herb. It belongs to the family Poaceae, it is native to the warm temperate and tropical regions and it originated in Africa [25-27]. *C. dactylon* is considered as a medicinal plant, which is widely used in folk medicine as a remedy for cardiovascular diseases such as heart failure and atherosclerosis [28, 29]. Other activities of *C. dactylon* reported were anticancer activity [30-32], antidiabetic effect [33], antiulcer [34], antibacterial [35], antioxidant activities [36]. Moreover, the plant was also reported to show wound healing effect [37], antilithiatic potential [38], diuretic property [39], antiarthritic activity [40], anthelmintic activity [41], antiarrhythmic effects [42] and bronchodilator effect [43]. The thrust of this study is to determine the corrosion inhibition efficiency on mild steel of the *C. dactylon* extract as well as the detection of its main phytochemical constituents.

EXPERIMENTAL METHODS

Test solution. NaCl & distilled water were used to prepare the aggressive solution (3.5% NaCl) for all experiments in the absence and presence of different concentrations of plant extract [6].

Plant collection. *Cynodon dactylon* aerial parts were collected from the Northwestern part of Libya (Mashrue Alhadba and from the farm of Faculty of Agriculture, University of Tripoli) in the period of September-October 2018. The plant specimen was taxonomically identified at the Botany department, Faculty of science, University of Tripoli, Tripoli, Libya. The collected plant was rinsed under running water to remove any dust or dirt, then dried in a shade at room temperature until dried, after that powdered by an electric mill.

Plant extraction. The powdered plant was extracted with 80% ethanol using Soxhlet apparatus for 3 hours. The ethanolic extract was filtered, concentrated using a rotary evaporator and finally stored in small jars at 2ºC until it is ready for use. At the time of the experiments, plant extract solutions were prepared from stock extract at concentrations of 800, 400, 200, 100 ppm using a 3.5% NaCl solution [10].

Phytochemical screening. *C. dactylon* extract was subjected to Dragendroff's, Mayer's, Wagner's tests to detect the presence of Alkaloids; Shinoda, Alkaline reagent tests to detect flavonoids; Keller-Killiani test for glycosides; Ferric chloride test for phenolic compounds and tannins; Ninhydrin, Millon's tests for amino acids; Biuret test for proteins; Liebermann-Burchard, Salkowski's tests to detect sterols and triterpenoids; Fehling's, Molisch, Benedict's tests to detect carbohydrates; Froth test for saponins and test for oils and fats, tests for organic acids and inorganic acids [44, 45].

Sample preparation. The metal used for this study was mild steel. It was a rod with an average length of 4.0 cm and a diameter of 1.1 cm for weight loss method. The specimen surface was ground with emery paper (down to 600), washed with distilled water, degreased with acetone and dried with a stream of air. The sample was analyzed using FONDARY MASTER PRO instrument (optical emission spectrometer) at the high vocational center of casting (Al-Sayeh, Tripoli, Libya), The results of the analysis describing the chemical composition of the steel is shown in Table 1.

Corrosion rate measurement

Weight loss (gravimetric) method. After the length, diameter and weight measurement of the mild steel sample by using vernier caliper and analytical balance respectively, the samples were completely immersed in 50 ml of the test solution of 3.5% NaCl in the presence and absence of different concentrations of the extract at different temperature (30, 50, 60 ºC). The samples were removed from the test solutions after 4, 24, 48 and 72 hour, washed immediately with distilled water, degreased with acetone and dried with a stream of air then re-weighed again. The weight loss data was obtained from the difference in weight of the specimens before and after the experiment.
The corrosion rate (CR) was calculated from

$$CR = \frac{WL}{At}$$

Where WL is weight loss in gram, A is the specimen surface area in cm^2 and t which is the immersion period in hours. The inhibition efficiencies (%I) for the corrosion of mild steel in 3.5% NaCl containing a different concentration of inhibitor were calculated using:

$$\%I = \left(\frac{CR_{blank} - CR_{inh}}{CR_{blank}}\right) x100$$

Where CR_{blank} and CR_{inh} are the corrosion rate in the absence and presence of the inhibitor, respectively (Al-Mhyawi 2014).

