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Corrosion Inhibition of Gum Exudates from *Acacia malacocephala* and *Acacia drepanolobium* on Mild Steel in Acidic Media

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ABSTRACT: The objective of this study was to investigate the corrosion inhibiting properties of gum exudates from *Acacia malacocephala* and *Acacia drepanolobium* on mild steel exposed in acidic electrolyte under stationary conditions using electrochemical impedance spectroscopy and potentiodynamic polarization techniques. The experiments were conducted in 0.16 M H_2SO_4 electrolyte and the temperature of the electrolyte was varied from 303 K to 323 K without and with the corrosion inhibitors. For the systems at 303 K, inhibition efficiency of over 95% was observed with 600 ppm of gum exudates from *A. drepanolobium* and 400 ppm of gum exudates from *A. malacocephala*. When the temperature was increased to 313 K and 323 K, the inhibition efficiency of 600 ppm of gum exudates from *A. drepanolobium* dropped to 89%, while the inhibition efficiency of 400 ppm of *A. malacocephala* was reduced to 90%. Thus, temperature was found to have an adverse effect on the inhibition efficiency of the gum exudates. The obtained results indicate that gum exudates from *A. drepanolobium* and *A. malacocephala* are good corrosion inhibitors to mild steel under acidic media. Although *A. drepanolobium* and *A. malacocephala* are regarded as morphologically similar, the difference in the concentrations of the gum exudates required to achieve maximum corrosion inhibition is one of the justifications to retain them as two distinct species.

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Mild steel materials are widely used in different areas of construction. However, an electrochemical process known as corrosion challenges them. For iron-based materials, corrosion process result into the formation of rust, a substance that thermodynamically resembles iron ores. Corrosion process cause gradual degradation of the useful properties of metallic materials, including performance strength, which consequently causes harm to a range of structures such as bridges, buildings, automobiles and pipelines. As a result, a considerable amount of funds has to be set aside for maintenance and replacement (Revie and Uhlig, 2008). In the view of improving the life span of metallic materials, the best corrosion mitigation techniques are employed depending on the environment where the metallic substrates are used. While in some environments, proper design is more economical, in others the use of corrosion resistant alloys is the best choice. Modification of the metal surface (coating, galvanizing and electroplating) is the

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most common and a well-known method. Electrical control (anodic protection) and electrochemical technique (cathodic protection) are used for protecting buried and storage structures. However, one or more methods can be employed to maximize corrosion protection. This is why apart from anodic or cathodic protection in piping and storage systems, it is unavoidable to adjust pH, or to remove corrosive species or to use corrosion inhibitors in fluids that are directly in contact with the internal metallic structures. Inhibitors are substances used to reduce corrosion rate when added in small amount to a particular corrosive environment (Roberge, 2000). Some studies have reported that nearly every organic molecule containing a heteroatom such as nitrogen, sulfur, phosphorous or oxygen has momentary corrosion inhibition efficiency. These molecules function through multiple chemical or physical adsorptions onto metal surfaces (Philip *et al*., 2016; Demadis *et al*., 2006). The use of plant extracts and their modified products as corrosion inhibitors for metals exposed to corrosive environments has continued to receive considerations as a strategy to replace synthesized organic inhibitors. The interest on plant extracts may be attributed to their renewability and ecological benignity (Obot *et al*., 2011; [a]Buchweishaija, 2009). Gum exudates from several *Acacia* plant species have been reported to have corrosion inhibiting properties in different electrolytes ([b]Buchweishaija, 2009; Buchweishaija and Mhinzi, 2008). *Acacia* gum exudates are plant secondary products that contain nitrogen which occur in the form of amino groups (-NH_2) on the terminal amino acid residue of the protein and the peptide linkage (-NHCO-). Secondary products produced by secondary metabolic pathways in plants are regarded as non-essential for normal growth as well as development of the plant, but often confer benefits in defence mechanism or attraction of pollinators. The nitrogen content of the gums from *A. drepanolobium* and *A. malacocephala* species have been reported to be high, but the latter is reported to contain significantly higher amount than that of *A. drepanolobium* gum (Mhinzi, 2003; Mhinzi and Mrosso, 1995; Anderson *et al*., 1985). Although a number of synthetic and natural inhibitors have been investigated, they are still few compared to the wide range of corrosive environments. Therefore, the search for corrosion inhibitors that are environmentally friendly, cheaply and easily available is still of great importance. As currently reported in a review (Medupin *et al*., 2023), the use of naturally occurring materials from plants in corrosion control is thought to be one of the best options. Therefore, the objective of this study was to assess the corrosion inhibiting properties of gum exudates from *A. malacocephala* and *A. drepanolobium* in acidic media.

