Comparative Study of Inhibitive Properties of Cashew Leaves and Cocoa Pod on the Corrosion Behaviour of API 5L Steel IN 0.5 M HCl and 0.5 M H₂SO₄

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Abstract - **The inhibitive properties of some selected agro wastes (cocoa pod and cashew leaves) on corrosion behaviours of API 5L steel in 0.5 M sulfuric acid and 0.5 M hydrochloric acid were studied. The study was carried out using the weight loss method. The properties of the extract were studied with Fourier Transform Infrared Spectroscopy. The analysis of the results showed that the inhibition efficiency increased with an increase in the concentration of extracts. The inhibition efficiency of the extracts was observed to be more effective in 0.5 M HCl as compared to 0.5 M H₂SO₄ solution. The highest inhibition efficiency of 73% was obtained at 6.0% v/v concentrations of the cashew leaves extracts in 0.5 M HCl solutions. While in 0.5 M H₂SO₄ solution 18% were obtained as the highest inhibition efficiency at 6.0% v/v concentrations cashew leaves extracts. Fourier transform infrared spectroscopy analysis showed O-H, C=O, C=C and C-N as the functional groups in the extracts.**

Keywords: API5L steel, Corrosion, Cocoa pod, Cashew.

I. INTRODUCTION

Corrosion is the deterioration of metals by chemical attack or interaction with their environment. It can also be defined as the gradual disintegration or deterioration of materials by chemical or electrochemical reactions with their environment [1]. Corrosion is a constant and continuous problem, often difficult to eliminate. Corrosion processes develop fast after disruption of the protective barrier and are accompanied by several reactions that change the composition and properties of both the metal surface and the local environment. It has been an everyday challenge in all sectors of the economy particularly the manufacturing industry [2] API 5L steel is one of the most important alloys being used in a wide range of industrial applications. Corrosion problems arise as a result of the interactions between aqueous solution and carbon steel, especially during the pickling process where the alloy is brought in contact with the highly concentrated acids [3]. There are several ways of tackling the issue of corrosion in the industry and one of such way is the use of organic inhibitors which is eco-friendly. Inhibitors protect metals by effectively adsorbing their surface and blocking the actives sites for metal dissolution and hydrogen evolution, thereby hindering overall metal corrosion in aggressive environments [4]. Many studies have been carried out to find suitable compounds useful as corrosion inhibitors for metals in different aqueous solutions [5]. According to Rocha [6], it was reported that there are a number of organic and inorganic compounds which can inhibit the corrosion of steel. Naturally occurring molecules exhibiting a strong affinity for metal surfaces are the focus of research-oriented toward the development of environmentally-friendly corrosion organic inhibitors compounds, showing good inhibition efficiency and low environmental risk [6]. Researchers have done some work on green corrosion [7-8]. The efficiency of organic corrosion inhibitors is related to the presence of polar functional groups. The polar function is usually regarded center for the establishment of the adsorption process. Organic compounds containing nitrogen, sulfur, oxygen, and heterocyclic compounds with a polar functional group and a conjugated double bond have been reported to inhibit mild steel corrosion [9].

II. MATERIALS AND METHODS

2.1 Materials

API 5L steel was used as a test material for this research. The elemental chemical composition of the steel was determined using a spark spectrometric analyzer. The API 5L steel was cut to dimensions of 10 mm by 10 mm with a thickness of 6 mm for use as test coupons. Each coupon was degreased with ethanol and surface preparation of the coupons was performed by mechanicallypolishing their surfaces using silicon carbide emery papers of grade 60 down to 1200, washed with distilled water and dried at room temperature.

2.2 Inhibitor preparation

The materials used for this research are agro wastes which include cashew leaves and cocoa pods. The agro wastes were obtained from The Federal University of Technology, Akure, Ondo State, Nigeria. To prepare the extract, the agro wastes were obtained in fresh form, cleaned and subjected to drying

in an oven until they were sufficiently dried. This was done to make sure that the natural constituent of the cocoa pods and cashew leaves were preserved. The cocoa pods and cashew leaves were pulverized using a grinding machine to obtain a very fine powder. 100g of each pulverized agro-waste were weighed and soaked in 100 ml of ethanol for 72 hours. The mixture was filtered after 72 hours to obtain the filtrates and further subjected to evaporation to leave the sample free of the ethanol. Evaporation was carried out in the laboratory by placing the extracts in a heating pan and heating them to a temperature of 80ºC on an electric heater. The stock obtained was used in preparing different concentrations of the extracts.

