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Research Article

Application of Natural Products as Corrosion Inhibitors in Different Steel and Media

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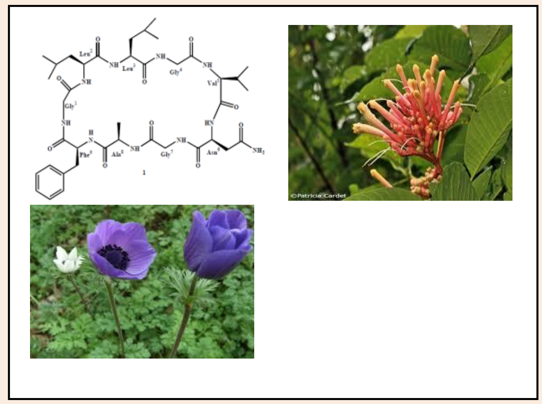
Abstract

Rapid industrialization has led to the onset of increased utilization of steel in various industries. Their encounter with aqueous corrosive environment in industrial application makes them susceptible to corrosion. This has lead to the search of better and efficient protection methods for the prevention of corrosion. A global phenomenon, corrosion manifests in various forms and the losses due to corrosion are enormous. Application of inhibitors to prevent corrosion is a widely accepted form of protection as it is one of the easily available methods. In recent years the usage of natural products as corrosion inhibitors is gaining momentum due to environmental considerations. In this direction, the present review highlights the role of phyto-chemical constituents present in the plant extracts on different types of steel in various media. Discussions are based on the nature of phyto-chemical constituents and its mechanistic action on steel corrosion.

Keywords: natural products, steel, carbon steel, plant extracts, corrosion inhibitors



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Introduction

Steel is recognised as the main constructing material in industry. Carbon steel is one of the most abundantly used alloy in various industries especially petro chemical industries. There is a great need to protect steel from dissolution by using corrosion inhibitors. Corrosion inhibitors have wide spread applications in the industrial field as a component for industrial equipments, and in acidization of oil wells.

Alkaloids

A largest group of secondary metabolites, the alkaloids comprise basically of nitrogen bases and oxygen. Alkaloids are found to have numerous pharmacological applications. Till date more than 12,000-alkaloids are known to exist in about 20% of plant species and only a few have been exploited for medicinal purposes.

The corrosion inhibition effect of alkaloids extract from *Annona squamosa* [1], *Palicourea guianensis* (AEPG) [2] *Isertia coccinea*(AEIC) [3] *Oxandra asbeckii* (OAPE)[4] and *Aspidosperma album* [5] plants on C38 steel in 1 M HCl medium were studied by Potentiodynamic polarization and AC impedance methods. The corrosion inhibition efficiency increases on increasing plant extract concentration for all the investigated inhibitors. Polarisation studies showed that the extracts behaved as mixed-type inhibitors in 1 M HCl. The inhibition efficiency of *Annona squamosa* extract was temperature dependent and its addition led to an increase of the activation corrosion energy revealing a physical adsorption between the extract and the metal surface. Inhibition efficiency of 89% was achieved with 100 mg

L^{-1} of AEPG at 25°C. The protection efficiency of AEIC extract was found to be 91 % at 100 mg L^{-1}whereas *Aspidosperma album* exhibited a maximum efficiency of 90% at 100 mg L-1.The adsorption of the extracts followed Langmuir's adsorption isotherm. The inhibitive effect of *Annona squamosa* was ascribed to the presence of organic compounds in the extract. According to the authors, the mechanism of the adsorption of the alkaloids extract on the metal surface occurs directly via donor–acceptor interactions between the p electrons of the heterocyclic compound and the vacant ''d'' orbitals of iron surface atoms

Tannins and Flavanoids

Tannins and flavonoids are phenolic and polyphenolic compounds of high molecular weight that are widely distributed in plant flora. They are found in the root, bark, stem and outer layers of plant tissue Nearly four thousand flavonoids are known to exist and only very few have been tried as corrosion inhibitors [6] .

