

Plant extracts used as corrosion inhibitors

Uso de extractos de plantas como inhibidores de corrosión

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Abstract

Corrosion issues are frequent in the chemical, petroleum, naval, civilian construction, transport method, communications systems, amongst others. Corrosion inhibitors are widely used for the control and prevention of this phenomena, most of them being compounds that are too toxic, costly and harmful to man and the environment. This situation has created the need of finding corrosion inhibitors that are friendly with the environment and low in cost. Plant extracts are biodegradable and represent a renewable source of chemical compounds that possess a high potential as inhibitors. This article offers a revision of the variety of superior plants and algae that have been used as metal corrosion inhibitors, showing the type of metal (steel, zinc and aluminum) and the conditions of the exposure media (acid and neutral).

Keywords: corrosion inhibitor; metals; natural products; plant extracts.

Introduction

To obtain metals in free form, from the minerals found in the mines, man has created methods in which large amounts of energy. The metals and alloys produced with high energy content react chemically and electrochemically with their surroundings to form a stable compound which conduces to the loss of the metal, in a process known as corrosion (Speight, 2014). In an aqueous media, corrosion is of electrochemical nature; this phenomena denotes the existence of an anodic zone (which suffers the deterioration), a cathodic zone, and an electrolyte, and it is absolutely necessary the presence of these 3 elements for the process to occur (Raja and Sethuraman, 2008).

Corrosion involves the movement of metallic ions in the solution, which are transported from the active zones of the metal (anode) to an acceptor in the less active zone (cathode), through the electrolyte, causing dilution and

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degradation of the material (Abdullah, 2011). The metals attacked by an aggressive media, lose their functionality in the applications for which they are used, therefore control and prevention actions are required.

Corrosion affects the economy, the expenses caused by the control and prevention of this problem are huge and it is estimated that it corresponds to 2 to 4% of the gross internal product of an industrialized country. (Huu, 2004; Abdel-Gaber *et al.*, 2006). The most prominent risks, as economic as environmental and social, are presented in the large industrial facilities, such as electricity production plants or chemical production facilities. Corrosion is many times the cause of the halts in process plants, reduces the efficiency of the equipment (Abdel-Gaber *et al.*, 2006) and causes accidents as fires, explosions and liberation of toxic products to the atmosphere, the water or the soil (Chen *et al.*, 2008; Restrepo *et al.*, 2009).

The industry in general spends in preventive and corrective maintenance due to the corrosion processes in tanks, equipment, tubing, accessories and others. To avoid these costs, it is useful to apply corrosion inhibitors, which avoid or reduce the corrosion on metals. In this revision, the plant-based corrosion inhibitors are mentioned particularly.

Corrosion Inhibitors

It is almost impossible to avoid corrosion; however, it is possible to control it. To predict corrosion damage of tubing, mixing tanks, spiral tubes and other metallic surfaces, the formation of acids needs to be inhibited by the use of an effective solution of corrosion inhibitors (Finšgar y Jackson, 2014).

Between the different methods of prevention and control, the use of corrosion inhibitors is widely generalized, being one of the most cost-effective and practical. The use of an adequate inhibitor may allow the choosing of lower grade carbon steel, which reduces significantly the capital costs of a project in comparison with the same project constructed in a high grade alloy (Finšgar y Jackson, 2014).

Inhibitors are substances that when added in small concentrations in the corrosive media, they reduce or prevent the reaction between the metal and the environment (Raja y Sethuraman, 2008; Sastri, 2014). These substances retard the process of corrosion, increment the behavior of anodic and cathodic polarization, reduce the movement or

diffusion of the ions from the metallic surface and increase the electric resistance of the surface (Satri, 2011). However, the corrosion inhibitors are effective for a specific metal in a specific media. Minor changes to the composition of the solution or alloy can alter significantly the inhibitory power (Finšgar y Jackson, 2014).

