Comparison of the Corrosion Inhibition Effect of *Portulaca oleracea* Extracts Prepared Using Ethanol and Water

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Editor's note: Corrosion inhibition through sustainable coatings based on plant extracts has garnered significant research interest in recent years, paving the way for the development of next-generation corrosion protection systems. In this study, Shiri developed a new class of sustainable coating for mild steel using extracts from *Portulaca oleracea*, prepared with two solvents: ethanol and water. The results indicate that the choice of solvent significantly influences the corrosion inhibition efficiency of the resulting inhibitor, highlighting more effective methods for creating sustainable corrosion protection systems.

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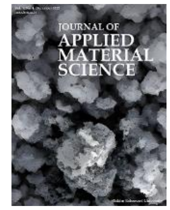

Communication

Comparison of the Corrosion Inhibition Effect of *Portulaca oleracea* Extracts Prepared Using Ethanol and Water

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Abstract

The most important problem that threatens metal structures is corrosion. Corrosion is a slow process, although it is very fast in environments such as industrial estates or the ocean. This phenomenon causes huge environmental pollution. Many chemical corrosion inhibitors are very toxic, but they are still used. Therefore, researchers are looking for green inhibitors, many of which are prepared from plant extracts. In this study, *Portulaca oleracea* extracts were prepared using two solvents (ethanol and water), and their corrosion inhibition potential on mild steel (MS) in salt solution was evaluated. For this purpose, electrochemical impedance spectroscopy (EIS) was used for electrochemical tests. The results showed that the role of the solvent is effective in preparing the extract, and ethanol is a more suitable solvent for preparing the inhibitor from *Portulaca oleracea*. Also, the extract prepared with ethanol showed an inhibition efficiency of 64%. According to the results of this study, it can be said that this extract can be investigated in protective coatings.

Keywords: Green chemistry; Plants; Corrosion Protection.

1. Introduction

Coating is one of the main methods of corrosion protection. Polymer coatings are one of the main classes of coatings widely explored for different corrosion protection applications [1-3]. Although properties and performance of polymers can be improved via nanomaterials and nanostructure [4-7], the unsustainable nature of polymeric coatings is the main reason for the growing interest in nature-based chemical inhibitors. In recent years, due to the toxicity of common chemical inhibitors, the use of plant extracts as green alternatives has received considerable attention, and researchers have conducted numerous studies [8-10].

The results of some studies have shown that inhibitors with an inhibition efficiency of up to 99% can be obtained from some plants [11, 12]. In general, all different parts of a plant can be used to prepare inhibitors, but the inhibition efficiency directly depends on the active phytochemical compounds of the plant, so inhibitors prepared from different parts of a plant will have different inhibition efficiencies [13-15]. Typically, a solvent is used to extract the active phytochemicals from a plant [16]. The solvent can penetrate the plant tissue and thus extract the desired compounds [17]. *Portulaca*

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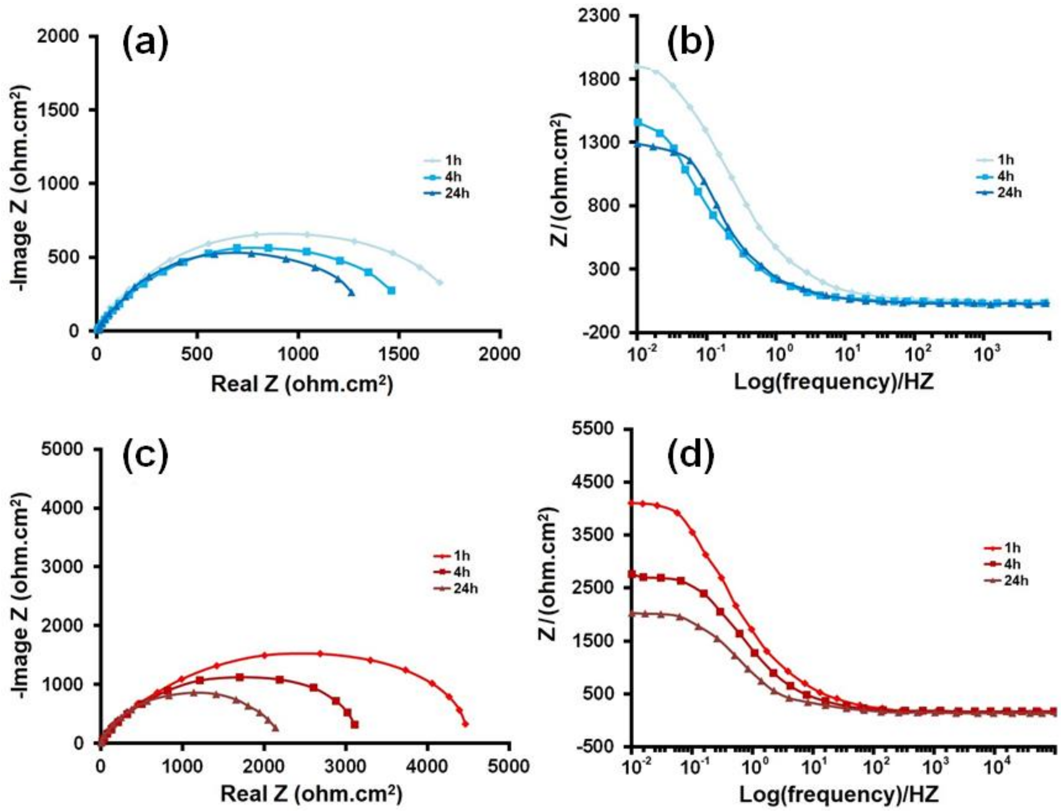

