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Phytochemical and spectroanalytical characterizations of some plants extract as green corrosion inhibitors

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- ✓ *GC-MS.*

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Abstract

An attempt were made to characterize the stems of three plant extracts of *Acacia Sengalensis* (gum arabic) (AS), *Acacia tortillis* (umbrella thorn) (AT) and *Grewa venusta* (wild jute)(GV) plants by quantitative analyses (phytochemical screening), atomic absorption spectrometry (AAS), Fourier transforms infrared spectroscopy (FT-IR) and Gas chromatography-mass spectrometry (GC-MS) techniques. The plants extracts were extracted in 1.5 litres of 70% ethanol and 30% distilled water as solvent using maceration method. Atomic absorption spectrophotometry (AAS) was used to determine the concentration of metallic ions in the plants. FT-IR was carried out using model-8400S spectrophotometer Schmadzu machine. GC-MS model 2010 Plus Schmadzu was also used to analyze the extracts. The phytochemical screening revealed that the extracts of the plants contain tannins, alkaloids, flavonoids, saponins, glycosides and volatile oils in varying amounts. Equally, the results of AAS revealed the presence of metallic elements of Ca, Mg, Cr, Mn, Co and Zn in the extracts of the plants. The FT-IR and GC-MS analyses revealed the presence of hydroxyl (OH), amino (NH), acetylene (≡CH), aliphatic (methyl and methylene (CH_3, CH_2)), aromatic compounds such as methyl ester ($C_{19}H_{36}O_2$), 1,2-Benzenediol ($C_6H_6O_2$) and 3-tert-butylsulfanyl-4 ($C_9H_{10}F_6N_2S$). Accordingly, the presence of phyto-constituents most especially those containing heteroatoms such as O, N, S and aromatic functional groups that have been found to be present in the plant extracts are indication of their potentials for use in the formulation of organic inhibitors for materials protection.

1. Introduction

Most of the synthetic compounds that were used as corrosion inhibitors even though have good anti-corrosion properties in most cases are highly toxic to both human beings and the environment. The synthetic chemical based inhibitors can cause temporary or permanent damage to organ systems such as kidney or liver, or disturb the biochemical processes in human beings [1]. The toxicity may manifest either during the synthesis of the compound or during its applications. Thus, the development of novel and nontoxic corrosion inhibitors from many parts of low-cost natural substances has been regarded as an economic, strategic, and environmentally plausible route. The discovery of plant products as environmentally friendly corrosion inhibitors are a fundamental field of study. The electronic and molecular structures in plant products resemble to those of usual inhibitor molecules [2-7].

Acacia sengalensis (AS) (gum Arabic) tree is a small deciduous acacia tree known by the common names Rudraksha, Gum Acacia, Gum Arabic Tree, or Gum Senegal Tree in English. It belongs to leguminosae family. It is native to semi-desert regions of sub- Saharan Africa as well as in Asia. It produces gum Arabic, which is used as a food additive in crafts and as a cosmetic. While the second plant is *Acacia tortilis (AT)* is known as Umbrella thorn, Israeli Babool and belongs to leguminosae family. It is found in the northern part of the Nigeria, savanna and Sahel of Africa and *Grewa venusta* (wild jute) *(GV)*, tree is a shrub that grows up to 10.5 m tall and is called wild jute in English and belong to tiliaceae family [8].

Extracts of plant materials constitute a wide variety of organic compounds containing atoms such as P, N, S, O. These atoms coordinate with the corroding metal atom (ions) resulting in the formation of protective films on surface of the corroding metals. Corrosion inhibitors of plants/extracts origin are termed organic inhibitors. Organic inhibitors, usually designated as film-forming, protect the metal by forming a hydrophobic film on the metal surface and believed to inhibit corrosion by adsorption [9]. It is universally accepted that the organic molecule inhibits corrosion by adsorbing at the metal-solution interface. Most common types are long chain (C_{18}) hydrogen and nitrogen containing compounds. The most common types of organic inhibitors as observed by [10] are:
(1) Monoamine: Primary amine, RNH_2, Secondary amine, R_2NH, Tertiary amine, $R\text{-}N(CH_3)_2$.