MATERIALS AND METHODS

Chemicals. H_2SO_4 (96%), CH_3OH (99.8%) and $(CH_3)_2CO$ (99.7%). These chemicals were purchased from Aldrich (UK) and were used as supplied. Aqueous solutions were prepared using distilled water.

The working electrode. The mild steel working electrode was made from mild steel sample collected from Dar es Salaam Water and Sewage Company (DAWASCO) Headquarters. The working electrode was fabricated to a circular disk of 109.5 mm diameter and thickness of 1.5 mm. The chemical composition of the working electrode used is presented in Table 1.

Table 1: The weight (%) elemental composition of the working electrode.

Element	C	Si	Mn	Al	Cr	Ni	V	Fe
Wt. %	0.172	0.020	0.443	<0.0005	0.210	0.071	<0.0005	98.31

Test electrolyte. The test electrolyte used was 0.160 M H_2SO_4.

Corrosion inhibitors. The corrosion inhibitors used in this study were gum exudates from *A. malacocephala* and *A. drepanolobium* sampled from central Tanzania, Singida region and used directly as they were sampled.

Test method and procedures. The electrochemical experiments were carried out in a 50 mL capacity double wall Pyrex glass container connected to a thermostat via rubber tubing to assist in controlling the temperature of the electrolyte. The three electrodes which are the working electrode, reference electrode and the counter electrode were inserted into the electrolyte and connected to a computer assisted Voltlab 80.In order to obtain identical surfaces for all electrochemical experiments, the working electrodes were polished and washed before performing electrochemical studies. Mild steel disk specimens were polished with silicon carbide sandpapers of increasing grits from 800 then 2400 and finally 4000; followed by fine polishing with diamond spray on microcloth polishing pad. Thereafter, the electrodes were rinsed with distilled water and degreased by sonication in acetone.

Test parameters. The parameters studied (detailed in Table 2) were the inhibitor concentration, temperature, and rotation speed.

Table 2: The studied test parameters

Parameter	**Value**
Inhibitor concentration (ppm)	
A. drepanolobium	0, 10, 25, 50, 100, 200, 300, 400, 500, 600, 700
A. malacocephala	0, 10, 25, 50, 100, 200, 300, 400, 500, 600
Temperature (K)	303, 313, 323

Electrochemical measurements. Electrochemical measurements were carried out using a mild steel working electrode. Ag/AgCl electrode was used as a reference electrode and platinum net was used as a counter electrode. The electrochemical impedance measurements were performed first, followed by potentiodynamic polarization measurements.

A computer aided Autolab PGSTAT20 Frequency Response Analyser (FRA) was used to measure electrochemical impedance. The observed data from the electrochemical impedance measurement were analyzed by fitting them to Equivalent Circuits (EC). The EC parameters were obtained by using a complex non-linear least square fitting programme, EQUIVCRT, developed by Bernard A. Boukamp, of the University of Twente, Netherlands.

Potentiodynamic polarization measurements were performed by a computer controlled PGSTAT20 potentiostat using the same cell set-up. Polarization measurements were performed on the specimens by sweeping the potential anodically at the rate of 1 mV/s in a range of 200 mV vs Ag/AgCl electrode, *i.e*., from 100 mV cathodic to the open circuit potential (OCP) up to 100 mV anodic to the OCP.

RESULTS AND DISCUSSION

Inhibitor concentration dependence: A good inhibitor provides highest corrosion protection when a very small amount is added into an operating environment of a metallic material. The minimum concentration of the inhibitor that provides maximum protection of a metal is referred to as its optimal concentration. It was necessary to search for the optimal concentration of the tested inhibitors because it is uneconomical to use more inhibitor than optimal concentration. In addition, usually very low concentration of the inhibitor in a system is required to avoid alteration of the physical qualities of the system. Some typical impedance plots in the Nyquist format recorded using mild steel working electrode exposed in 0.160 M H_2SO_4 in the absence and presence of various concentrations of gum exudates from *A. drepanolobium* and *A. malacocephala* species are presented in Figure 1 and Figure 2, respectively. To avoid overcrowded figures, some data are not included in the plots. As can be seen from these figures, the impedance plots contain semicircles characterized by single capacitive loop. The sizes of the semicircles increase with increase in inhibitor concentrations, indicating the charge transfer process at the metal/solution interfaces as the main controlling factor of corrosion of mild steel (Roberge, 2000).