The inhibitive action of mangrove tannins, extracted from mangrove barks and phosphoric acid, on pre rusted steel in a 3.5% NaCl solution was evaluated and the inhibitive efficiency was compared with that of mimosa tannins[7]. Electrochemical studies reflected that the inhibition efficiency of solutions containing 3.0 g L^{-1} tannins depended upon the concentration of phosphoric acid added and the pH of the solution. Mangrove and mimosa tannins exhibited highest efficiency at pH 0.5 and pH 2.0, while addition of phosphoric acid was found to be effective at pH 5.5.

The inhibitive behaviour on steel of flavanoid monomers that constitute mangrove tannins [8] namely catechin, epicatechin, epigallocatechin and epicatechin gallate was investigated in an aerated HCl solution via electrochemical methods. The monomers were found to be mainly cathodic inhibitors and the inhibition efficiency was dependent on concentration. Quantum chemical calculations using semi empirical approach indicated that the most probable adsorption centers were in the vicinity of the phenolic groups. The inhibitive performance of the investigated tannins was quite comparable with that of the commercially available mimosa, quebracho and chestnut tannins.

Natural Oils

The essential oil of various natural products obtained by hydrodistillation using clevenger type apparatus were successfully tested as corrosion inhibitors in acidic media especially hydrochloric and sulphuric acids. The inhibitors were investigated using electrochemical polarisation and weight loss measurements. The corrosion rate of steel decreased in the presence of natural oils. While *Eucalyptus* natural oil and *Artemisia herba alba* oil acted as a cathodic inhibitor, the rest of them acted as mixed inhibitors. *S.aucheri mesatlantica* revealed that the oil acted as mixed type inhibitor with a strong predominance of anodic character.

The inhibition efficiency of the tested inhibitors were found to increase with oil content. The adsorption of the tested essential oils on the C38 steel surface obeyed the Langmuir adsorption isotherm. This inhibitor formulation formed a thick film that plays a barrier layer on the iron surface to minimize the contact area with corrosive solution and hinder metal oxidation.

Table 1 Insight into the components and efficiency of the tested Natural oils

S. No	Plant name / Parts	Medium	Major Components	% Efficiency	Reference
1	Eucalyptus / Natural oil	1 M HCl		72% at 3 mL/L	9
2	*Eucalyptus globules*/ Essential oil	0.5M H_2SO_4	Pentadecanoic acid (01.90%) Palmitic acid (36.00 %) Palmitoleic acid (07.30%)	81% at 6g/L	10

			Margaric acid (00.70%) Heptadecenoic acid (01.00%) Stearic acid (03.30%) Oleic acid (27.20 %) Linoleic acid (19.30%)		
3	Artemisia herba alba/ Essential oil	0.5M H_2SO_4	chrysanthenone (30.6%) and camphor (24.4%).	74% at 1 g/L.	11
4	*Salvia aucheri mesatlantica/* Essential oil of aerial parts	0.5M H_2SO_4	camphor (49.59%)	86.12% at 2 g/L	12
5	*Argan oil/* Kernel (AKE) & Cosmetic argan oil (CAO)	1M HCl	Palmitic acid (13.8 %), Oleic acid (46.3 %), Linoleic acid (32.3 %), Schottenol (48.4 %); Spinasterol (39.1 %) and γ-tocopherol (86.9 %).	97% at 1g/L of AKE and 91% at 6g/L of CAO	13
6	carob / seed oil	1M HCl	linoleic acid (45.05%), oleic acid (33.66%), palmitic acid (14.84%), and stearic acid (3.50%).	86.7% at 0.5 g/L	14
7	*Opuntia ficus indica* / seed oil		oleic acid (18:1,20%) linoleic (18:2,61%) acid, palmitic acid (16:0,13%) stearic (18:0,4%) acid		15
8	*Mentha spicata L/* Aerial parts	1M HCl	Carvone (29.00%) and Trans carveol (14.00%)	97% at 2.00 g/l	16

Aqueous extracts

A.Y. El-Etre et al., 2000 proved that natural honey exhibited a very good performance as inhibitor for steel corrosion in high saline water [17] on the corrosion of C-steel. The inhibition efficiency increased with an increase in natural honey concentration. The inhibition efficiency was found to be dependent on immersion time due to the growth of fungi in the medium. The adsorption of natural honey on the C-steel was found to follow the Langmuir adsorption isotherm