(2) Diamines: $R\text{-}NHCH_2CH_2CH_2NH_2$

(3) Amides: $R\text{-}CONH_2$

(4) Polyethoxylated compounds: Amines

Organic inhibitors react by adsorption on metallic surface. Cationic inhibitors, like amines, or anionic inhibitors, sulphates are preferentially adsorbed depending on the charge of the metal surface. The formation of a bond between the metal substrate and the organic inhibitor impedes the anodic and cathodic process and protects the metal surface through film formation. The formed film provides a barrier which keeps water away and thus prevents corrosion. THE hydrocarbon chain attracts the organic molecules and forms an oily layer which prevents corrosion by acting as a barrier against fluids. The following are the main features of corrosion inhibitions by organic inhibitors.

1. The polar nitrogen groups attached to a hydrocarbon chain donate electrons to the metal surface and form a strong chemi-adsorptive bond,
2. The strength of protection is dependent on this bond. The hydrocarbon portion of the inhibitor is oil soluble and it is water repellent and
3. The hydrocarbon chain orients towards the solution and forms a hydrophobic network (repels water from the metal surface). The water molecules are desorbed and replaced by organic molecules [11].

Generally the potential and ability of plants/extracts to be used as corrosion inhibitors depend on their phytochemical constituents, the types of bonds presence in the hydrocarbon molecules constituting the plants /extracts, the length of the hydrocarbon molecule and the presence of N, S, O and P bearing molecules. Over the years, plant extracts have been reported as good corrosion inhibitors; however, the characteristics of the constituents that provide the inhibitions are still subject of debate and an important research focus [12].
Hence, this work is aimed to characterize stems of three plants extracts of *Acacia sengalensis* (gum Arabic) *(AS)* tree, *Acacia tortillis* (umbrella thorn) *(AT)* tree and *Grewa venusta* (wild jute) *(GV)* tree by quantitative analysis, Atomic Absorption Spectrometry (AAS). Fourier transforms infrared spectroscopy (FT-IR) and Gas chromatography-mass spectrometry (GC-MS) techniques.

2. Experimental details

The major equipment used in the characterization of the plants extracts include Ethanol distillation unit, Atomic Absorption Spectrophotometer (AAS), complete units of Fourier Transforms Infrared Spectroscopy (FT-IR) and Gas Chromatography–Mass Spectrometer (GC-MS) machines.

2.1 *Materials and extraction of phytoconstituents of the plants*

Plants used for this study were collected from an uncultivated farmlands located in Zaria in the northern parts of Nigeria. All the three (3) plant samples were identified and collected by Herbarium staff from the Department of Biological Sciences, Ahmadu Bello University, Zaria. The plants stem were washed with water to remove dust particles and cut into small pieces. They were kept in an open place to dry at a temperature about 30˚C. The dried plants were then pulverized using mortar and pestle. About 900gm of powder of each sample stems was extracted in 1500 ml (1.5 litres) of 70% ethanol and 30% distilled water as solvent using Maceration Method at the Department of Pharmacognosy, Ahmadu Bello University, Zaria. The phytochemical screening was also done on the extracts.

2.2 *Preparation of powdered extracts and its characterization*

The concentrated solutions of the extracts were evaporated to solid residue using evaporating dish over water bath at temperature range of 100-120°C. The dried extracts were then scraped from the evaporator using a scraper to obtain powder. The dried powder extracts were then stored in air tight container and used for subsequent characterization. Atomic absorption spectrophotometry was used in the determination of the presence and concentration of metallic ions in the extracts of the stems of the plants. A known amount of the sample was placed in a dish and heated with Bunsen burner in a fume cupboard until there was no smoke being emitted. This was transferred to the desiccators to cool after which 0.1M HCl solution was added to the ash. The resulting solution was filtered and diluted appropriately. Suitable salts of the metals in questions were used to prepare standard solutions. Appropriate lamps were installed with corresponding standard solutions to produce calibration curves. The calibration curves were then used to determine the concentration of each element in the diluted solutions of the extracts. Fourier transforms infrared spectroscopic analysis was conducted using a-8400S spectrophotometer Schmadzu machine for the identification of chemical bonding and functional groups presence in the extracts. The spectra produced for each extracts were recorded and used in identifying the compounds and chemical functional groups presence in each extract using the standard library that accompanied the FTIR machine.