The selection and the amount of inhibitor used depend on the media, the type of metal, the protection time desired and the temperature desired. The maximum temperature limit is one of the key factors in the selection of the inhibitor, since some components are sensitive to thermal decomposition, meaning that they lose effectivity as inhibitors when subjected to heat. The scientific community and the industry do not understand the mechanism or the role of corrosion inhibitors, and is difficult, sometimes impossible to predict if a particular compound will work or not. In general, the inhibitors are effective for ferrous materials only at temperature levels from 121 to 149°C (Finšgar y Jackson, 2014).

There are various kinds of inhibitors like the inorganics: chromate, phosphate and molybdate salts. In this type of compounds, the anions are the responsible for the reduction of the corrosion speed on the metal. The organic inhibitors are used in cooling systems and are generally of the anionic type such as mercaptobenzothiazole (MBT), sodium sulphates and phosphonates (Tansuğ *et al.*, 2014). The figure 1 shows the types of corrosion inhibitors according to their origins reported in literature.

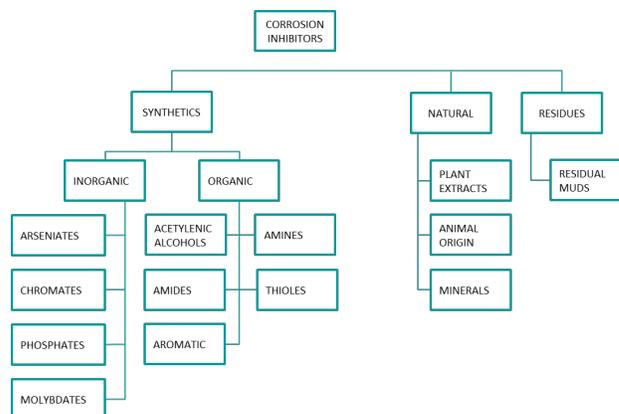


Figure 1. Corrosion inhibitor classification according to origin

Arsenic acid was used as corrosion inhibitor in 1932; however, it is known that arsenic compounds produce arsenic gas, which is poisonous in acid conditions. In the 1970's decade, the salts and arsenic acids were replaced by organic molecules that generally contain nitrogen, oxygen, phosphorus, aromatic groups or any insaturation (Finšgar y Jackson, 2014).

In the organic inhibitors' group, the following are included: acetylenic alcohols, amines (Quraishi y Jamal, 2001), amides, imidazoles (Okafor et al., 2009; Zhang et al., 2007), nitriles, iminium salts, triazoles, piridine and its derivatives, quinoline derivatives, thiourea derivatives, thiosemicarbazide, thiocyanates, amongst others (Finšgar y Jackson, 2014). Acetylenic alcohols are widely used due to their availability and low cost. The most used inhibitors used in the natural resources extraction industry is the propargylic alcohol and its derivatives, such as cinnamaldehyde and aromatic compounds such as quaternary benzylpiridine chloride (Finšgar y Jackson, 2014).

The inhibitors with a mercapto (-SH) group are able to form stable compounds with the metallic ions through the thiolate bond.

Most of these inhibitors are modified with an aromatic ring that has certain substituents, with the purpose of increasing the hydrophobicity in the top layer of the inhibiting coat. The inhibition mechanism is based on the chemical absorption of the inhibitor's ions and the metal on the surface. The inhibition efficiency is directed by the position of the SH group on the ring, it being ortho, meta or para located. (Tansuğ *et al.*, 2014).

The heterocyclical compounds, this meaning those that in the ring possess at least one atom, different to carbon, have been useful as corrosion inhibitor (Raja y Sethuraman, 2010) and their synthesis has been conducted continuously. Most of these compounds contain nitrogen, sulphur and oxygen with a solitary pair of electrons and additionally possess aromatic systems (Popova and Christov, 2006). It is believed that the locations where these atoms are, is where the adsorption occurs, since they can act on the metallic surface through adsorption and there, through the blockage of the active sites, the corrosion speed is reduced (Achary *et al.*, 2008; Oguzie et al., 2004; Eddy and Ebenso, 2010)

The molecules that contain nitrogen and the acetylenic alcohols form a film on the surface of the metal that retards the metal's dilution process in an anodic reaction as well as the evolution of hydrogen in the cathodic reaction (Barmatov. *et al.*, 2012).