The inhibitive action of the aqueous extract of the root of shirsh el zallouh [18] (*Ferula harmonis*) toward the corrosion of C-steel in HCl solution was investigated**.** The inhibition efficiency was measured using weight loss and potentiostatic polarization techniques. The electrochemical behavior of the extract was investigated using cyclic voltammetry. It was found that the addition of the extract reduces the corrosion rate of C-steel. The inhibition efficiency increases with increasing extract concentration. The adsorption of the extract components on the C-steel surface follows Langmuir adsorption isotherm. The inhibition efficiency decreases as the temperature is increased. The presence of extract increases the activation energy of the corrosion process of C-steel. The principal component is found to be ferunitol benzoate, which, according to the authors was one of the main compounds instrumental for minimizing corrosion loss

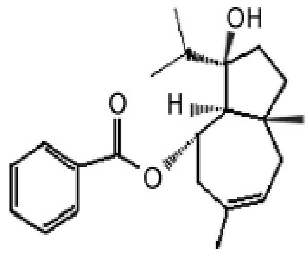

Figure 1 Structure of Ferunitol Benzoate

Abbouda et al., 2009 investigated the effect of extract of brown alga *Bifurcaria bifurcata* (Bb) [19] on the corrosion of steel in 1M HCl solution using weight loss, potentiodynamic, and polarization resistance measurements. Experimental data revealed that Bb extract acted as an inhibitor in the acid environment. The extract was a mixed-type inhibitor, predominating as an anodic inhibitor at higher concentration. It was found that the inhibition efficiency increased with an increase in Bb extract concentration. The process of inhibition was attributed to the adsorption of the extract molecules, the precipitation of Fe-chelates, and/or formation of complex at the electrode surface.

In a similar case, aqueous extracts of fruit peels namely mango, orange, passion fruit and cashew peels [20]were tested against corrosion of carbon steel in a 1M HCl solution using electrochemical impedance spectroscopy, potentiodynamic polarization curves, weight loss measurements and surface analysis. The inhibition efficiency increased with increasing extract concentration and decreased with temperature. The adsorption of components of the fruit peel extracts on the surface of the carbon steel followed Langmuir adsorption isotherm.

Crushed dried black pepper seeds [21] extracted in boiled water and its isolated piperine were utilized as a corrosion inhibitor for C38 steel in 1 M HCl solution using weight loss method. Results obtained from weight loss measurements indicate that the black pepper extract exhibited an efficiency exceeding 95% at 2g/L. The piperine isolated from the black pepper seeds afforded an efficiency of 99 % at 10^{-3} M. The inhibitors were found to be adsorbed onto the steel surface by the assumptions of Langmuir adsorption isotherm

Juniper Oxycedrus extract (JOE) [22] was investigated against corrosion of carbon steel in a 1.0 M HCl solution using electrochemical impedance spectroscopy, potentiodynamic polarization curves and weight loss measurements. The results indicated that the inhibition efficiency increased with change in concentration and temperature. JOE extract behaved as a mixed-type inhibitor as observed from Impedance studies. The adsorption of Juniper Oxycedrus Extract on the surface of the carbon steel followed Langmuir adsorption isotherm.

Anemone coronaria extract (ACE) [23] was investigated for its anti corrosion property on carbon steel in molar hydrochloric acid using weight loss method, potentiodynamic porarization curve and electrochemical impedance spectroscopy (EIS) measurements. Potentiodynamic polarization measurements studies reflect that ACE act essentially as cathodic-type inhibitor for steel in 1.0 M HCl. The inhibition efficiency increased with increasing concentration to attain a value of 90.07% at 2 g/L. Adsorption of ACE on the steel surface obeyed Langmuir adsorption isotherm**.**

The effect of Argan plant extract (APE) [24] on the corrosion of the steel in hydrochloric acid medium was studied using gravimetric, electrochemical polarization and impedance spectroscopy (EIS) measurements. Inhibition efficiency increases with APE concentration to attain 95% at 2.5 g/L. The authors note good agreement between gravimetric and electrochemical methods (potentiodynamic polarization and EIS). Polarization measurements also demonstrated the mixed nature of the inhibitor.