A gas chromatograph-mass spectrometer (GC-MS) model 2010 Plus Schmadzu was used for the analysis of the extracts of the stems of the plants. The machines is directly coupled to a QP 2010 Plus Auto-system XL equipped with two fused-silica capillary columns (60 m x 0.22 mm, film thickness 0.25 μm), Rtx-1 (polydimethylsiloxane) and Rtx-Wax (polyethylene glycol). GC conditions used include Ion source temperature: of 150 °C and energy ionization of 70 eV. The GC-MS mass spectra and data generated were analyzed and used to identify the compounds and chemical functional groups presence in each extract [13,14].

3. Results and Discussion

3.1 *Phytochemical analysis*

The phytochemical constituents of the extracts of the plants determined by analytical /quantitative methods are presented in table 1.Similar works based on the phytochemical of plant extracts had also been carried out [17].

3.2 *Atomic absorption spectrophotometer*

Table 2 gives the metallic elements present in the extracts of the plants determined using atomic absorption spectrophotometer (AAS) [15-17].

Table 1: The results of phytochemical screening of the plants (*AS, AT and GV)*

S/No	Plants	Alkaloids	Tannins	Saponins	Flavonoids	Glycosides	Volatile oil
1	A.S	1.43±0.32	15.25±0.11	3.67±0.33	0.00	0.65±0.12	0.65±0.24
2	A.T	1.12±0.39	13.45±0.34	3.33±0.21	0.98±0.33	0.45±0.11	0.86±0.56
3	G.V	1.21±0.45	14.65±0.52	2.99±0.87	0.96±0.59	0.43±10	0.77±0.21

Table 2: Metallic cations content of the extracts of the plants determined by AAS

Elements (mg/l)% / Extracts	Ca	Mg	Cr	Co	Mn	Pb	Cu	Zn
A.S	75	16	0.98	0.43	3.55	1.54	0.12	2.33
A.T	78	16.5	1.12	0.65	2.43	0.99	0.16	0.13
G.V	75	18	1.34	1.21	2.21	1.22	0.76	0.23

3.3 FT-IR Spectroscopy

FT-IR spectroscopy was used to determine the functional groups present in the plant extracts. The wavelength of many IR absorption bands are characteristics of specific types of chemical bonds and IR spectroscopy finds its greatest utility for qualitative analysis of organic and organometallic molecules. It was used to confirm the identity the functional groups that are present in the compounds and as a tool to determine the newly synthesized molecules [8-14]. Tables 3-8 show the FTIR absorption spectra and the corresponding band assignment of the chemical bonds and functional groups present in the extracts of the stems of the three plants; *AS, AT and GV*.

Table 3: Peaks and intensity for *AS* extract from reflectance FT-IR spectroscopy

S/No	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	439.78	15.454	58.329	846.78	339.48	133.023	83.628
2.	870.89	91.994	1.287	949.01	846.78	2.776	0.236
3.	1038.7	78.329	17.732	1178.55	949.01	11.683	7.484
4.	1420.62	87.551	5.843	1560.46	1178.55	15.024	4.29
5.	1648.23	82.784	10.783	1866.19	1560.46	11.901	4.226
6.	2141.06	94.861	1.869	2347.45	1952.99	7.944	2.297
7.	2518.15	94.97	0.344	2568.3	244.82	2.63	0.097
8.	2968.55	78.611	8.252	3034.13	2568.3	24.457	3.592
9.	3400.62	47.027	43.336	3797.96	3035.09	131.815	88.477

Table 4: Prominent peaks obtained from reflectance FT-IR spectroscopy for *AS extract*

Frequency (cm^{-1})	Band assignment
439.78	-
870.89	$(CH_2) > 3$
1038.7	R–CH=CH–R
1420.62	$C=CH_2$ mono, 1,1
1648.23	C=C stretch
2141.06	–N=C=S
2518.15	C≡N
2968.55	CH_2
3400.62	Aliphatic primary amines have a weak NH_2

3.4. GC-Mass Spectroscopy

Mass spectroscopy is a powerful tool for the identification of materials. Mass spectrometry is a powerful analytical technique that is used to identify unknown compounds, to quantify known compounds and to elucidate the structure and chemical properties of molecules. The molecular weight of sample can be determined from MS Spectrum. Structural information can also be generated from certain types of mass spectrometers. The molecular weights of the compounds and the presence of isotopes can also be revealed [34-40]. Tables 9-14 also gave the chromatogram/mass spectra data and the corresponding structures of the compounds likely to be presence in the extracts of the stem of the three plants; *AS, AT and GV.*