The inhibitors that contain azolic compounds with hydrophobic terminal groups are used frequently. The azol group is capable of forming coordinated covalent bonds with the vacant d orbitals in the metal's atoms. Also, rings that have conjugated atoms (π electrons) which

affect positively the interactions between the metal and the inhibiting compound (Tansuğ *et al.*, 2014).

Most synthetic inhibitors are too costly and dangerous to living beings due to their high toxicity (Raja y Sethuraman, 2008; Abdullah, 2011).

Synthetic inhibitors can reach natural waters and be distributed throughout the ecosystem affecting species that are sensitive to its components (Rizzo, 2004). Some organic type inhibitors can even cause liver damage, disrupt biochemical processes, as the general enzymatic functioning in general (Abdallah *et al.* 2010).

Plant extract based inhibitor

The dangers of the most organic synthetic inhibitors are commonly known and the new environmental legislation such as the Toxic Substance Control Law of the Environmental Protection Agency (EPA) of the United States and the Hazardous Substance Restrictions Directive of the European Union, generate the need to develop corrosion inhibitors that are environmentally friendly, that do not have heavy metals like chrome and lead or organic compounds. Due to this reason, the use of plants as corrosion inhibitors is suggested. Most of natural inhibitors are non-toxic, biodegradable and abundant in nature. To the moment, extracts from seeds, fruits, flowers, leaves, etc. (Raja y Sethuraman, 2008; Abdullah, 2011) and it has been found that they reduce the corrosion speed considerably. In the plant extracts, a large number of chemical compounds are present, especially heterocyclic compounds, which inhibit corrosion efficiently (Sathiyathan et al., 2005; Oladele and Okoro, 2011). The inhibiting effect is attributed to the adsorption of these organic substances on the surface of the metal, that blocks the active sites or form a protective coating (Abdel-Gaber *et al.*, 2006; Singh *et al.*, 2010; Anuradhaa *et al.*, 2008).

The existing data shows that most of the organic inhibitors act by adsorption in the metal/solution interface; by displacing the water molecules, forming a compact film that acts as a barrier (Abdel-Gaber *et al.*, 2006). Adsorption is influenced by the nature of the metal, the charge on the metal's surface, the electrolyte type, the temperature and the chemical structure of the inhibitor. In fact, the specific interaction between the functional groups, the surface of the metal and heteroatoms as nitrogen, oxygen, sulphur and phosphorus play a key role in inhibition due to the availability of free paired electrons they have (Abdullah, 2011). The availability of solitary electrons and π electrons in the inhibitor's molecules facilitates the transference

of electrons from the inhibitor to the metal, and form a coordinated covalent bond (Chauhan y Gunasekaran, 2007).

In general, the principal types of interactions between the organic inhibitor and the metal surface are chemisorption and or physisorption. It has been suggested that the adsorbed molecules physically bond to the metal in the local cathodes and the metal's dilution is retarded when the cathodic reaction is halted, while the molecules adsorbed chemically protect the anodic areas (Oguzie, 2008).

Mild steel corrosion inhibition

Natural corrosion inhibitors have been studied widely on mild steel, which include:

The TAGETES ERECTA, known as "Flor de la Maravilla", used as corrosion inhibitor, in a 0,5 M solution of H_2SO_4 , through gravimetry, potentiodynamic polarization and spectroscopic measurements of electrochemical impedance; the extract functioned as a mixed type inhibitor, meaning, cathodic and anodic; the adsorption of the inhibitor on the surface of mild steel followed the Langmuir's adsorption isothermal line, which indicates monolayer adsorption. The activation parameter that defines adsorption showed that the inhibitor was absorbed physically (Mourya *et al.*, 2014).