Figure 1. Nyquist and Bode plots of MS at different immersion times (a and b), and in the presence of the *Portulaca oleracea* extract prepared using ethanol (c and d).

oleracea is a herbaceous plant that originally belonged to India but is now spread to various parts of the world [18]. This plant is rich in nutrients, including polysaccharides, which have numerous applications, making it a popular vegetable [19]. In this study, *Portulaca oleracea* was extracted using water and ethanol, and its inhibition efficiency was evaluated.

2. Experimental

2.1. Materials

Sodium chloride (NaCl) and MS were obtained from Merck and Mobarakeh Steel Company, respectively. The *Portulaca oleracea* plant was obtained from a local market (Lahijan city, a region in northern Iran).

2.2. Preparation of extract, MS substrate, and electrochemical tests

First, the *Portulaca oleracea* leaves were washed with distilled water. Then, ethanol was added to the *Portulaca oleracea*, and the extract was prepared after 20 min of heating (at 50 °C). To prepare the extract using water, the same procedure as before was repeated. Substrates and electrochemical tests were performed as reported in a previous paper [20].

3. Results and discussion

The evaluation results are reported in Figure 1 and Table 1. The changes in the diameter of the Nyquist plots (see Figure 1a) indicate the degradation of the MS in the absence of the extract. The diameter of the curve represents the charge transfer resistance (R_{ct}), which is seen to decrease with increasing immersion time. It can be said that with increasing immersion time, the corrosive species will have the time to penetrate the MS and cause its degradation. Also, the Bode plots (see Figure 1b) show a decreasing trend with increasing immersion time. But, the evaluation results in the presence of extract are very different (see Figures 1c-d and Figure 2a-b). As can be seen, we see an increase in the R_{ct} value. Also, the Bode plots show a significant

Table 1. Electrochemical parameters obtained from EIS results

Samples	Time (h)	R_{ct}(a) (ohm.cm²)	R_s (ohm.cm²)	log |z| (ohm.cm²)	η (%)
Without extract	1	1701.18	7	1900.27	-
	4	1461.28	7.8	1456.86	-
	24	1264.23	7.5	1288.16	-
Extract prepared *via* ethanol	1	4680.59	12	4497.43	64
	4	3348.66	14	2963.91	56
	24	2298.42	13	2229.97	45
Extract prepared *via* water	1	4463.56	12	4105.31	62
	4	3108.61	14	2763.91	53
	24	2133.62	13	2029.97	40

increase in the presence of the extract, which is due to the surface passivation of the MS surface by the functional groups of the extract [20-22].

As mentioned earlier, in this manuscript, two solvents (ethanol and water) were used to prepare the extract. It can be said that the most important factor that affects the quality of the extract is the solvent [13, 23, 24]. In fact, the solvent penetrates the plant and extracts the active compounds. It has been reported in the literature that ethanol can extract alkaloids, flavonols, polyacetylenes, polyphenols, propolis, sterols, tannins, and terpenoids, and water can extract anthocyanins, lectins, polypeptides, saponins, starches, tannins, and terpenoids [13, 20]. *Portulaca oleracea* contains malic acid, polysaccharides, alkaloids, flavonols, terpenoids, polyphenols, carotene, and vitamins B, C, and E [18, 19]. Therefore, ethanol is a better solvent for preparing the extract, and as the results show, the inhibition efficiency of the extract prepared with ethanol is higher, indicating that there are more active compounds in the prepared extract.