From the phytochemical screening results in table 1, it can be seen that the extracts (stems) contain tannins, alkaloids, flavonoids, saponins, glycosides and volatile oil at certain volumes. With *AS* having the highest amount of alkaloids, tannins, saponin and glycoside followed by *GV* while *AT* has the least amounts of the four compounds. However, flavonoid is present in *AT* and *GV* only and absence in *AS*. These phytochemical constituents are important ingredients in the extracts that participate in the inhibition processes of metal protection as observed by [15,16].

Equally, some of these phytoconstituents contain heteroatoms such as O, N, S and aromatic functional groups which have played important roles in inhibition of plant extracts. Similar works were also reported for plant extracts [17,18]. The results also showed that plant extracts contain some metallic elements as revealed by the AAS analysis. A*T* haves the highest amount of calcium and cobalt. While *AS* has the highest amount of manganese, lead and Zinc. *GV* contains more chromium and copper as shown in Table 2. Some of the metallic elements are also known to play active role in inhibition process of materials as observed [19-25].

The FTIR spectra of *AS* extract in Table 3 show the peaks of 870, 1038. 1420.62, 1648.23, 2141.06, 2518.15, 2968.55 and 3400.62 frequencies which corresponded to the presence of $CH_2R–CH=CH–R$, $C=CH_2$ mono, 1,1, C=C stretch, −N=C=S, C≡N, $CH_{2,}$ NH_2 as functional groups are presented in Table 4. While those of AT have frequency bands in the region of 1019.41, 1109.11, 1229.66, 1395.54, 1646.30, 2118.87, 2845.1, 2962.76, and 3420.87 indicating the presence of C–O, C–H, C–O, $CH_{2,}$ C=O, NCS, N or O, methylene segments $(CH_2)n$ and (OH, NH, CH) functional groups are presented in Tables 5 and 6.

Table 5: Peaks and intensity for *AT* extract from reflectance FT-IR spectroscopy

S/No	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	445.57	16.765	51.707	952.87	339.48	198.489	115.419
2.	1019.41	58.694	21.197	1082.1	952.87	20.021	7.443
3.	1109.11	77.127	1.83	1168.9	1082.1	9.143	0.419
4.	1229.66	78.778	1.034	1279.81	1168.9	11.169	0.336
5.	1395.54	74.203	0.979	1418.69	1279.81	16.127	0.212
6.	1646.3	55.973	24.891	1877.76	1544.07	41.068	13.052
7.	2118.87	83.108	4.302	2350.34	1877.76	33.625	5.977
8.	2845.1	73.743	2.459	2877.89	2626.17	23.202	-1.151
9.	2962.76	64.43	5.069	3013.87	2877.89	22.896	2.188
10.	3420.87	21.978	53.435	3812.43	3014.84	309.077	208.17
11.	3959.03	83.998	0.006	4199.17	3957.1	17.89	-0.048
12.	4421.96	83.707	0.282	4480.79	4199.17	21.064	0.066

Table 6: Prominent peaks obtained from reflectance FT-IR spectroscopy for *AT extract*

Frequency (cm^{-1})	Band assignment
445.57	-
1019.41	C–O stretching
1109.11	δ(C–H)
1229.66	C–O stretching
1395.54	CH_2
1646.30	C=O stretching
2118.87	NCS
2845.1	C-H stretching, N or O atom
2962.76	$(CH_2)n$ chain, the $CH_{2,}$ methylene segments $(CH_2)n$
3420.87	Hydroxy (OH), Amino (NH) and Acetylene (CH) Groups
3959.03	-
4421.96	-

The various hydroxyl, oxygen atoms, aromatic rings and compounds that were present in the extracts acted as reaction center for adsorption process to take place hence bringing about inhibition of corrosion process. These characteristics have been reported as potential inhibitors for materials protection in some environments [26-29]. For GV extract the spectra are in the frequency bands range of 1026.16, 1419.66, 1650.16, 2150.7, 2520.08, 2844.13, 2958.9, 3398.69, 3398.69, 3875.12, and N–H$^+$ indicating the presence of C=S, Carbonate, Nitrate, Ammonium Compounds, NH_2, X≡Y and X≡Y≡Z, thio-phenol, N–H$^+$, C=NH$^+$, O=C– NH_2 and (OH, NH, ≡CH) are presented in Tables 7 and 8.

