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Research Article

Corrosion Inhibition Potential of *Cucurbita Maxima* Plant Extract on Mild Steel in Acid Media

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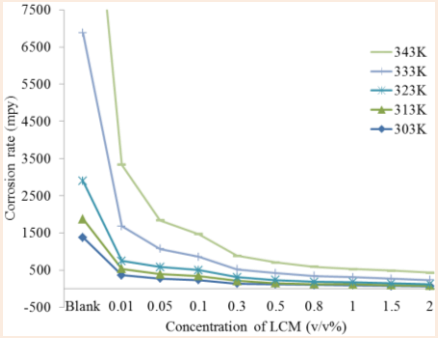
Abstract

The corrosion inhibition efficiency of leaves of *Cucurbita maxima* (LCM) on the corrosion behavior of mild steel (MS) in 1N HCl was studied using weight loss measurements and FTIR techniques. The results revealed that the LCM acts as good green corrosion inhibitor. The corrosion rate (CR) decreased and inhibition efficiency increased with increase in concentrations of LCM. The IE value reaches 98% at 2% v/v concentration of LCM. The adsorption of inhibitor on MS surface was found to obey Langmuir and Temkin adsorption isotherms. The nature of the metal surface was analyzed by FTIR technique.



Keywords: *Cucurbita maxima*, mild steel, corrosion rate, inhibition efficiency, adsorption isotherm, FTIR.

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Introduction

In many industries, mild steel is the material of choice in the fabrication of reaction vessels, storage tanks etc which is easily subjected to corrosion in the presence of acids [1]. Acid solutions such as HCl are widely used in acid pickling, industrial cleaning, and oil well cleaning etc. Corrosion inhibitors are used as effective alternatives for the protection of metallic surfaces against corrosion. The use of inhibitors is one of the most effective ways to prevent corrosion. Corrosion inhibitors will reduce the rate of either anodic oxidation or cathodic reduction or both. This will give as anodic, cathodic or mixed type of inhibition. Synthetic inhibitors has created environmental problem due to its toxicity properties [2]. Natural plant products play an important role in corrosion inhibition studies. Natural plant extracts are eco friendly, non toxic and relatively less expensive. Extracts of plant materials contain a wide variety of organic compounds. Most of them posses an active functional groups such as nitro ($-NO_2$), hydroxyl ($-OH^-$) and heterocyclic compounds with л electron [3-4]. These groups coordinate with the corroding metal atom, through their electrons. Hence protective films are formed on the metal surface and corrosion is prevented [5].

Several corrosion inhibition studies of mild steel by plant extracts in acidic media has been carried out and reported [6-9]. Khamis etal [10] has proved the use of herbs (such as coriander, hibiscus, anis and black cumin) as new type of green inhibitors for acidic corrosion of steel. Parikh etal [11] studied the anticorrosion activity of Onion, garlic and bitter guard for mild steel in HCl media. Oguzie investigated the inhibition efficiency of *Telforia occidentalis* extract as corrosion inhibitor in both HCl and H2SO4 media [12]. Berberine an alkaloid isolated from *Captis* was studied for its anticorrosion effect for mild steel corrosion in H_2SO_4 medium by yan Li etal [13]. The inhibitive effect of ethyl acetate extract of *Uncaria gambir* on mild steel in 1M HCl has been investigated by M.Hazwan Hussin etal [14].Acid extract of *Allium sativum*, alcoholic extract of *Acalypha indica*, aqueous extract of *lawsonia inermis* used as inhibitors for mild steel in HCl medium[15,16]. Juice extract of *Mangifera indica*, acid extract of *Andrographis paniculata* and *Datura stramonium* extract used as inhibitors for mild steel in HCl medium [17]. *Cucurbita maxima* belong to the family cucurbitaceae. Cucurbita species is found to contain tocopherol, carotenoids, β sitosterol, saponins, carbohydrates, amino acids and fatty acids [18].

The objective of this study is to investigate inhibition efficiency of leaves of *Cucurbita maxima* on mild steel corrosion in HCl medium using the weight loss method and FTIR technique.