2.3 Gravimetric analysis

The convectional gravimetric or weight loss method involves the weighing of the samples before immersion and then re-weighing after the duration of the pre-determined period. Afterwards, the samples are then re-immersed for the next duration. The prepared API 5L steel samples measuring 1cm by 1cm were weighed and subsequently immersed in containers containing 100 ml of the test solutions. The solutions consisted of control solutions (the acidic solution without the addition of inhibitors) and the other one was the acidic solutions with the addition of different concentrations of the inhibitors. The substrates were held in the solutions for a period of 30 days and with intervals of 3 days in order to check for weight loss. After the duration, the samples were removed from the test media and reweighed. From the weight loss data obtained, the corrosion rates (CR), inhibition efficiency (IE) and surface coverage (Ө) were calculated.

2.4 FTIR analysis

FTIR analysis was carried out to determine the functional groups present in the extracts. They were carried out using Perkin-Elmer-1600 Fourier transform infra-red spectrophotometer at the Central Laboratory of the Federal University of Technology, Akure, Ondo – State, Nigeria.

III. RESULTS AND DISCUSSION

The elemental composition of the API5L understudy is presented in Table I.

Table I: Chemical composition of API5L steel

Element	C	Mn	S	Cr	Ni	Cu	As	Fe
Composition (%)	0.0766	0.2980	0.0239	0.0226	0.0167	0.0235	0.0142	Bal.

Figures I and II show the functional groups of the extract. Fourier transform infrared spectroscopy was used to determine the spectra of the extracts. In the analysis of the cocoa pod and cashew leaves extracts, stretching frequencies for the functional group of OH, C=C, C=O, and CN were observed within the range of 3266.68 to 3350.01 cm^{-1}, 1633.34 to 1650.01 cm^{-1}, 1966.8 cm^{-1} and 1033.34 to 1083.35 cm^{-1}. FTIR spectra of the extracts showed the presence of oxygen and nitrogen atoms in functional groups (O-H, C-N) and unsaturated (C=C). The presence of oxygen and nitrogen atoms in the extracts met the general characteristics of a typical corrosion inhibitor [10].
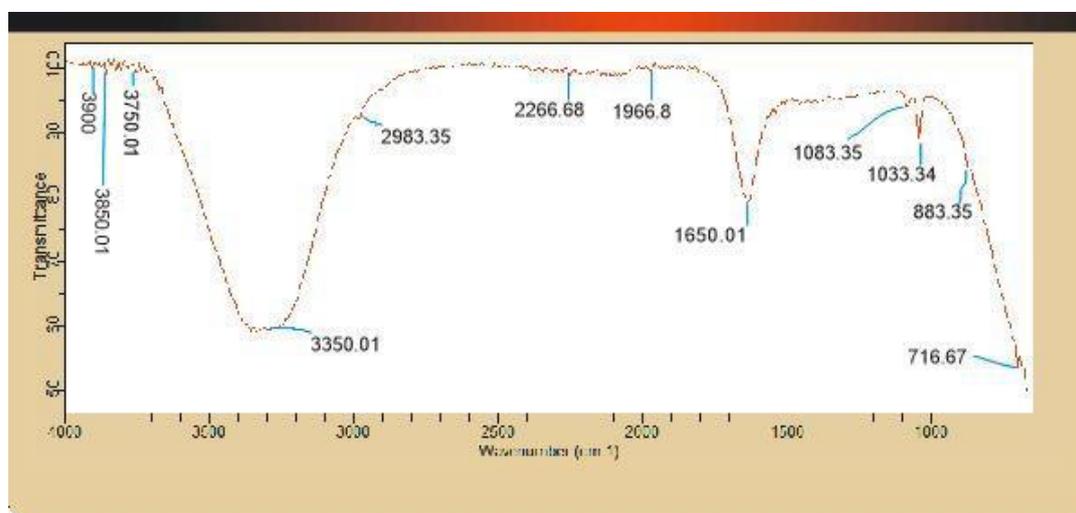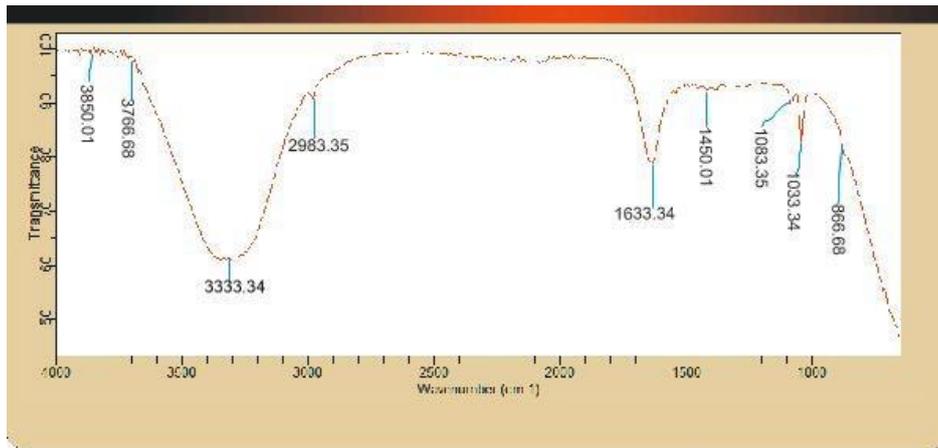