Table 7: Peaks and intensity for *GV* extract from reflectance FT-IR spectroscopy

S/No	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	448.46	13.124	54.212	951.9	339.48	207.807	117.467
2.	1026.16	48.817	28.859	1189.15	952.87	41.043	14.875
3.	1419.66	67.589	7.969	1557.57	1190.12	50.749	6.612
4.	1650.16	61.623	14.751	1867.16	1557.57	41.671	7.322
5.	2150.7	77.719	2.887	2347.45	1873.91	48.916	4.472
6.	2520.08	77.587	0.64	2573.13	2437.14	14.67	0.24
7.	2844.13	63.624	2.282	28721	2637.74	33.282	-1.912
8.	2958.9	54.51	8.445	3033.16	28721	37.178	4.903
9.	3398.69	23.059	45.738	3805.68	3033.16	294.577	169.131
10.	3875.12	76.175	0.003	3878.98	3873.19	0.684	0
11.	4413.28	75.194	0.501	4487.54	4172.17	37.939	0.241

Table 8: Prominent peaks obtained from reflectance FT-IR spectroscopy for *GV extract*

Frequency (cm^{-1})	Band assignment
448.46	-
1026.16	(C=S) Compounds
1419.66	Carbonate, Nitrate, Ammonium Compounds:
1650.16	amine NH_2
2150.7	Triple Bonds and Cumulated Double Bonds (X≡Yand X≡Y≡Z)
2520.08	Thio-phenol
2844.13	Acidic Protons (N–H$^+$)
2958.9	Amines with > NH_2^+, >NH$^+$, and C=NH$^+$
3398.69	O=C– NH_2
3875.12	Hydroxyl (OH), Amino (NH), and Acetylene (≡CH) Groups
4413.28	

The chromatogram mass spectra data and the likely corresponding compounds present in the extract of the stem of *AS* are given in tables 9 and 10. Accordingly, the information from the GC-MS data in Table 9 shows that quantitatively, the *AS* stems extract contains: 18.52% of 2, 2-Norpinene, 23.74% of heptadiene followed by methyl ester; 17.69% as the major chemical constituents. In table 10, it can be seen that *AS* extract generally contain the following compounds and functional groups: Cyclohexene, 3, 7 dimethyl, 1-ethenyl-1-methyl-2, methyl ester and other phenolic compound: 2, 2-Norpinene, Heptadiene methyl hexofuranoside and methyl ester. These compounds and functional groups had been used as corrosion protection of materials in both acidic and alkaline environments [30-37].

Table 9: GC-MS data of *Acacia senegalensis* extract

					Peak Report HC			
Peak	R Time	I Time	F. Time	Area	Area %	Height	Height %	A/H
1.	9.471	9.425	9.525	149655	1.16	50286	1.16	2.98
2.	9.942	9.900	10.000	187609	1.45	67655	1.56	2.77
3.	10.210	10.158	10.283	423848	3.29	158441	3.66	2.68
4.	10.755	10.708	10.825	924529	7.17	337204	7.79	2.74
5.	11.313	11.258	11.375	550400	4.27	209953	4.85	2.62
6.	11.553	11.375	11.650	2388362	18.52	893753	20.65	2.67
7.	12822	12.775	12.908	3062007	23.74	1293754	29.90	2.37
8.	16.337	16.150	16.550	1902646	14.74	146573	3.39	12.98
9.	19.034	18.967	19.125	1027047	7.96	310804	7.18	3.30
10.	22.279	22.242	22.333	2280833	17.69	858842	19.85	2.66
				12896927	100.00	4327265	100.00	

Table 10: The chemical compounds identified in the ethanol distillate of *Acacia senegalensis (AS)* stem extract by GC-MS analysis