Experimental

Materials

The sheet of mild steel used for this study has the following chemical composition (wt %) (0.047% C; 0.22% Mn; 0.015% Ni; 0.002% S; 0.026% Al; 0.002% P; 0.001% Mo; Fe balance) The sheet was 2 mm in thickness and was mechanically press – cut into 5 cm × 2 cm coupons. These were polished with 400 and 600 grade emery papers, degreased, dried in acetone and stored in desiccator. The 1n HCl solution, prepared from AR grade HCl was employed as the corrodent for the study. 25 g of dried and powered leaves of *Cucurbita maxima* (LCM) was refluxed in 500 ml of 1N HCl solution for 3 h. The refluxed solution was allowed to stand for overnight, filtered and stored. The filtrate was diluted with appropriate quantity of 1N HCl to obtain inhibitor test solutions of 0.01%, 0.05%, 0.1%, 0.3%, 0.5%, 0.8%, 1%, 1.5%, 2% v/v concentrations.

Methods

Gravimetric Experiments

The weight loss measurements carried out at various time intervals (1, 3, 5, 7, 18, and 24 h) at room temperature. The pre cleaned and weighed mild steel specimens were suspended in a 100 ml beaker containing the test solutions using glass hooks with rods. To determine weight loss with respect to time, the specimens were retrieved from the test solutions at various time intervals, cleaned, dried and reweighed. The weight loss was taken to be the difference between the weight of the mild steel specimens at a given time and its initial weight. All tests were run in triplicate and the data showed good reproducibility. Average values of each experiments obtained and used in subsequent calculations. The percentage inhibition efficiency (IE %) was calculated from the following equation [19].

$$IE\ \% = [(W_o - W_i) / W_o] \times 100 \quad (1)$$

Where W_o and W_i are the weight loss values in absence and in presence of inhibitor.
The corrosion rate (CR) was calculated from the following equation [20].

$$CR\ (mpy) = 534W / \rho\ A\ t \quad (2)$$

Where W is the weight loss in mg, ρ is the density of mild steel (7.8g/cm^3), A is the area of specimen (4.7244 in^2) and t is the time of immersion.

The effect of temperature on the corrosion rate of mild steel coupons in 1N HCl solution at 303, 313, 323, 333 and 343K was also studied with same concentrations of the LCM extract for immersion period of 1 h.

FTIR analysis

The IR spectrum was performed by using a Shimadzu spectrophotometer in the spectral region between 4000 and 500 cm^{-1}. The 5% LCM solution and MS samples with different inhibitor concentrations (0.05%, 0.5% and 2% v/v of LCM extract) were employed for FTIR analysis. The film was carefully removed and mixed thoroughly with KBr made into pellets and the spectrum was recorded.

Results and Discussions

Gravimetric method

The non electrochemical technique of weight loss was done in order to determine the corrosion rate (CR) and percentage of inhibition efficiency (IE %). The loss in weight of MS specimens in 1N HCl in the absence and in the presence of different concentrations of LCM extract was determined for different immersion periods (1, 3, 5, 7, 18 and 24 h) at room temperature. The calculated CR of mild steel and IE of LCM extract are listed in Table 1. The CR of mild steel as a function of immersion time with different concentrations of LCM is shown in Fig 1. It is observed that at room temperature, CR of mild steel decreased on increasing LCM concentration. This behavior could be attributed to the increase in adsorption of LCM at the metal solution interface on increasing its concentration. Fig 2 shows the variation of IE of LCM as a function of immersion periods with different concentrations of inhibitor. It indicates that the plant extract shows a significant inhibitive effect on mild steel. It is observed that the IE increases

with increase in LCM concentration. Maximum inhibition efficiency of 98% was obtained at 2% v/v LCM concentration at room temperature.