From Figure 1 it can be seen that, 600 ppm of the gum exudates from *A. drepanolobium* gave the largest semicircle. Beyond 600 ppm no further significant increase in the size of the semicircle was observed, signifying that 600 ppm is the minimum concentration of this inhibitor giving maximum corrosion protection of mild steel in the test condition.

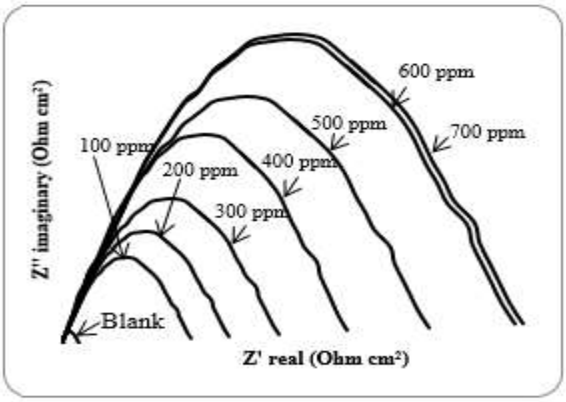

Fig 1: Impedance plots in Nyquist format for mild steel electrodes taken after 1 hour of exposure in 0.16 M H_2SO_4 solution in the absence and presence of varying concentrations of *A. drepanolobium* gum

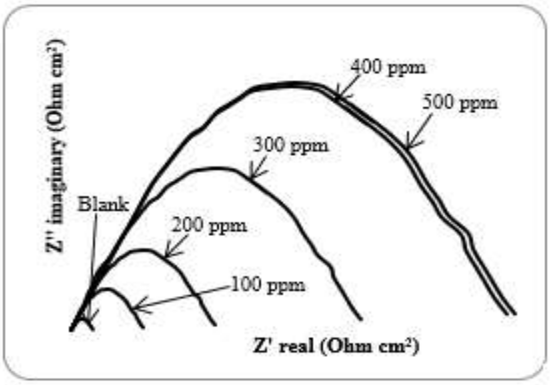

Fig 2: Impedance plots in Nyquist format for mild steel electrodes taken after 1 hour of exposure in 0.16 M H_2SO_4 solution in the absence and presence of varying concentrations of *A. malacocephala* gum

Similarly, as can be seen from Figure 2, the largest semicircle for gum exudates from *A. malacocephala* was obtained at a concentration of 400 ppm, beyond which no significant changes were observed. This suggests that 400 ppm of *A. malacocephala* gum is the optimum concentration. The differences in the optimum concentration of the inhibitors may be attributed to the differences in terms of the active constituents present in *A. malacocephala* and *A. drepanolobium* gum exudates.

The obtained impedance data were then analyzed by fitting them to equivalent circuit model using the Non-Linear Least Square Fitting Program to estimate equivalent circuit parameters which are charge transfer resistance (R_{ct}), constant phase element (Q), dimensionless value (n), and the double layer capacitance (C_{dl}). Other parameters are open circuit potential E_{ocp}, corrosion rate (R_{corr}) and inhibitor efficiency (I_{eff}) (Tables 3 and 4). From the modified Stern-Geary relation, corrosion current density values were estimated as equal to the reciprocal of charge transfer resistance.

$$i_{\mathrm{corr}} = R_{\mathrm{ct}}^{-1} \qquad (1)$$

The inhibition efficiency values were computed using the relation:

$$I_{\mathrm{eff}} = \frac{R\mathrm{corr}_{\mathrm{u}} - R\mathrm{corr}_{\mathrm{i}}}{R\mathrm{corr}_{\mathrm{u}}} \times 100 \qquad (2)$$

Where $R\mathrm{corr}_{\mathrm{u}}$ and $R\mathrm{corr}_{\mathrm{i}}$ correspond to uninhibited and inhibited current densities, respectively.

Table 3: Electrochemical parameters obtained from impedance measurements on mild steel electrodes after 1 hour of exposure in 0.16 M H_2SO_4 solutions in the absence and presence of varying concentrations of gum exudate from *A. drepanolobium*

C_{inh} (ppm)	E_{ocp} (mV vs Ag/AgCl)	R_{ct} (Ω cm²)	Q (μF cm²)	n	C_{dl} (μF cm²)	R_{corr} $(\mathrm{mm\,y^{-1}})$	I_{eff} %
0	-420	144	15	0.88	2218	5.38×10^{-7}	0
10	-407	183	7.4	0.91	178	4.23×10^{-7}	21.3
25	-403	207	5.1	0.87	45	3.74×10^{-7}	30.5
50	-399	241	3.9	0.89	49	3.21×10^{-7}	40.3
100	-387	329	3.0	0.80	4	2.36×10^{-7}	56.2
200	-383	1335	2.1	0.88	1.7	4.25×10^{-8}	92.1
400	-374	7000	0.52	0.80	0.6	1.02×10^{-8}	98.1
600	-211	34618	0.36	0.69	0.04	2.15×10^{-9}	99.6
800	-156	34711	0.033	0.69	0.001	1.61×10^{-9}	99.7