**Figure I: Fourier transform infra-red spectroscopy analysis of cashew leaves extracts**

**Figure II: Fourier transform infrared spectroscopy analysis of cocoa pod extracts**

Figures III to VI show the variation in mass loss of API 5L steel substrates in 0.5 M HCl and 0.5M H2SO4 in different concentrations of the extracts as a function of time. Generally, the addition of inhibitors reduces the weight loss of the samples in 0.5 M HCl and 0.5M H2SO4 environment, thereby reducing the corrosion rates. Figure VII to X showed the inhibition efficiency of the sample in the environment under study at different concentration of the extracts of cashew and cocoa pods. The inhibition efficiency of the cashew leaves was higher than the cocoa pod at 4%V/V and at 6%V/V. The efficiency of the cocoa pod was higher than thecashew leaf at 2%V/V.
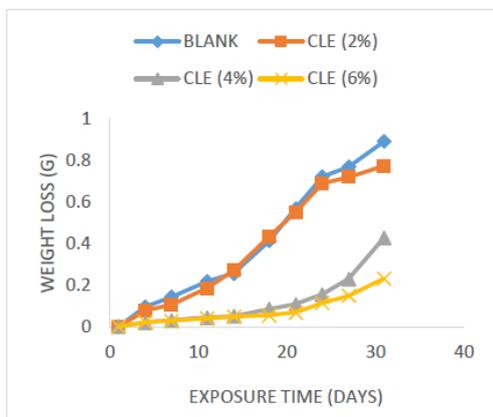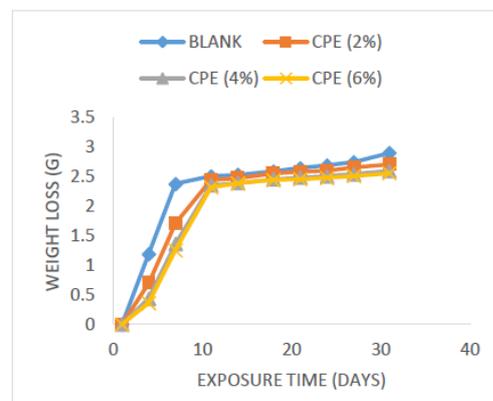

Figure III: Plot of weight loss as a function of time for corrosion of API 5L steel in 0.5 M HCl in the presence and absence of cashew leaves extract
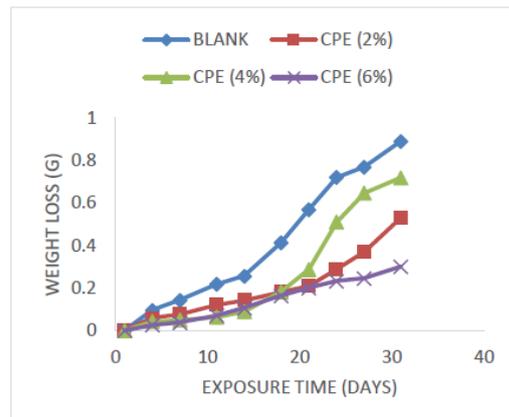
Figure IV: Plot of weight loss as a function of time for corrosion of API 5L steel in 0.5 M HCl in the presence and absence of cocoa pod extract
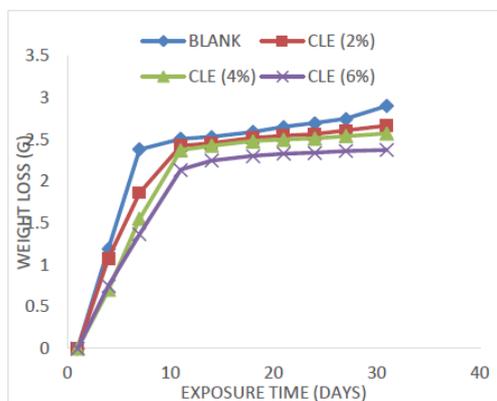
Figure V: Plot of weight loss as a function of time for corrosion of API 5L steel in 0.5 M H2SO4 in the presence and absence of cashew leaves extract