The corrosion inhibition of low carbon steel in 1 M HCl solution with different concentrations of *Schinopsis lorentzi`s* extract, [25] was studied using Tafel extrapolation, linear polarization and electrochemical impedance spectroscopy (EIS). It was found that *Schinopsis lorentzii* extract acted as mixed type inhibitor and inhibition efficiency increased with the increase of extract concentration. The adsorption of the molecules of the extract on the low carbon steel surface was in accordance with the Temkin adsorption isotherm. The results showed that *Schinopsis lorentzii* extract could serve as a corrosion inhibitor of the low carbon steel in hydrochloric acid environment.

The adsorption and corrosion inhibition of *Osmanthus fragran* leaves extract (OFLE) [26] on C-steel in hydrochloric acid was investigated by potentiodynamic polarisation, electrochemical impedance spectroscopy (EIS), atomic force microscopy (AFM), Fourier transform infrared spectroscopy (FTIR) and quantum chemical calculations. OFLE acted as a highly efficient mixed type inhibitor. The adsorption of OFLE on the C-steel surface obeyed Langmuir adsorption isotherm. The calculated adsorption thermodynamic parameters indicated that the adsorption was a spontaneous, exothermic process accompanied by an increase in entropy.

The inhibitive action of an ethanol extract of the leaves of *Pachycormus discolor (EEPD)* [27] on the corrosion of carbon steel in 1M HCl at different temperatures were analysed using gravimetric method and electrochemical tests. The inhibition of EEPD was performed via adsorption of the extract species on carbon steel surface. The ethanol extract was found to obey Langmuir adsorption isotherm. Potentiodynamic polarization results indicated that the ethanol extract acted as mixed type inhibitor. The results revealed that the inhibition efficiency (IE) of EEPD increased with increasing concentration. The IE was found to increase with temperature with an efficiency of 94.52% IE at 25°C and 97.89% at 75°C.

The inhibitive action of extract of curry leaves (*Murraya koenigii*) [28] on carbon steel in 1N HCl studied using weight loss, gasometric studies and electrochemical polarization and AC impedance measurements indicated that the extract afforded a maximum inhibition efficiency of 84.6% at an optimum concentration (4% in v/v of the extract) .Potentiodynamic polarization studies indicated that the studied curry leaves extract acted as a mixed type inhibitor. *Prunus cerasus* juice [29] acted as an efficient inhibitor for Carbon steel in HCl solution. The inhibition efficiency increased with an increase in inhibitor concentration. The inhibition was attributed to adsorption of the inhibitor on the steel surface.

Sesbania sesban extract (SSE) [30] pomegranate shells extract [31] *Brugmansia suaveolens* (BS) and *Cassia roxburghii* (CR) [32] were tried as corrosion inhibitors for carbon steel in 1M HCl solution by potentiodynamic polarization and weight loss techniques. The corrosion inhibition efficiency was found to increase with all the investigated inhibitors. The polarization studies showed that all the extracts acted as mixed type inhibitors. The results showed that the adsorption of the extracts on the carbon steel surface obeyed Langmuir isotherm. SSE was found to afford a maximum efficiency of 91.08% with 2.00 g/l. While Corrosion inhibition efficiency of SSE increased as the temperature increased, the IE for others decreased with increase in temperature. BS afforded a maximum efficiency of 94.69% and 94.69% for CR.

Methanolic extract of *Ficus abutilifolia* (FA) was applied as a corrosion inhibitor for oil well tubular steel (N-80 steel) in 15% Hydrochloric acid pickling solution [33] and its efficiency was compared with that of Propargyl Alcohol. Optimum inhibition efficiency for the tubular steel in the presence of *Ficus abutilifolia* was 59.12% at 30°C, 55.06% at 60°C while those for Propargyl Alcohol were 96.79% at 30°C and 90.98% at 105°C. The inhibition efficiencies of the inhibitors (FA and PA) increased with increase in concentration and decreased with increase in temperature and followed the trend: PA>FA. The authors stated that the adsorbed species formed a insoluble complex with the metal thereby minimizing corrosion.