Table 4: Electrochemical parameters obtained from impedance measurements on mild steel electrodes after 1 hour of exposure in 0.16 M H_2SO_4 solutions in the absence and presence of varying concentrations of gum exudates from *A. malacocephala*

C_{inh} (ppm)	E_{ocp} (mV vs Ag/AgCl)	R_{ct} (Ω cm²)	Q (μF cm²)	n	C_{dl} (μF cm²)	R_{corr} $(\mathrm{mm\,y^{-1}})$	I_{eff} %
0	-420	144	15	0.88	2221	5.38×10^{-7}	0
10	-411	497	14.1	0.88	1125	4.24×10^{-7}	21.2
25	-397	1658	13.9	0.80	295	3.64×10^{-7}	32.3
50	-391	3465	13.6	0.78	175	2.94×10^{-7}	45.3
100	-387	5445	13.3	0.78	15	6.62×10^{-8}	87.7
200	-381	12750	11.6	0.80	4	5.86×10^{-8}	89.1
300	-368	17000	8.14	0.83	4	2.53×10^{-8}	95.3
400	-323	21749	4.20	0.73	0.2	2.69×10^{-9}	99.5
500	-291	21750	1.64	0.65	0.05	2.15×10^{-9}	99.6

From Tables 3 and 4, it is seen that the values of E_{ocp} shift anodically as the concentration of inhibitor was increased. It is well known that the adsorbed inhibitor may not cover the whole metal surface but occupies the sites that are electrochemically active and then reduce the rate of anodic or cathodic reactions or both. Since E_{ocp} shift anodically with increase of inhibitor concentration, then the inhibitor reduce the rate of anodic reactions. It is also seen from Tables 3 and 4 that the values of R_{ct} increase as the concentration of the inhibitors were increased. This is an indication that the gum exudates have corrosion inhibitive properties since they resist charge transfer, thus impeding the electrochemical processes. It is also observed from these Tables that the C_{dl} values decrease as the concentrations of the gum exudates were increased. This is attributed to the decrease of the thickness of layer acting as an interphase between the corroding metal and the electrolyte; suggesting that gum exudate molecules are adsorbed at the mild steel surface. Furthermore, it is observed that values of Q decreases significantly as inhibitor concentration increases. These observations are attributed to a steady substitution of water molecules by the inhibitor molecules on the metal surface resulting in the declining of the level of metal dissolution reaction. The inhibitor efficiencies of the gum exudates from *A. drepanolobium* and *A. malacocephala* shown in Tables 3 and 4 are comparable. As can be seen, to afford an inhibition efficiency of 99.6%, 600 ppm of gum exudates from *A. drepanolobium* was required, which is not significantly higher than 500 ppm of *A. malacocephala* exudates required to achieve 99.6% inhibition efficiency. Polarization measurements facilitate the understanding of how an inhibitor works, *i.e.*, either by modifying the anodic process or cathodic process, or both. Polarization curves for mild steel working electrodes taken after 1 hour of exposure in 0.16 M H_2SO_4 solution in the absence and presence of varying concentrations of *A. drepanolobium* and *A. malacocephala* exudates are presented in Figures 3 and 4, respectively. It can be observed in Figure 3 that the increase in concentration of *A. drepanolobium* gum exudates in the electrolyte lowers the current densities and shift the corrosion potential anodically. Both cathodic and anodic processes are notably affected with increase in concentration of this inhibitor up to 600 ppm where no further significant changes were observed. This implies that, for *A. drepanolobium* gum exudates, 600 ppm is the optimum concentration.

The same trend was observed in Figure 4 except that the optimum concentration of *A. malacocephala* gum exudates was found to be 400 ppm.