Figure VI: Plot of weight loss as a function of time for corrosion of API 5L steel in 0.5 M H2SO4 in the presence and absence of cocoa pod extract
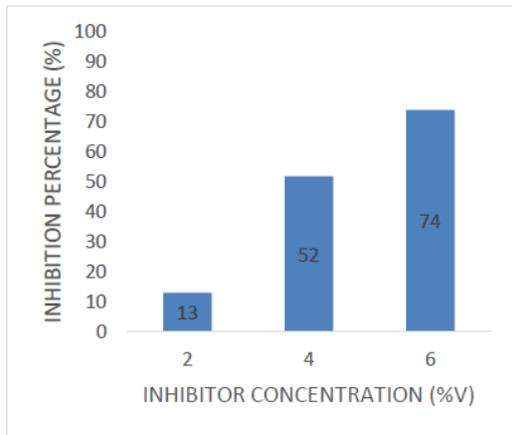
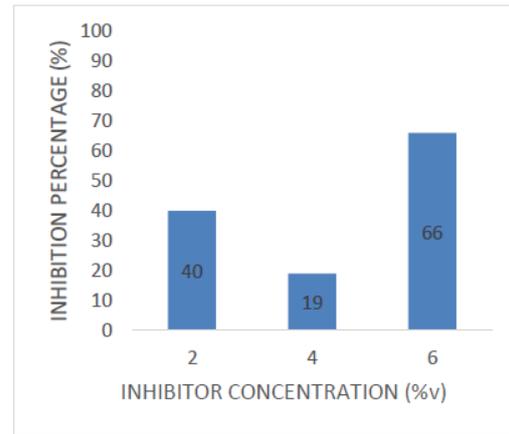**Figure VII: Inhibition efficiency of cashew leaf extract in 0.5M HCl solution**

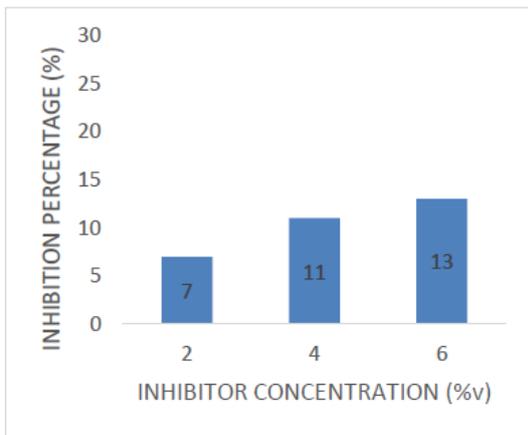**Figure VIII: Inhibition efficiency of cocoa pod extract in 0.5M HCl solution**

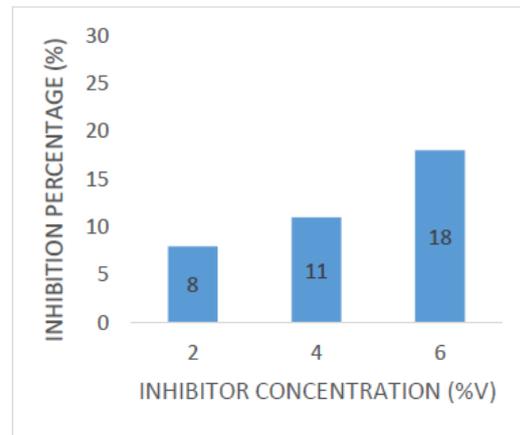**Figure IX: Inhibition efficiency of Cocoa Pod Extract in 0.5M H2SO4 solution**

Figure X: Inhibition efficiency of Cashew Leaf Extract in 0.5M H2SO4

Table II: Corrosion parameters obtained from the weight loss measurements of API 5L steel samples in 0.5 M HCl