The effect of extracts of Chamomile (*Chamaemelum mixtum* L.), [34] Halfabar (*Cymbopogon proximus*), Black cumin (*Nigella sativa* L.), and Kidney bean (*Phaseolus vulgaris* L.) plants on the corrosion of steel in aqueous 1 M sulphuric acid were investigated by electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization techniques. EIS measurements showed that the dissolution process of steel occurs under activation control. Potentiodynamic polarization curves indicated that the plant extracts behave as mixed-type inhibitors. Inhibition was found to increase with increasing concentration of the plant extract up to a critical concentration. The investigators reflect that the inhibitive actions of plant extracts could be due to the adsorption of stable complex at the steel surface.

The inhibitive effect of lupine (*Lupinous albus* L.) [35] extract on the corrosion of steel in aqueous solution of 1 M sulphuric and 2 M hydrochloric acid was investigated by potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) techniques. Potentiodynamic polarization curves indicated that the lupine extract acted as a mixed-type inhibitor. EIS measurements showed that the dissolution process is under activation control. The extract was found to be more effective in case of hydrochloric acid.

Oguzie et al.,2010 reported the inhibition of low-carbon-steel corrosion in 1M HCl and 0.5M H_2SO_4 by extracts of *Dacryodis edulis* (DE) [36] using gravimetric and electrochemical techniques. DE extract was found to inhibit the uniform and localized corrosion of carbon steel in the acidic media, affecting both the cathodic and anodic reactions. The corrosion process was inhibited by adsorption of the extracted organic matter onto the steel surface.

Tests on *Chenopodium ambrosioides* leaves extract [37] as a carbon steel corrosion inhibitor in 0.5 M sulfuric acid indicated that inhibition efficiency of the inhibitor increased with temperature, decreased with the acid concentration and attained a maximum value after 12 hours of exposure .The authors contemplated that the inhibitory effect could be due to the presence of nitrates on this extract.

The inhibition potential of lignin extract of sun flower [38] was investigated by evaluating the corrosion behaviour of medium carbon low alloy steel immersed in 1M H_2SO_4 solution containing various concentration of the extract. Mass loss, corrosion rate, and adsorption characterization were utilized to evaluate the corrosion inhibition and adsorption properties of the extract. The results revealed that the lignin extract is an efficient inhibitor of corrosion in mild steel immersed in 1M H_2SO_4. The corrosion rates were observed to decrease with increase in concentration of lignin extract but increase with temperature. The activation energies and the negative free energy of adsorption obtained from the adsorption studies indicate that the lignin extract is physically adsorbed on the surface of the steel and that the adsorption is strong, spontaneous and fit excellently with the assumptions of the Langmuir adsorption isotherm.

The inhibition effect of Ginkgo leaves extract (GLE) [39] on the corrosion of cold rolled steel (CRS) in 1.0–5.0 M HCl and 0.5–2.5 M H_2SO_4 solutions was investigated by weight loss, Potentiodynamic polarization curves, electrochemical impedance spectroscopy (EIS) and scanning electron microscopy (SEM) methods. The results show that GLE is a good inhibitor, and exhibits more efficiency in 1.0 M HCl than 0.5 M H_2SO_4. The adsorption of GLE on CRS surface obeyed Langmuir adsorption isotherm. GLE acted as a mixed-type inhibitor in 1.0 M HCl, while a cathodic inhibitor in 0.5 M H_2SO_4.The maximum IE values are 94.8% (1.0 M HCl) and 82.0% (0.5 M H_2SO_4) at 100 mg l_1, and gw values are higher than 90% and 80% at 30 in HCl and 50 mg l_1 in H_2SO_4 solutions, respectively, which indicates that GLE acts as a good inhibitor for steel in both acids.