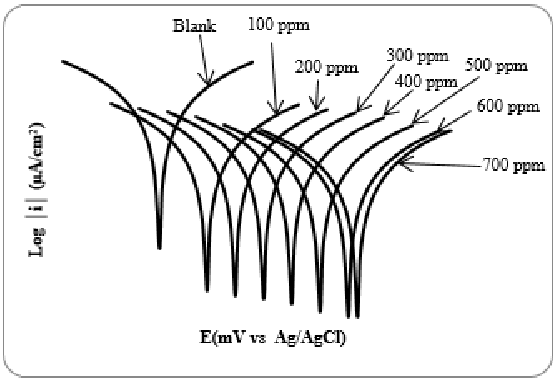

Fig 3: Polarization curves for mild steel working electrodes taken after 1 hour of exposure in 0.16 M H_2SO_4 solution in absence and presence of varying concentrations of *A. drepanolobium* gum exudates

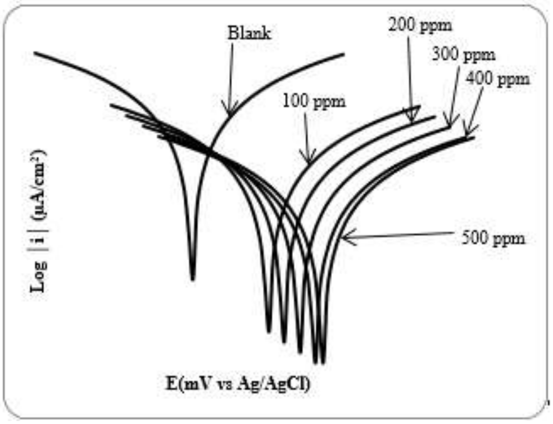

Fig 4: Polarization curves for mild steel working electrodes taken after 1 hour of exposure in 0.16 M H_2SO_4 solution in absence and presence of varying concentrations of *A. malacocephala* gum exudates

The Tafel extrapolation data obtained from polarization curves in Figures 3 and 4 are presented in Tables 5 and 6. These include corrosion potentials (E_{corr}), Tafel constants (b_{a} and b_{c}), corrosion current densities (i_{corr}), corrosion rates (R_{corr}) and inhibition efficiencies (I_{eff}). These data were obtained via tangents to the cathodic and anodic polarization curves. The intercepts obtained by drawing tangents to the cathodic and anodic polarization curves at regions between open circuit potential and 5 mV cathodically and anodically were used to estimate E_{corr}, i_{corr}, b_{a} and b_{c}. The R_{corr} (milimeters per year, mm y^{-1}) was calculated from the corrosion current density using equation 3, by assuming a uniform corrosion.

$$R_{\text{corr}} = \frac{315.36 \times W \times i_{\text{corr}}\,(\text{mm y}^{-1})}{zF\rho} \qquad (3)$$

Where z is the valence of iron (eq mol^{-1}), W is atomic mass (g mol^{-1}), ρ density of mild steel (g cm^{-3}), and F is Faraday constant (C mol^{-1})

As seen in Table 5, anodic and cathodic Tafel slopes decreased with increased inhibitor concentration. This is an indication that *A. drepanolobium* gum exudates inhibit both anodic and cathodic reactions, *i.e.*, mixed type inhibitor. The E_{corr} values shifted anodically with increase in *A. drepanolobium* gum exudate concentration, which means that the inhibitor affects anodic reactions more strongly. The i_{corr} and R_{corr} values, which are directly related, decreased with increase of *A. drepanolobium* gum exudates concentration up to an optimum concentration of 600 ppm. Correspondingly, 600 ppm of *A. drepanolobium* gum exudates gave the highest I_{eff} value of over 97%. Similar patterns of results were reported elsewhere (Philip *et al*., 2016, Ji *et al*., 2013). From Table 6 similar results are observed with the exception of the optimum concentration (400 ppm) of *A. malacocephala* gum exudates.

Table 5: Electrochemical parameters obtained from polarization curves obtained after 1 hour of exposure of mild steel electrodes in 0.16 M H_2SO_4 solutions in the absence and presence of varying concentrations of *A. drepanolobium* gum exudates

C_{dl} (ppm)	E_{corr} (mV vs Ag/AgCl)	b_a (mV/dec)	b_c (mV/dec)	i_{corr} (μA/cm^2)	R_{corr} (mm y^{-1})	I_{eff} (%)
0	−645	54	−49	38.8	0.4508	–
200	−465	29	−34	3.918	0.0455	89.9
400	−460	37	−27	2.409	0.028	93.7
600	−430	32	−27	1.36	0.016	96.5
800	−420	30	−26	1.32	0.015	96.6

Table 6: Electrochemical parameters obtained from polarization curves obtained after 1 hour of exposure of mild steel electrodes in 0.16 M H_2SO_4 solutions in the absence and presence of varying concentrations of *A. malacocephala* gum exudates