RESULTS AND DISCUSSION

Phytochemical screening. The phytochemical screening confirms that *C. dactylon* extract contains alkaloids, flavonoids, glycosides, phenolic compounds, tannins, amino acids, proteins, sterols, triterpenoids, carbohydrates, oil and fats, saponins, and organic acids.

Inhibition efficiency. The results showed that the inhibition efficiency of *C. dactylon* extract was 97.78%. That means the plant extract could act as an excellent corrosion inhibitor in 3.5% NaCl media. This is due to the adsorption of some phytochemical compounds from the plant extract on the mild steel surface; more specifically, the heteroatoms in the phytochemical compounds will bind to the iron and change the charge density of mild steel, causing the cathodic and anodic reactions to be delayed. The inhibition efficiency of *C. dactylon* extract increased with the increase of its concentration and immersion time as shown in Figure.1.

Table 1: Chemical composition of steel

Element	C	Si	Mn	S	P	Cr	Fe
Wt%	0.178	0.303	0.546	0.0127	0.0086	0.0127	Balance

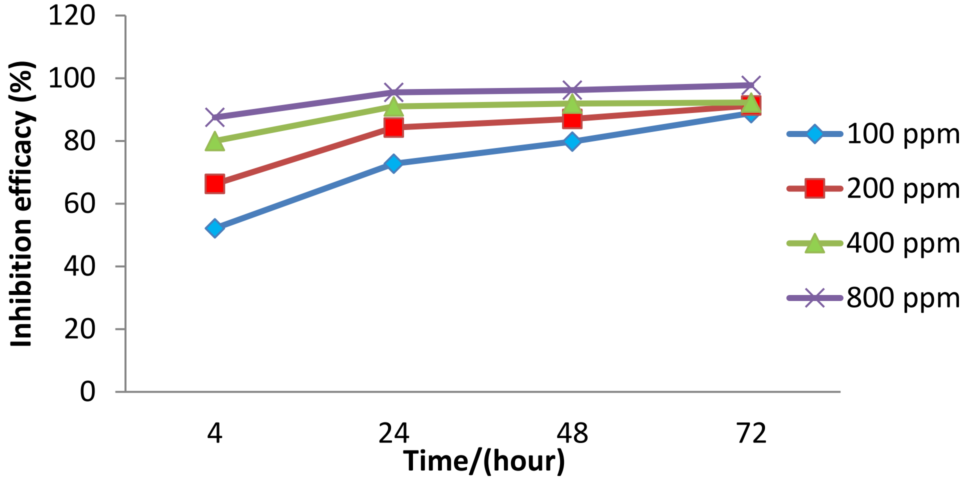

Figure 1: Effect of *C. dactylon* extract concentrations and immersion time on protection efficiency on mild steel

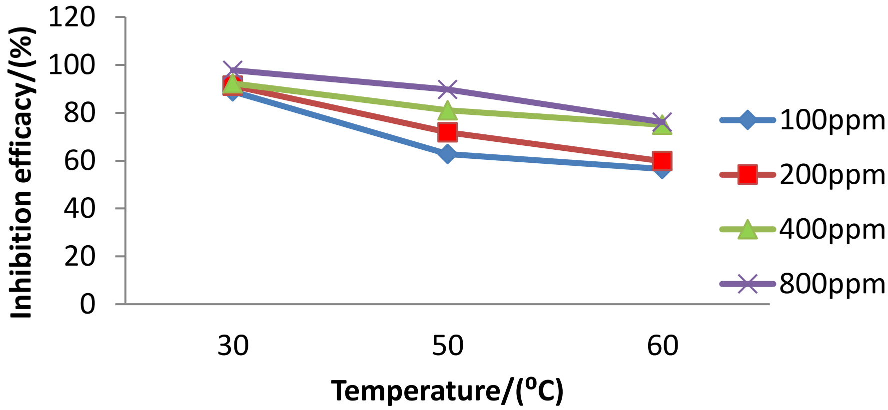

Figure 2: Effect of temperatures on the inhibition efficiency of *C. dactylon* extract on mild steel.