The bark extract of the watermelon was used as mild steel corrosion inhibitor in HCl and H_2SO_4 solutions. The adsorption followed the model of Temkin's isothermal. The extract behaved as a mixed type inhibitor in both media; being the HCl solution better than the H_2SO_4 (Odewunmi *et al.*, 2014).

The ethanol based coconut fiber and acetone extracts were used as corrosion inhibitors of mild steel in a H_2SO_4 0,5M solution between 30 and 60°C. Weight loss and electrochemical tests are conducted to evaluate the efficacy of the extract's inhibition capacities, finding that the inhibitor retards the steel's dilution, but the effect was higher for the ethanolic extract. The efficiency of the inhibition capacities increased with the concentration's increase but decreased with the rising of temperature, which is suggester to the physical adsorption (Umoren *et al.*, 2014).

The alcoholic extracts of eight plants: Lycium shawii, Teucrium oliverianum, Ochradenus baccatus, Anvillea

garcinii, Cassia italica, Artemisia sieberi, Carthamus tinctorius and Tripleurospermum auriculatum, were studied to evaluate the inhibitory effect on corrosion on mild steel in HCl, 0,5 M using the potential of an open circuit, polarization curves and alternating current impedance methods. All the plant extracts inhibited the corrosion of mild steel in acid media, through adsorption and acted as mixed type inhibitors (Al-Otaibi *et al.*, 2014).

The inhibition effect of the leaf and bark extract of Neolamarckia cadamba was investigated for corrosion on mild steel, 1,0 M. The measurements of potentiodynamic polarization, electrochemical impedance, and Electronic scanning microscopy and FTIR spectroscopy showed that the extracts reduced the corrosion speed significantly at all concentrations (Raja *et al.*, 2013).

Peach juice has been investigated as a corrosion inhibitor for mild steel in hydrochloric acid (HCl), at different temperatures. The inhibitor was adsorbed physically on the surface of the metal describing a Langmuir's isothermal. The maximum inhibition efficiency was 91% at 50°C, with an inhibitor concentration of 50 cm^3/l (Yaro *et al.*, 2011).

The inhibitory effect of the alkaloid extract of Rauwolfia serpentina was evaluated on mild steel submerged in acid solution. It was found that the inhibition efficiency reached a 95% of HCl solution and 96% in a H_2SO_4 solution with a 50 ppm inhibitor concentration at a temperature of 323K (Raja and Sethuraman, 2010).

The inhibitory performance of the Henna extract (Lawsonia inermis) and its principal constituents (Lawsone, galic acid, α -D-glucose and tannic acid) for mild steel in HCl 1M. The henna extract is considered low cost and environmentally friendly. The authors demonstrated that this extract is effective in the prevention of corrosion, however, when the temperature increased from 25°C to 60°C, the inhibitory efficiency decreased. Besides, it was proven that all the compounds present in the extract act as inhibitors themselves and some of them as oxygen eliminators. (Ostovari *et al.*, 2009).

The Justicia gendarussa plant extract has been studied as corrosion inhibitor for mild steel in HCl 1,0M at 25-70°C. The principal components of this extract are β -sitosterol, friedelina, lupenol, phenolic dimers, o-substituted aromatic amines, benzylic alcohol and flavonoids. The inhibition efficiency increased with concentration, but decreased with temperature. At 80°C there is no inhibitory

effect, due to the thermal decomposition of the extract compounds (Satapathy et al., 2009).

The effect of the different parts of the Carica Papaya, as corrosion inhibitors for mild steel in H₂SO₄. The research showed that the higher inhibition efficiency was obtained from the leaves with 85.8% at 30°C. The efficiencies were increased with the concentration of the extracts and decreased with the increase of temperature (Okafor and Ebenso, 2007).