Figure 2c shows the equivalent circuit that matched the impedance results. Typically, the compounds in the extracts are adsorbed onto the surface. As previously mentioned, *Portulaca oleracea* contains compounds such as flavonoids, polyphenols, and terpenoids. These

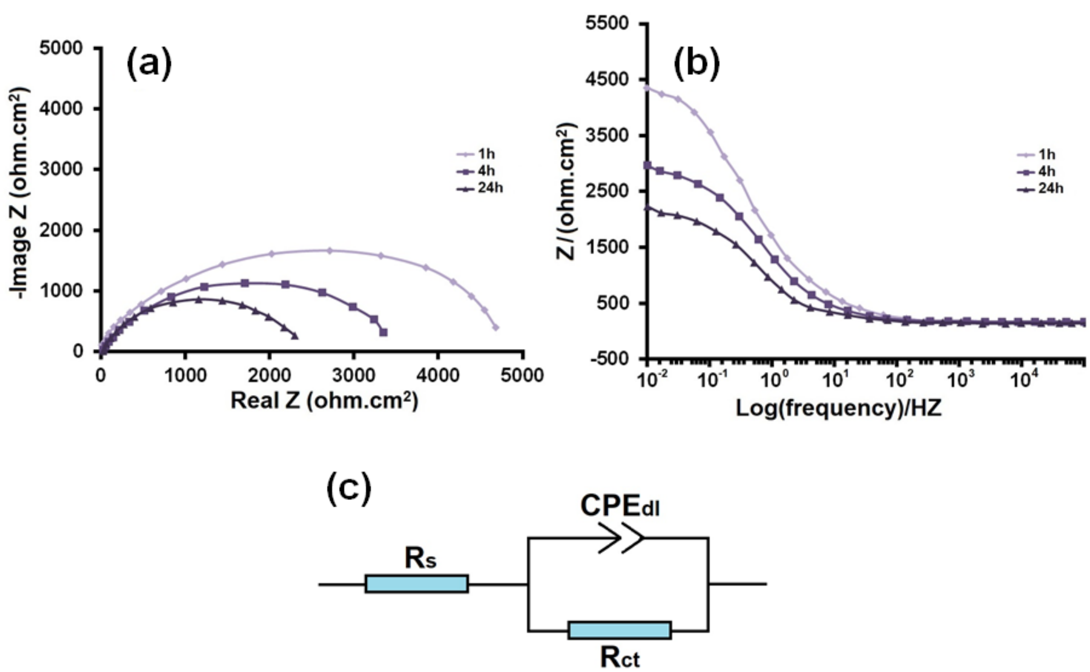

Figure 2. Nyquist and Bode plots of MS at different immersion times in the presence of the extract prepared using water (e and f) and an equivalent circuit to describe the results (c), with Rs representing the solution resistance

Table 2. Comparison between the highest inhibition efficiency of *Portulaca oleracea* with other plants

Plant	Substrate	Corrosive Medium	Maximum inhibition efficiency (%)	Reference
Date seed	Mild steel	NaCl	71	[10]
Morus alba 'Pendula'	Mild steel	NaCl	61	[20]
Matcha	Mild steel	NaCl	70	[22]
Orange peel	Mild steel	NaCl	94	[23]
Portulaca oleracea	Mild steel	NaCl	64	This study

compounds can adsorb onto the metal surface. This adsorption is related to the π-electron transfer between oxygen atoms and aromatic rings of compounds with vacant *d*-orbitals on the surface, which block the anodic regions and form a protective layer [20-22]. Also, Table 2 presents a comparison between the highest inhibition efficiency in this study and the results of several other studies.

4. Conclusions

In summary, a corrosion inhibitor was prepared from *Portulaca oleracea* using two solvents (ethanol and water). The results showed that this extract has the ability to inhibit corrosion. Also, considering the compounds of this plant, ethanol is a more suitable solvent for preparing the inhibitor. In general, inhibitors prepared from plants are very popular due to their non-toxicity and cheapness, but their effectiveness is of great importance with temperature changes and increasing immersion time. Normally, many active compounds are degraded with increasing temperature, so this aspect of research is very important.

Conflict of Interest

The authors declare no conflict of interest.

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