C_{dl} (ppm)	E_{corr} (mV vs Ag/AgCl)	b_a (mV/dec)	b_c (mV/dec)	i_{corr} (μA/cm^2)	R_{corr} (mm y^{-1})	I_{eff} (%)
0	−645	54	−49	38.8	0.4508	–
100	−605	39	−44	0.95	0.011	97.9
200	−602	31	−39	0.295	3.4×10^{-3}	99.2
300	−590	36	−39	0.305	3.5×10^{-3}	99.2
400	−580	28	−32	0.155	1.8×10^{-3}	99.6
500	−577	27	−30	0.152	1.8×10^{-3}	99.6

Effect of temperature on corrosion inhibition: Impedance measurements were taken 1 hour after exposing freshly polished mild steel electrodes in uninhibited and inhibited test solutions of both gum exudates at 303 K, 313 and 323 K are shown in Figures 5 to 7.

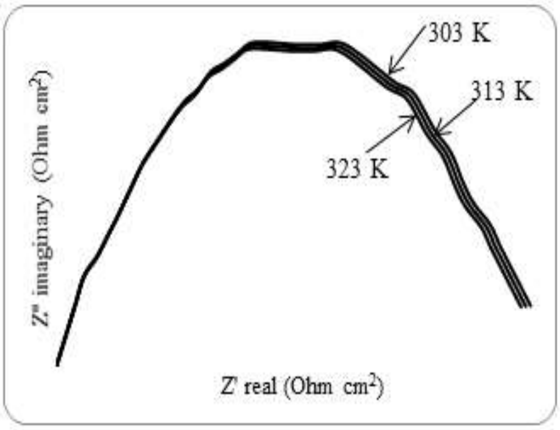

Fig 5: Impedance curves for mild steel taken after 1 hour of exposure in 0.16 M H_2SO_4 solution without inhibitor at 303 K, 313 K and 323 K temperature

From Figure 5 it is clearly seen that for the uninhibited electrolyte, there is a very small decrease in the size of the semicircle with the increase in temperature of the system. For the inhibited system, (Figure 6 and 7), it is clearly seen that the size of the semicircles decreased a little bit significantly as the temperature of the system was increased.

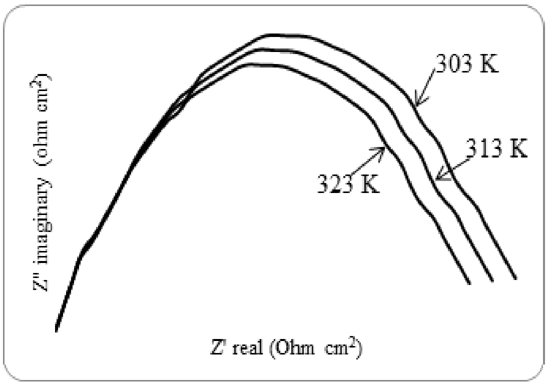

Fig 6: Impedance curves for mild steel taken after 1 hour of exposure in 0.16 M H_2SO_4 solution with 600 ppm *A. drepanolobium* inhibitor, at 303 K, 313 K and 323 K temperature

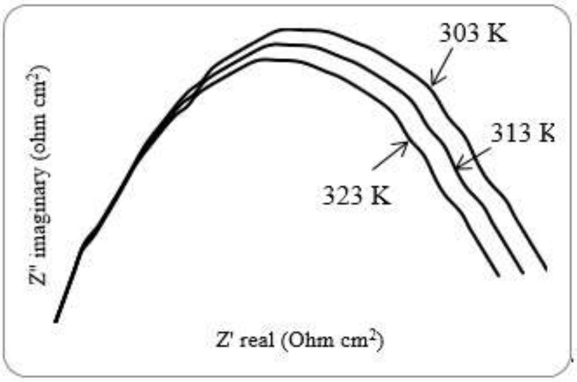

Fig 7: Impedance curves for mild steel taken after 1 hour of exposure in 0.16 M H_2SO_4 solution with 400 ppm *A. malacocephala* inhibitors at 303 K, 313 K and 323 K temperature

The results presented in Table 7 indicate that there is a decrease in the corrosion rates of mild steel with increase in temperature. A minimum corrosion rate for mild steel was reached at 303 K. The inhibition efficiencies for the inhibited systems (Table 7) decreased with increase in temperature. This may be attributed to the fact that the inhibitor's molecules adsorption on the metal surface decrease with increase in temperature hence causing increased rate of dissolution of mild steel and partial desorption of inhibitor from the metal surface. Similar behaviour has also been reported by Chen *et al*,. (2000).