Peaks	Extract	Compounds Name	Molecular Formula	Molecular Weight g/mol
1	*Acacia Senegalensis (AS)*	Cyclohexene or 3-methyl-6-(1-methylethylidene)-	$C_{10}H_{16}$	136
2		6-Octen-1-ol, 3,7-dimethyl-, acetate	$C_{12}H_{22}O_2$	198
3		2,6-Octadien-1-ol, 3,7-dimethyl-, acetate,	$C_{12}H_{20}O_2$	196
4		Cyclohexane, 1-ethenyl-1-methyl-2	$C_{15}H_{24}$	204
5		Bicyclo 4,11,11-trimethyl-8-methylene-,[	$C_{15}H_{24}$	204
6		Bicyclo[3.1.1]hept-2-ene, 2, 2-Norpinene	$C_{15}H_{24}$	204
7		Cyclohexene, 1,5-Heptadiene,	$C_{15}H_{24}$	204
8		alpha-d-annofuranoside, methyl	$C_7H_{14}O_6$	194
9		Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	270
10		11-Octadecenoic acid, methyl ester	$C_{19}H_{36}O_2$	296

Tables 11 and 12 represent the GC-MS spectra data and the corresponding chemical compounds/functional groups found in *Acacia tortilis* stem extract with their retention indices, percentages relative peaks area, heights etc in table 11. The results revealed the presence of phenolic compounds, methyl, benzene and hydroxyl groups in the stem extract. Further analysis of the data shows that the extract contain 53.97% 1,2,3-Benzenetriol as the major compounds, followed by 4-O-Methyl mannose with 38.28% and 11,13-Tetradecadien-1-ol of 3.53% in table 12.

Table 11: GC–MS data of *Acacia tortilis with ethanolic* extract

					Peak Report HC			
Peak	R Time	L Time	F. Time	Area	Area %	Height	Height %	A/H
1.	9.874	9.783	10.067	610363	2.59	62370	3.87	9.79
2.	12.714	12.642	13.058	12730270	53.97	938320	58.19	13.57
3.	16.597	16.133	17.050	9028496	38.28	392154	24.32	23.02
4.	20.255	20.175	20.383	386929	1.64	94997	5.89	4.07
5.	23.148	23.042	23.333	831638	3.53	124618	7.73	6.67
6.				23587696	100.00	1612459	100.00	

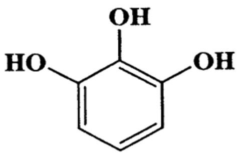
Table 12: The chemical compounds identified in the ethanol distillate of *Acacia tortilis (AT)* stem extract by GC-MS analysis

Peaks	Extract	Compounds Name	Mol. Formular	Mol. Weight (g/mol)
1	*Acacia Tortilis (AT)*	1,2-Benzenediol, o-Dioxybenzene	$C_6H_6O_2$	110
2		1,2,3-Benzenetriol, Fourrine 85	$C_6H_6O_3$	126
3		4-O-Methyl mannose	$C_7H_{14}O_6$	194
4		Octadecanoic acid	$C_{18}H_{36}O_2$	284
5		11,13-Tetradecadien-1-ol	$C_{14}H_{26}O$	210

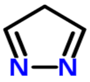
Examination and analysis of GC-MS spectra and data of grewa venusta presented in tables 13 and 14 revealed the presence of phenolic, tannins, alkaloids and the aromatic compounds. With 2-Pentanone at 22.84 %, 1,2,3-Propanetriol1 at 10.19 %, 4H-Pyrazole at 12.96%16, Dodecanoic acid (30.16%), Stearic acid (10.24%) and 1,9-Nonanediol (5.95%). Similar analysis had carried out for corrosion inhibition of materials in environments [38-42].

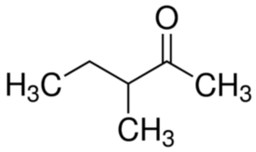
Table 13: GC–MS data of *Grewa venusta* ethanolic extract

					Peak Report HC			
Peak	R Time	I Time	F. Time	Area	Area %	Height	Height %	A/H
1.	5.119	5.083	5.217	134883	2.57	53829	6.23	2.51
2.	8.068	8.017	8.208	1201168	22.84	262173	30.34	4.58
3.	9.952	9.892	10.225	536040	10.19	54313	6.29	9.87
4.	13.182	13.067	13.458	681543	12.96	48799	5.65	13.97
5.	15.736	15.60	16.067	1585941	30.16	156761	18.14	10.12
6.	19.039	18.983	19.125	165650	3.15	54801	6.34	3.02
7.	20.250	20.167	20375	538550	10.24	130800	15.14	4.12
8.	22.526	22.475	22.592	101864	1.94	37913	4.39	2.69
9.	23.142	23.058	23.200	312818	5.95	64587	7.48	4.84
				5258457	100.00	863976	100.00	