Corrosion inhibition of mild steel

The inhibition of corrosion on steels with a higher percentage of carbon has been widely researched. A surfactant prepared from the Adenopus breviflorus seed oil was applied as a corrosion inhibitor for carbon steel in HCl 0,5M through the weight loss method. The inhibitory mechanism was studied by the surface's properties and electronic scanning microscopy photographs, finding that it was by adsorption. The results presented the prepared surfactant as an effective corrosion inhibitor of mild steel in HCl 0,5M (Adewuyi et al., 2014).

Apricot juice was used to inhibit corrosion of carbon steel in a H₃PO₄ 1,0M solution at different temperatures, through the weight loss method. The adsorption essays showed that the inhibitor adsorbed on the metal surface followed Langmuir's isothermal; that the corrosion speed is influenced by temperature, inhibitor's concentration and the combined interaction of the 2 factors (Yaro et al., 2013).

The Euphorbia falcata L. extract was evaluated as corrosion inhibitor of carbon steel in HCl 1,0M using gravimetric, impedance, polarization and electronic scanning microscopy techniques. The results obtained from the polarization curves indicate that the extract is a good inhibitor for corrosion and the efficacy of the protection increased with concentration. The obtained results from the polarization curves show that the extract is a mixed type inhibitor; that inhibition of corrosion of carbon steel in HCl 1,0M is controlled mainly by a fisisorption process (El Bribri et al., 2013).

The inhibition of corrosion in carbon steel in HCl 1,0M and H₂SO₄ by the Spirulina platensis was studied at different temperatures with the weight loss method, potentiodynamic polarization, spectroscopic measurements of electrochemical impedance and electronic scanning microscopy. The inhibition efficiency increased

with the increase in the inhibitor's concentration in HCl as well as H₂SO₄. The results of the weight loss studies correlated well with the impedance and polarization studies. The results showed that the adsorption mode was fisisorption (Kamal and Sethuraman, 2012).

The Olea europaea L, also known as olive, was used as corrosion inhibitor for steel surfaces in a brine solution. The inhibitory characteristics were studied through electrochemical impedance (EIS) and potentiodynamic polarization curves. The mechanism of incrustation was attributed to the formation of the calcium cafeate complex, which is absorbed on the surface of the steel in an early stage, poisoning the crystalline nuclei around them. The potentiodynamic polarization curve indicates that the olive leaf extract can inhibit corrosion on steel and the accumulation of limestone (Abdel-Gaber et al., 2011).

The Neem leaf extract was found highly effective to inhibit corrosion on carbon steel in HCl 1,0M, reaching efficiencies of 87% at room temperature, with a concentration of 3g/L of the extract (Nahle et al., 2010).

In the inhibition and adsorption characteristics study for the ethanol extract of Heinsia Crinata on carbon steel in H₂SO₄ solutions, weight loss method, thermometrical and hydrogen evolution, while the adsorption properties were studied through IR spectroscopy. The inhibitory efficiency of the extract varied with concentration, the immersion and temperature. The inhibitory properties were attributed to the presence of alkaloids, saponines, tannines, cardiac glucosides and anthraquinone. (Eddy and Odiongenyi, 2010).

The corrosion inhibitory effect of Aniba rosaeodora extract on C38 steel in HCl 1.0M was studied using potentiodynamic polarization and electrochemical impedance spectroscopy. The polarization studies showed that the extract is a mixed type inhibitor whose inhibition efficiency increased with the inhibitor's concentration (Chevalier et al., 2014).

The extracts from Radish leaves and black cumin were tested as corrosion inhibitors on carbon steel, in presence of industrial waters. The obtained data reveals that the black cumin extract is relatively better than the radish leaf extract, however, both plants have the potential to be employed in the inhibition of corrosion in gas, petroleum or large amounts of water (Badiea and Mohana, 2009).