Table 7: Electrochemical parameters obtained from impedance measurements on mild steel electrodes in 0.160 M H_2SO_4 solutions in the absence and presence of varying concentrations of *A. drepanolobium* and *A. malacocephala* inhibitors after 1 hour of exposure at various temperatures, 303 K, 313 K and 323 K

		E_{ocp} (mV vs Ag/AgCl)	R_{ct} (Ω cm^2)	Q (μFcm^2)	n	C_{dl} (μF cm^2)	R_{corr} (mm y^{-1})	I_{eff} (%)
303 K	Blank	–420	76.5	144	0.91	105	1.01×10^{-6}	
	A. drepanolobium (600 ppm)	–211	34618	0.36	0.69	20	2.02×10^{-9}	99.8
	A. malacocephala (400 ppm)	–323	21250	4.20	0.73	80	4.04×10^{-9}	99.6
313 K	Blank	–472	49.8	0.026	0.84	103	1.56×10^{-4}	
	A. drepanolobium (600 ppm)	–201	4954.9	5.4×10^{-6}	0.92	6	1.56×10^{-5}	90
	A. malacocephala (400 ppm)	–279	7459	3.1×10^{-4}	0.89	18	1.56×10^{-4}	90
323 K	Blank	–483	19.14	1.12	0.83	49	1.58×10^{-4}	
	A. drepanolobium (600 ppm)	–261	199.1	0.406	0.76	5.8	1.58×10^{-5}	89
	A. malacocephala (400 ppm)	–271	160.3	0.033	0.85	2	1.89×10^{-5}	88

From Table 7 it is observed that corrosion rate for blank systems does not change significantly as the temperature of the system is increased from 303 K to 323 K. However, the corrosion rates are also observed to increase as the temperature is increased for the inhibited systems. This observation implies that inhibition efficiency of *A. drepanolobium* and *A. malacocephala* gums is reduced when temperature is increased and which means that temperature has an adverse effect on the performance of *A. drepanolobium* and *A. malacocephala* gums as corrosion inhibitors.

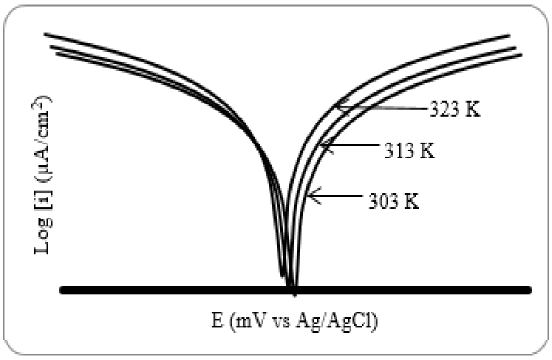

Fig 8: Polarization curves for mild steel working electrodes taken after 1 hour of exposure in 0.16 M H_2SO_4 solution at 303 K, 313 K and 323 K in absence of inhibitor

Figures 8, 9 and 10 are polarization curves obtained after exposing mild steel in 0.160 M H_2SO_4 solution in the absence and presence of *A. drepanolobium* and *A. malacocephala* inhibitors at different temperatures.

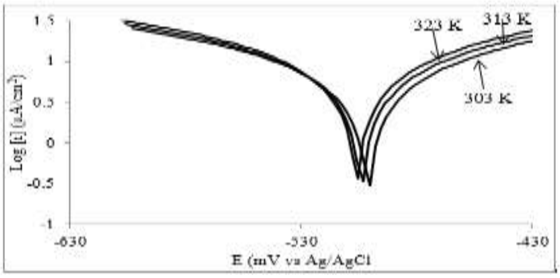

Fig 9: Polarization curves for mild steel working electrodes taken after 1 hour of exposure in 0.16 M H_2SO_4 solution at 303 K, 313 K and 323 K with 600 ppm *A. drepanolobium* inhibitor

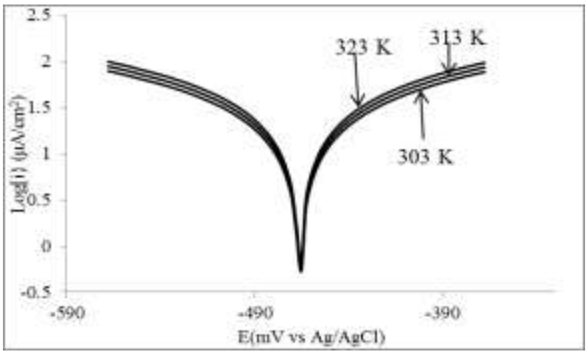

Fig 10: Polarization curves for mild steel working electrodes taken after 1 hour of exposure in 0.16 M H_2SO_4 solution at 303 K, 313 K and 323 K with 400 ppm *A. malacocephala* inhibitor