The inhibitive effect of water and alcoholic extracts of *Medicago Sative (MS)* [40] on the corrosion of steel in 2.0M H_2SO_4 containing 10% EtOH has been studied using chemical (weight-loss(ML), hydrogen evolution(HE)), electrochemical (potentiodynamic polarization (PDP) and impedance spectroscopy (EIS)) techniques. The results showed that the inhibition efficiency increased with the increase of *Medicago Sative (MS)* concentration. The water and alcholic extracts of *MS* plant acted as mixed type inhibitors with nearly the same efficiency.

Corrosion inhibition of steel in sulphuric acid by aqueous extract of Ajowan (*carom*) seeds [41] has been studied using chemical (HE and ML) and electrochemical (EIS and PDP) measurements at 30^{0}C**.** The results indicated that Ajowan extract inhibit the corrosion process in 2.0M H_2SO_4 and the inhibition efficiency increased with increase of inhibitor concentration. Impedance studies showed that Ajowan seeds act as mixed type inhibitor. Adsorption process of Ajowan molecules on steel surface obeyed Freundlich adsorption isotherm.

Marisela Belloa et al., 2010 investigated the effect of physically and chemically modified cassava starch [42] as corrosion inhibitors for carbon steel under alkaline conditions in 200mgL−1 NaCl solutions. Two species were tested: an activated starch (AS) and a carboxymethylated starch (CMS) with two different degrees of substitution (DS). The inhibitive properties were studied by means of electrochemical impedance spectroscopy. It was found that modified starches have corrosion inhibitive properties and that their protection level depends on the type and amount of active groups present in the molecules. From the results, it was observed that AS provided better inhibition efficiency than CMS. This behavior could be attributed to the strong ionic interaction between AS and ferrous cations, which was confirmed by the electrostatic potential mapping of the monomeric units. Atomic force microscopy studies reflected that a densification of the inhibitive layer was responsible for the higher protection level afforded by AS.

The inhibition of steel corrosion in hydrochloric acid and sodium chloride solutions by *Nicotiana* leaves extract [43] was investigated by potentiodynamic polarization and electrochemical impedance spectroscopy measurements. Polarization curves showed that the extract behaves as a mixed type inhibitor in acidic medium, while it acts as anodic type in neutral medium. Impedance measurements indicated that the size of the semicircles obtained increased with increasing the concentration of the extract. *Nicotiana* leaves extract was found to be more effective in controlling corrosion of steel in acidic solution than in neutral one.

The Inhibition efficiency [IE] of an aqueous extract of *Eclipta alba* leaves [44] in controlling corrosion of carbon steel in sea water was evaluated by weight loss method. The weight loss study revealed that the formulation consisting of 6mL of EAE (*Eclipta alba* extract) and 25 ppm of Zn^{2+} has 92% inhibition efficiency in controlling corrosion of carbon steel in sea water. Polarization study reveals that EAE and Zn^{2+} system functions as mixed type inhibitor.

The study of corrosion inhibition of AISI 1030 steel in a chloride environment with water hyacinth extract [45] as inhibitor was carried out. Samples of AISI 1030 steel were subjected to sea – water environment with the inhibitor at varied concentrations for an exposure period of forty – five days. The result showed that as the concentration of the inhibitor increased, the severity of corrosion reduced on the AISI 1030 steel. It was observed that the steel sample with 20 ml of 20 g of the inhibitor afforded a highest inhibition efficiency of 89.63 % in the forty – five days exposure period.

The effectiveness of alcoholic Mentha extracts - *Mentha spicata L., Mentha x gentilis L., Mentha crispa L., Mentha piperita L.*, and *Mentha x piperita L.* to inhibit the corrosion of low-carbon steel in aqueous acid solution was tested .The protection efficiency afforded by the extracts are as depicted below for two drops of extracts at an immersion time of 2h. According to the authors, the high efficiency of M.crispa extract compared to other mentha species could be due to the presence of the phytochemical constituent Carvone in it.