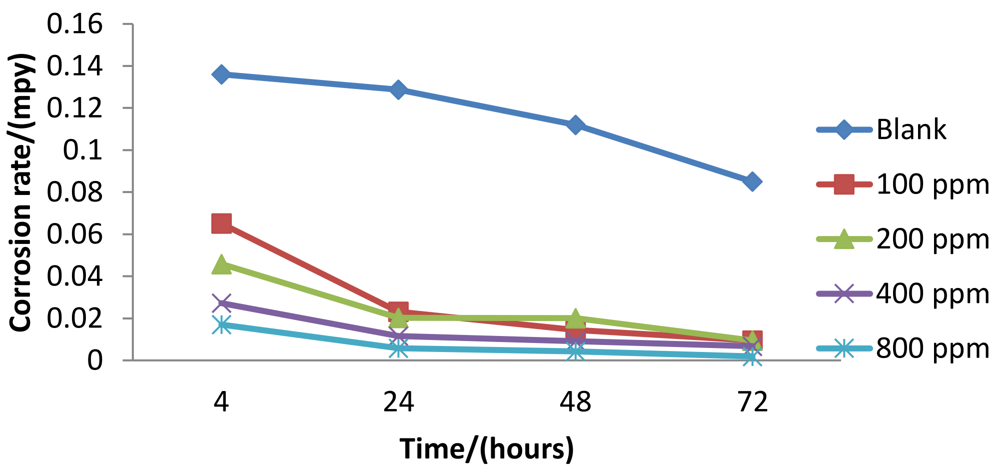

Figure 3: Effect of immersion time on the corrosion rate of mild steel in the presence and absence of *C. dactylon* extract.

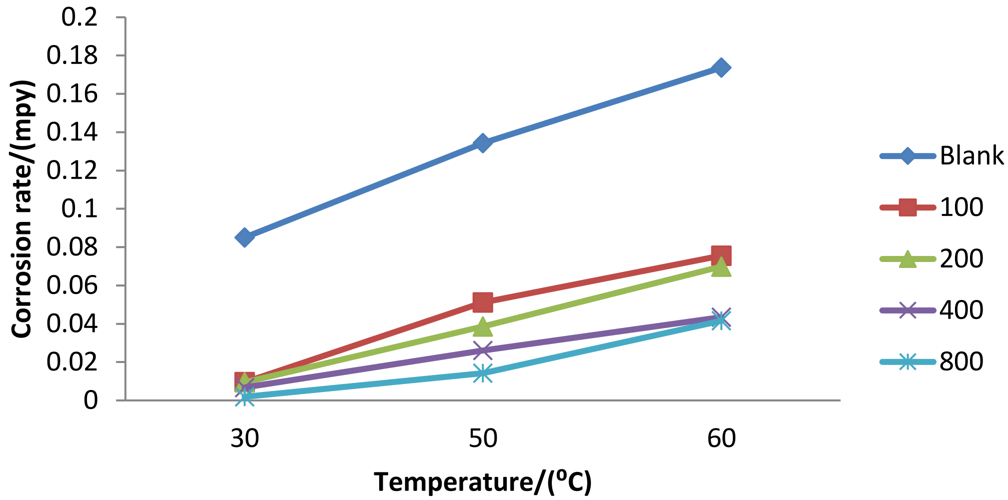

Figure 4: Effect of temperature on the corrosion rate of mild steel in the presence and absence of *C. dactylon* extract

The effect of temperature on the inhibition efficiency is presented in Figure.2. The results showed that the inhibition efficiency of the *C. dactylon* extract decreased with the increase of temperature.

Corrosion rate. The effect of concentration and immersion time on the corrosion rate is presented in Figure 3. The results show that the corrosion rate decreases with the increase of inhibitor concentration and immersion time.
The effect of temperature on the corrosion rate is presented in Figure 4. The results show that the corrosion rate increases with the increase of temperature.

Conclusion. The ability of *C. dactylon* extract to prevent corrosion on mild steel in 3.5% NaCl solution was examined by observing weight loss. The findings implicated *C. dactylon* as a good corrosion inhibitor. The protection efficiency of mild steel by this plant extract increased notably upon immersion time and inhibitor concentration but decreased with the increase of temperature. Our findings reveal that this important medicinal plant may serve as an effective precursor in corrosion inhibitor technology. Further investigations on the mechanism of action are needed as well as the constituents responsible for that activity should be isolated.

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