It has been reported that the Aloe Vera plant has good inhibitory properties through chemisorption. Based

on the chemical structure of the aloe, it was concluded that the inhibitory action is due to the chelating effect that its functional groups has with the ferric ions, which facilitates a strong coordination on the surface of the studied steel. (Eddy and Odomelam, 2009).

The *Bifurcata bifurcata* extract has been used in the corrosion inhibition of carbon steel in presence of HCL 1,0M. The process of inhibition was attributed to the adsorption of the inhibitor's molecules, to the precipitation of iron chelates and the formation of complexes on the surface (Abbout *et al.*, 2004).

On the application of Artemisa oil as corrosion inhibitor on steel in HCL, the highest inhibition efficiency was 76% at an inhibitor's concentration of 19g/dm³ (Bouyanzer and Hammouti, 2004).

Corrosion inhibition on stainless steel

The *Silybium marianum* leaf extract has been evaluated as a corrosion inhibitor for 304 stainless steel in a HCL 1,0M through weight loss method, potentiodynamic polarization and electrochemical impedance spectroscopy measurements. The potentiodynamic polarization curves indicated that the *S. marianum* extract behaves as a mixed type inhibitor (Soltani *et al.*, 2014).

The inhibitory action of the Aloe Vera leaf as protection against corrosion of stainless steel in a H₂SO₄ 1,0M solution was studied with weight loss method and electrochemical impedance spectroscopy measurements. The lineal polarization results indicated the efficacy of the extract as the concentration increased too. (Mehdipour *et al.*, 2014).

Corrosion inhibition of other metals and alloys.

The *Camellia sinensis* plant extract was used for the corrosion inhibition on tin in acid and alkali media. The extract reduced the cathodic reaction speed with more strength than the anodic reaction speed. The inhibitory efficiency increased with the immersion time. The inhibitors were easily adsorbed by the tin surface, through the formation of an inhibitory coating that avoids the corrosion of the surface (Ramde *et al.*, 2014).

The ethanolic extract of *Mansoa alliacea* was tested as corrosion inhibitor on zinc in NaCl 3% using the polarization and electrochemical impedance spectroscopy.

The potentiodynamic polarization curves showed that the plant extract behaves as a mixed type inhibitor. Inhibition efficiencies around 90% were obtained. The polarization curves show that the extract affects the anodic and cathodic reactions (Suedile *et al.*, 2014).

The corrosion inhibition properties of the aqueous extract of *Coriandrum sativum* L. seeds were studied by Prabhu and Rao (2013) for the control of corrosion on aluminum in phosphoric acid solution 1,0M using potentiodynamic polarization and electrochemical impedance spectroscopy. The inhibitor's adsorption on the metallic surface obeyed to the Langmuir's adsorption isothermal curve. The polarization measurements showed that the extract acted as mixed inhibitor.

The inhibition of corrosion on aluminum in H₂SO₄ 0,5M by *Spondias mombin* L. using standard gravimetric techniques at temperatures between 30-60°C. The tendency of temperature related inhibition efficiency, to propose the inhibition mechanism. The extract's inhibition efficiency increased with concentration but decreased with temperature (Obi-Egbedi *et al.*, 2012).

Jojoba oil, applied for the inhibition of corrosion on iron in HCL, determined that corrosion speed decreased significantly in presence of the oil and its inhibition efficiency increased up to almost 100% with an oil concentration of 0,515g/L (Chetouani *et al.* 2014).

Reinforced concrete corrosion inhibition

The inhibition of corrosion in reinforced steel with *Bambusa arudinacea* extract was studied. The concrete mix was designed for a 30MPa compression resistance with a 0,45 water to cement ratio. The samples were submitted to 360 days of exposure testing. The *B. Arudinacea* avoided corrosion on the steel (Aspitia *et al.*, 2014).

On table 1, the research documents from 2012 to 2014 regarding plant extracts used as corrosion inhibitors.