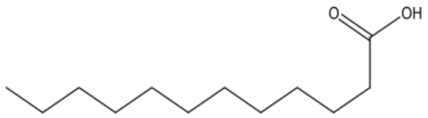


1,2,3-Benzenetriol





2-Pentanone



Dodecanoic acid

As the natural extract contains infinite components at various contents and the majority contains one and/or more than function group as ketone, alcohol, acid, aldehyde…, the inhibitory effect is generally interpreted by the intermolecular synergistic effect of several molecules [43-45].

Table 14: The chemical compounds identified in the ethanol distillate of *Grewa venusta (GV))* extract by GC-MS analysis

Peaks	Extract	Compounds Name	Molecular Formula	Molecular Weight g/mol
1	*Grewa Venusta (GV)*	2-Pentanone, 4-methoxy-4-methyl	$C_7H_{14}O_2$	130
2		4H-Pyran-4-one, 2,3-dihydro-3,	$C_6H_8O_4$	144
3		1,2,3-Propanetriol, mono acetate	$C_5H_{10}O_4$	134
4		4H-Pyrazole, 3-tert-butylsulfanyl-4	$C_9H_{10}F_6N_2S$	292
5		Dodecanoic acid, 3-hydroxy-	$C_{12}H_{24}O_3$	216
6		Hexadecanoic acid, 15-methyl-,	$C_{18}H_{36}O_2$	284
7		Octadecanoic acid, Stearic acid	$C_{18}H_{36}O_2$	284
8		Cyclohexanol, 3,5-dimethyl	$C_8H_{16}O$	128
9		1,9-Nonanediol, dimethanesulfonate	$C_{11}H_{24}O_6S_2$	316

Conclusions

Over the years plant extracts have been reported as good corrosion inhibitors; however, the characteristics of the constituents/extracts that provide the inhibition are still subject of debate and an important research focus. The various hydroxyl, oxygen atoms, aromatic rings and compounds that are present in the extracts would act as reaction center for adsorption process to take place hence bringing about inhibition of corrosion process. Conclusively, the extracts of the stems of *AS, AT and GV* plants are found to contain many functional groups such as amino acids, carbonate, nitrate, methylene segments and hence can be consider as potentials materials for formulation of green corrosion inhibitors which can be proposed for metals, alloy and composite materials in environments such as acid, alkaline, seawater, soil and so on.

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References

1. Ostovari A., Hoseinieh S.M., Peikari M., Shadizadeh S. R., Hashemi S. J., *Corros Sci*. 51 (2009) 1935.
2. Raghavendra N., Ishwara B. J., *J Bio Tribo Corros.* 3 (2017) 3(12); 1.
3. Abiola O. K., Oforka N. C., Ebenso E. E., Nwinuka N. M., *Anti-Corros Methods & Mats.* 54 (2007) 219.
4. Ahamad I., Khan S., Ansari K. R., Quraishi M.A., *J Chem. Pharm Res.* 3 (2011) 703.
5. Oguzie E. E., *Port Electrochimica Acta* 26 (2008) 303.
6. Raghavendra N., Ishwara B. J., *Res Chem Intermed* 42 (2016) 6351.
7. Zucchi F., Omar I. H., *Surf Tech*. 24 (2008) 391.
8. Kubmarawa D., Ajoku G. A., Enwerem N. M., Okorie D.A., *Africa J of Biotechn*. 6 (2007) 1690.
9. Dourna A., Mokhtar A., Niyaz M. M., *The Electrochem Soci. Meeting*, (2006) 23.
10. Bouyanzer A., Hammouti B., Majidi L., Haloui B., *Portg. Electrochem. Acta*, 28 (2010) 165.
11. Talbot D., Talbot J., *CRC Press, Florida* 1998.
12. Ameer M. A., Fekry A. M., Ghoneim A.A., Attaby F. A., Inter J Electrochem Sci. 5 (2010) 1847.
13. Obi-Egbedi N. O., Essien K. E., Obot I. B., J Comput Method and Mole Design, 1 (2011) 26.