Inhibitors (extracts)	Concentration (%v/v)	Immersion time (hours)	Weight loss (g)	Inhibition efficiency (%)	Corrosion rate (mmpy)
Cocoa pod	0	720	0.8906	0	0.014
	2.0	720	0.5307	40	0.008
	4.0	720	0.7195	19	0.011
	6.0	720	0.3012	66	0.004
Cashew leaves	0	720	0.8906	0	0.014
	2.0	720	0.5717	13	0.012
	4.0	720	0.2734	51	0.007
	6.0	720	0.7734	73	0.004

Table III: Corrosion parameters obtained from the weight loss measurements of API 5L steel samples in 0.5 M H_2SO_4

Inhibitors (extracts)	Concentration (%v/v)	Immersion time (hours)	Weight loss (g)	Inhibition efficiency (%)	Corrosion rate (mmpy)
	0	720	2.8987	0	0.045
Cocoa pod	2.0	720	2.7074	6	0.042
	4.0	720	2.5950	10	0.040
	6.0	720	2.5567	11	0.039
Cashew leaves	0	720	2.8987	0	0.045
	2.0	720	2.6626	8	0.031
	4.0	720	2.5690	11	0.036
	6.0	720	2.3720	18	0.033

In Figure III, it was noticed that the weight loss and corrosion rate of the blank solution increased when compared to the solution containing the cashew leaves extracts in 0.5M HCl. Corrosion rate with values of 13.803×10^{-3}, 11.985×10^{-3}, 6.6490×10^{-3} and 3.5973×10^{-3} (empty) were obtained at 0, 2, 4, and 6 % v/v concentration of the cashew leaves extract respectively. Furthermore, the inhibition efficiency increased with an increase in the concentration of the extract. The highest inhibition efficiency was obtained at 6 % v/v with a value of 69 %. The cashew leave inhibits the corrosion of API5L steel in 0.5M HCl.

In Figure IV, it was observed that in blank solution, the weight loss of the sample was higher than the sample with cocoa pod extract in 0.5 M HCl. Corrosion rate with values of 13.803×10^{-3}, 8.215×10^{-3}, 11.1515×10^{-3} and 4.6683×10^{-3} (mmpy) were obtained at 0, 2, 4, and 6 % v/v concentration of the extract respectively. The highest inhibition was recorded at 6 %v/v concentration of the cocoa pod extract with an inhibition efficiency of 66% while the least inhibition efficiency was obtained at 4 %v/v concentration with an inhibition efficiency of 19 %. The corrosion rates are reduced with increasing corrosion inhibitors.

In Figure V, it was revealed that the weight loss and corrosion rate of the sample in blank solution increased exponentially compare to the solutions containing the cashew leaves extracts. Corrosion rate with values of 4.4927×10^{-2}, 3.7028×10^{-2}, 3.5728×10^{-2} and 3.2986×10^{-2} (mmpy) were obtained at 0, 2, 4, and 6 % v/v concentration of the extract respectively. In addition, the inhibition efficiency increased with an increase in the concentration of the extract and highest inhibition efficiency was obtained at 6 % v/v with a value of 18 %.

In Figure VI, it was observed that in blank solution, weight loss of the sample was very high when compared with those that contained cocoa pod extract. Corrosion rate with values of 4.4927×10^{-2}, 4.1962×10^{-2}, 4.022×10^{-2} and 3.9626×10^{-2} (mmpy) were obtained at 0, 2, 4, and 6 % v/v concentration of the extract respectively. Furthermore, the inhibition efficiency increased with an increase in the concentration of the extract and the highest inhibition efficiency was obtained at 6 % v/v with a value of 11 %.

IV. CONCLUSION

Inhibitive properties of the cocoa pod and cashew leaves extracts on API 5L steel in 0.5 M HCl and 0.5 M H_2SO_4 environments showed that corrosion rate and inhibition efficiency increased with an increase in the concentration of the extracts. The inhibition efficiencies of the extracts were more effective in 0.5 M hydrochloric acid than in 0.5 M sulfuric acid. Higher inhibition efficiency value of 74% were obtained at 6.0% v/v concentration of cashew leaves extracts in 0.5 M HCl and 18% at 6.0% v/v concentration of cashew leaves extract in 0.5 M H_2SO_4 environment. Finally, between the two inhibitors cashew leaves extract was very effective and showed good inhibitive properties in both 0.5 M HCl and 0.5 M H_2SO_4 at 2.0% v/v and 6.0% v/v concentrations of the extracts respectively.

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