Conclusions

The concern for the conservation of the environment and the new legislations to control the emission of toxic substances that are harmful to life on the planet, created the need for the study of plant extracts as corrosion inhibitors. Such extracts have become an important, ample, abundant,

renewable source of inhibitors due to their varied ingredient richness that have high efficiency for corrosion inhibition.

In this revision, some of the studies that have been conducted are shown, in which good inhibition efficiencies are obtained in condition studies. There are many options that can be explored when evaluating if a plant-based extract is a good inhibitor, accounting for the variables involved: the material type, media type, media

concentration, temperature, immersion time, extract origins, amongst others. The most studied material is mild steel, due to its industrial applicability. The most frequent media on the reported studies are the HCL and the H₂SO₄ at 1,0M concentration. The used temperatures are in the range of 25-60°C.

In most of the reported studies, it was found that the inhibition efficiency increased with the increase in the inhibitor's concentration, but decreased when

Table 1. Plant-based corrosion inhibitors research papers reported in the 2012 - 2014 period

Plant	Metal	Method	Reference
<i>Tagetes erecta</i>	Mild steel	H ₂ SO ₄ 0.5 M	Mourya <i>et al.</i> , 2014
<i>Silybum marianum</i>	Stainless steel 304	HCl 1.0 M	Soltani <i>et al.</i> , 2014
Neem	Carbon steel	HCl 1.0 M	Nahle <i>et al.</i> , 2010
<i>Bambusa arundinacea</i>	Reinforce concrete	Cloruros	Aspitia <i>et al.</i> , 2014
<i>Adenopus breviflorus</i>	Mild steel	HCl 0.5 M	Adewuyi <i>et al.</i> , 2014
Watermelon	Mild steel	HCl y H ₂ SO ₄	Odewunmi <i>et al.</i> , 2014
Coconut	Mild steel	H ₂ SO ₄ 0.5 M	Umoren <i>et al.</i> , 2014
<i>Aniba rosaedora</i>	C38 steel	HCl 1.0 M	Chevalier <i>et al.</i> , 2014
<i>Camellia sinensis</i>	Tin	Na ₂ SO ₄ 0.1 M	Ramde <i>et al.</i> , 2014
<i>Lycium shawii</i> , <i>Teucrium olive-rianum</i> , <i>Ochradenus bac-catus</i> , <i>Anvillea garcinii</i> , <i>Cas-sia italica</i> , <i>Artemisia sieberi</i> , <i>Carthamus tinctorius</i> y <i>Tri-pleurospermum auriculatum</i>	Mild steel	HCl 1.0 M	Al-Otaibi <i>et al.</i> , 2014
<i>Aloe vera</i>		H ₂ SO ₄ 1.0 M	Mehdipour <i>et al.</i> , 2014
<i>Mansoa alliacea</i>	Stainless steel	NaCl 3%	Suedile <i>et al.</i> , 2014
Peach	Zinc	H ₃ PO ₄	Yao <i>et al.</i> , 2013
<i>Coriandrum sativum L.</i>	Carbon steel	H ₃ PO ₄ 1.0 M	Prabhu y Rao, 2013
<i>Neolamarckia cadamba</i>	Aluminum	HCl 1.0 M	Raja <i>et al.</i> , 2013
<i>Euphorbia falcata</i>	Mild steel	HCl 1.0 M	El Bribri <i>et al.</i> , 2013
<i>Spirulina platensis</i>	Carbon steel	HCl 1.0 M y 1.0 M de H ₂ SO ₄	Kamal y Sethuraman, 2012
<i>Spondias mombin L.</i>	Carbon steel	H ₂ SO ₄ 0.5 M	Obi-Egbedi <i>et al.</i> , 2012
	Aluminum		

the temperature increased. Due to the high efficiency percentages found, even higher than 90%, the inhibitors based on plant extracts are an emerging technology with great potential to be used in the protection of metals against, having an advantage due to their biodegradability, their high availability and their harmless nature with the environment.

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