Table 2 Natural products tested as corrosion inhibitors and the phytochemicals responsible for inhibition

S.No	Plant name & Reference	Steel type / Medium	Techniques Utilised			Adsorption Isotherm	Phytochemicals responsible for inhibition
			Mass Loss	Electro chemical	Surface analysis		
1.	**Ajowan** (*carom*) seeds	Steel/2.0M H_2SO_4	✓	✓		Freundlich	Thymol (39.36%), γ-Terpinene(30.97%), *p*-Cymene(19.47%), β-Pinene(5.45%),α-Pinene(1.48%) and Limonen

2.	alcoholic extracts of ***Medicago Sative***	Steel/2.0M H_2SO_4	✓	✓	SEM	Langmuir	
3.	alkaloids extract from *Oxandra asbeckii* plant	C38 steel/1 M HCl	✓	✓	Raman	Langmuir	
4.	*Annona squamosa*	C38 steel/1 M HCl		✓		Langmuir	alkaloids- liriodenine and oxoanalobine
5.	aqueous extracts of mango, orange, passion fruit and cashew peels	carbon steel/1M HCl	✓	✓	✓	Langmuir	
6.	*Alkaloid extract from Isertia coccinea*	C38 steel/ 1 M HCl	✓	✓		Langmuir	
7.	Argan plant extract	steel /1M HCl	✓	✓		-	
8.	*Artemisia herba alba*	Steel/0.5 M H_2SO_4	✓	✓		-	chrysanthenone (30.6%) and camphor (24.4%).
9.	*Bifurcaria bifurcata*	Carbon steel/1M HCl	✓	✓	UV-visible	-	carotenes, chlorophylls, and xanthophylls), fatty acids, phlorotannins, sterols, diterpenes.
10	cassava starch	carbon steel/200mgL−1 NaCl		✓			
11	*Chamaemelum mixtum* L, *Cymbopogon proximus*, *Nigella sativa* L, *Phaseolus vulgaris* L	Steel/1 M H_2SO_4		✓			
12	*Dacryodis edulis*	low-carbon-stee/1 M HCl and 0.5 M H_2SO_4	✓	✓			Ascorbic acid Alkaloid, β-Caryophyllen
13	*Eclipta alba* leaves	carbon steel /sea water	✓	✓	FTIR SEM		Wedelolactone
14	*Eucalyptus globules*	C 38 Steel /0.5M H_2SO_4	✓	✓		Langmuir	

15	*Ferula harmonis*	C-steel/1 M HCl	✓	✓		Langmuir	Sesquiterpene alcohol, jaeschkeanadiol (ferutinol). 30% *p*-hydroxybenzoate (ferutinine). aryl esters of jaeschkeanadiol epoxyjaeschkeanadiol, bisabolol,
16	fruit peels	carbon steel/1 M HCl	✓	✓	surface analysis.	Langmuir	
17	Ginkgo leaves extract	cold rolled steel/1.0–5.0 M HCl and 0.5–2.5 M H_2SO_4	✓	✓	SEM	Langmuir	
18	lignin extract of sun flower	carbon low alloy steel/1M H_2SO_4	✓			Langmuir	
19	*Lupinous albus L*	Steel/1 M H_2SO_4 and 2M HCl		✓		-	
20	mangrove tannins	Steel/3.5% NaCl		✓			
21	mimosa tannin	low carbon steel/ H_2SO_4	✓				
22	natural oil extracted from Eucalyptus	Steel/1M HCl	✓	✓			
23	*Nicotiana* leaves extract	Steel/ HCl		✓			
24	*Osmanthus fragran* leaves	C-steel/1M HCl		✓	AFM FTIR quantum chemical	Langmuir	
25	*Pachycormus discolor*	carbon steel / 1M HCl	✓	✓		Langmuir	
26	*Palicourea guianensis*	C38 steel/1 M HCl		✓		Langmuir	
27	*Prunus cerasus* juice	Steel/ HCl		✓		-	
28	*Salvia aucheri mesatlantica*	Steel/0.5 M H_2SO_4	✓	✓		Langmuir	camphor (49.59%)
29	*Schinopsis lorentzi*	low carbon steel/1 M HCl		✓			

Conclusions

Resources from nature are utilized effectively to control corrosion in various media and it may be applied in various industries since these natural resources happen to be an ecofriendly and environmentally viable option. Green corrosion inhibitors are nowadays taking its turn to produce a green environment and this review aptly suits for the present day scenario.

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