14. Lebrini M., Robert F., Roos C., Inter J Electrochem Sci. 5 (2010) 1698.
15. Ambrish Singh., Singh V. K., Quraishi M. A., Inter J Corros. 1 (2010) 10.
16. Asuke F., Yaro S. A., Oloche O. B., J Appld Sci Resch. 6 (2010) 1759.
17. Ayeni F. A., Victor A. S., Yaro S. A., Eurasian Chem Techno J. 9 (2007) 91.
18. Kamal C., Sethuraman M. G., Arabian J Chem. 5 (2012) 155.
19. Singh A., Ebenso E. E., Quraishi M. A., *Inter J Corros.* (2012) 897430.
20. Al-Turkustani A. M., Arab S. T., Al-Dahiri R. H., *Mod Appled Sci.*4 (2010) 105.
21. Raja P. B., Sethuraman M. G., *Mats Letts.* 62 (2008) 113.
22. Yan Li., Peng Z., Qiang L., Baorong H., *Appld Surf Sci.* 252 (2005) 1245.
23. Pandian Bothi Raja., Rahim Afidah Abdul., Osman Hasnah., Awang Khalijah., *Acta Phys. Chim. Sin*, 26 (2010) 2171.
24. Singh A., Ebenso E. E., Quraishi M. A., *Inter J Corros.* (2012) 897430.
25. Adesuyi A. O., Awosanya O. A., Adaramola F. B., Omeonu A. I., *Current Resch of J Bio Sci.* 4 (2012) 4.
26. Abu-Dalo M. A., Othman A. A., Al-Rawashdeh N. A. F., *Inter J Electrochem Sci.* 7 (2012) 9303.
27. Souza T. F., Magalhães M., Torres V. V., D'Elia E., *Inter J Electrochem Sci.* 10 (2015) 22.
28. Raghavendra N., Ishwara B. J., *J Bio Tribo Corros.* 2 (2016) 34.
29. Raja P. B., Sethuraman M. G., *Mats Letts.* 62 (2008) 113.
30. Arockia J. S., Susai Rajendran., Ganga V. S., John A. A., Narayanasamy B., *Port Electrochim Acta.* 27 (2009) 1.
31. Hosary A. A., Saleh R. M., Shams Eldin A. M., *Corros. Sci.*l. 12 (1972) 897.
32. Fouda A. S., Megahed H. E., Fouad N., Elbahrawi N. M., *J. Bio. Tribo. Corros.* 2 (2016) 6.
33. Martinez S., Stern I., *Appl Surf Sci.* 23 (2002) 83.
34. Kamal C., Sethuraman M. G., *Res Chem Intermed* 39 (2013) 3813.
35. Vinod Kumar K. P., Sankara N., Pillai M., Rexin T. G., *J Mater Sci* 46 (2011) 5208.
36. Al-Otaibi M. S., Al-Mayouf A. M., Khan M., Mousa A.A., Al- Mazroab S. A., Alkhathlan H. Z., *.Arabian J Chem.* 7 (2014) 340.
37. Okafor P. C., Ikpi M. E., Uwah I. E., Ebenso E. E., Ekpe U. J., Umoren S. A., *Corros Sci.* 50 (2008) 2310.
38. da Rocha J. C., Gomes J.A.C.P., D'Elia E., *Corros Sci.* 52 (2010) 2341.
39. Orubite K. O., Oforka N. C., *Mats Chem and Phy.* 70 (2001) 95.
40. Zakvi S. J., Mehta G. N., *J. Electrochem. Soc. Ind.* 37 (1988) 237.
41. Souza T. F., Magalhães M., Torres V. V., D'Elia E., *Int. J. Electrochem Sci.* 10 (2015) 22.
42. Mohd H. H., Mohammed J. K., *J Phy Sci.* 21 (2010) 1.
43. ElHajjaji F., Greche H., Taleb M., Chetouani A.,, Aouniti A., Hammouti B., *J. Mater. Environ. Sci.* 7 (2) (2016) 566-578.
44. Bouknana D., Hammouti B., Messali M., Aouniti A., Sbaa M., *Port. Electrochim. Acta*, 32 (2014) 1-19.
45. Ali A.I., Megahed H.E., El-Etre M.A., Ismail M.N., *J. Mater. Environ. Sci.* 5 (2014) 923-930

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