In these figures, the potential region is observed to be shifting gradually for the uninhibited and inhibited systems for every studied temperature. The effect of the inhibitor is seen to be high at all studied temperatures, and a significant reduction in corrosion currents on both anodic and cathodic regions of the curves is also observed. The cathodic region shows more effect as compared to the anodic region. This observation is similar to what has been reported by Eddy and Ebenso (2008) who found that the inhibition efficiency of *M. sapientum* peel extracts at a fixed concentration decreased with increase in temperature. It was suggested that this effect may be due to competition between forces of adsorption and desorption. The electrochemical parameters obtained from the Figures 8, 9 and 10 are presented in Table 8. It is from Table 8 that corrosion rate for blank systems does not change significantly as the system temperature is increased from 303 K to 323 K. However, the corrosion rates are also observed to increase as the temperature is increased for the inhibited systems. This observation implies that inhibition efficiency of *A. drepanolobium* and *A. malacocephala* gums is reduced when temperature is increased and thus temperature has an adverse effect on the performance of *A. drepanolobium* and *A. malacocephala* gums as corrosion inhibitors.

Table 8: Electrochemical parameters and calculated corrosion rates and inhibitor efficiencies obtained from polarization measurements at 303 K, 313 K and 323 K.

		b_a (mV/dec)	b_c (mV/dec)	E_{corr} (mV *vs* Ag/AgCl)	i_{corr} (μA/cm^2)	R_{corr} ($\mathrm{mm\,y^{-1}}$)	I_{eff} (%)
303 K	Blank	41	-35	-741	66.52	2.037	-
	A. drepanolobium (600 ppm)	36	-51	-672	3.98	0.143	93
	A. malacocephala (400 ppm)	39	-45	-573	4.01	0.122	94
313 K	Blank	23	-40	-701	7.14	0.901	-
	A. drepanolobium (600 ppm)	39	-54	-608	0.64	0.072	92
	A. malacocephala (400 ppm)	31	-43	-457	0.78	0.117	87
323 K	Blank	21	-35	-717	4.99	0.391	-
	A. drepanolobium (600 ppm)	36	-59	-686	0.50	0.035	91
	A. malacocephala (400ppm)	29	-35	-431	0.65	0.055	86

Chemotaxonomic aspects of gum Exudates from A. malacocephala and A. drepanolobium: As reported by Mhinzi and Mrosso (1995), *A. drepanolobium* and *A. malacocephala* species are morphologically very similar and it is not possible to differentiate them on the basis of herbarium specimens only. The two species are both spiny bush trees that grow up to 6 m high, flat-topped at maturity with an open spreading crown. It has been reported that the difference that can be observed in the field is the flowering time, whereby *A. malacocephala* flowers during the dry season, with its flowers disappearing during the first rains, whereas *A. drepanolobium* flowers in the rainy season. Chemotaxonomic evidence such as analytical data can be used to distinguish closely related species. Some parameters such as ash content, specific rotation, molecular weight, nitrogen and methoxy contents can serve as chemical fingerprints in chemotaxonomic identification (Mhinzi 2003). The available physicochemical data, such as methoxy content, nitrogen content and acid equivalent weight suggests that the gum exudates from the two species are not similar. *A. drepanolobium* gum exudate is almost water-soluble (*ca*. 0.4% w/w) whereas *A. malacocephala* possess substantial insoluble gel fraction. The nitrogen content of *A. malacocephala* (*ca*. 0.84% w/w) is significantly higher than that of *A. drepanolobium* gum (*ca*. 0.30%). Likewise, the acid equivalent weights of the gums from *A. malacocephala* and *A. drepanolobium* are reported to be different (Mhinzi and Mrosso 1995).

This work has shown that the corrosion inhibiting properties of the gums from *A. malacocephala* and *A. drepanolobium* on mild steel in acidic media under stationary conditions are different. *A. drepanolobium* gum exudates require a higher concentration to attain optimum inhibition (600 ppm), than gum exudates from *A. malacocephala* (400 ppm). It is therefore evident that the corrosion inhibitive properties of the gum exudates from the two species are different, justifying *A. malacocephala* and *A. drepanolobium* as two distinct species.

Conclusion: Both *A. drepanolobium* and *A. malacocephala* gum exudates provide excellent protection of mild steel against corrosion in acidic media at stationary state. The inhibition efficiency decreased slightly with 20 K temperature rise. In addition, the difference in concentrations of the gum exudates required to achieve maximum corrosion inhibition of mild steel supports the fact that the two plant species are taxonomically different. Therefore, gum exudates from the two plant species studied are potential corrosion inhibitors in acidic media.

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