Table 1 CR of mild steel and IE of LCM in 1N HCl with different immersion periods at room temperature

S.No	Conc.of LCM % v/v	1 Hr		3Hrs		5 Hrs		7Hrs		18 Hrs		24 Hrs	
		CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %
1	Blank	1378	-	1304	-	1059	-	787	-	1065	-	962	-
2	0.01	366	73	220	83	106	90	174	78	242	77	286	70
3	0.05	275	80	150	88	70	93	96	88	122	89	138	86
4	0.1	235	83	119	91	70	93	73	91	64	94	72	93
5	0.3	135	90	68	95	48	95	41	95	31	97	45	95
6	0.5	126	91	54	96	39	96	37	95	32	97	35	96
7	0.8	100	92	36	97	38	96	30	96	31	97	28	97
8	1	92	93	37	97	32	97	26	97	30	97	30	97
9	1.5	78	94	40	97	28	97	27	97	25	98	22	98
10	2	70	95	36	97	22	98	23	97	23	98	17	98

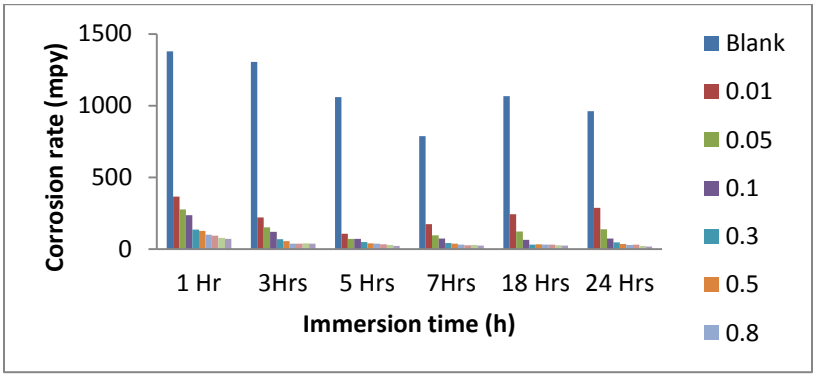

Fig 1 Corrosion rate of mild steel with different concentrations of PCM at different immersion periods

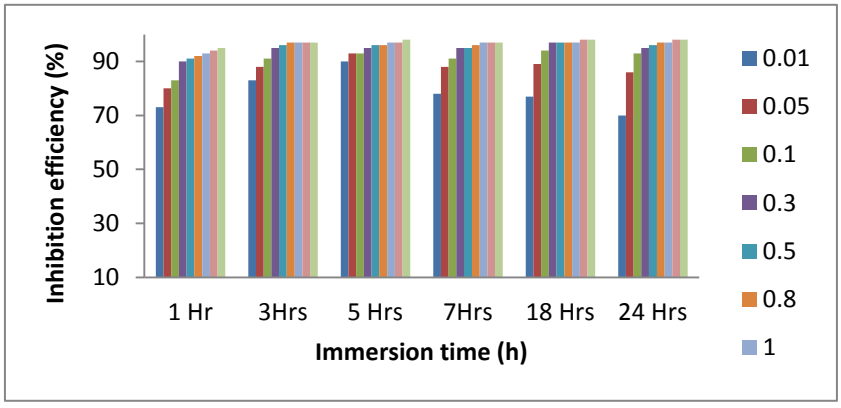

Fig 2 Inhibition efficiency of different concentrations of PCM at different immersion periods

The influence of temperature on the corrosion of mild steel in 1N HCL without and with the presence of LCM extract was studied using weight loss method in the temperature range of 303K – 343K with 1h of immersion. The CR and IE values are listed in Table 2. The variation of CR of mild steel as a function of different concentrations of LCM is shown in Fig 3. The plot of IE versus temperature with different concentrations of LCM is shown in Fig 4. Maximum inhibition efficiency of 97% was obtained at 2% v/v LCM concentration at different temperature range.

Table 2 CR of mild steel and IE of LCM in 1N HCl at different temperatures.

S.No	Conc. Of LCM %v/v	303K		313 K		323 K		333 K		343 K	
		CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %	CR (mpy)	IE %
1	Blank	1378	-	493	-	1025	-	3977	-	7340	-
2	0.01	366	73	166	66	218	78	929	76	1653	77
3	0.05	275	80	118	76	188	81	488	88	768	90
4	0.1	235	83	109	78	157	85	358	91	606	92
5	0.3	135	90	78	84	92	91	218	94	358	95
6	0.5	126	91	26	95	78	92	188	95	288	96
7	0.8	100	92	26	95	61	94	153	96	249	97
8	1	92	93	26	95	57	94	135	97	218	97
9	1.5	78	94	17	97	48	95	122	97	218	97
10	2	70	95	13	97	39	96	109	97	201	97

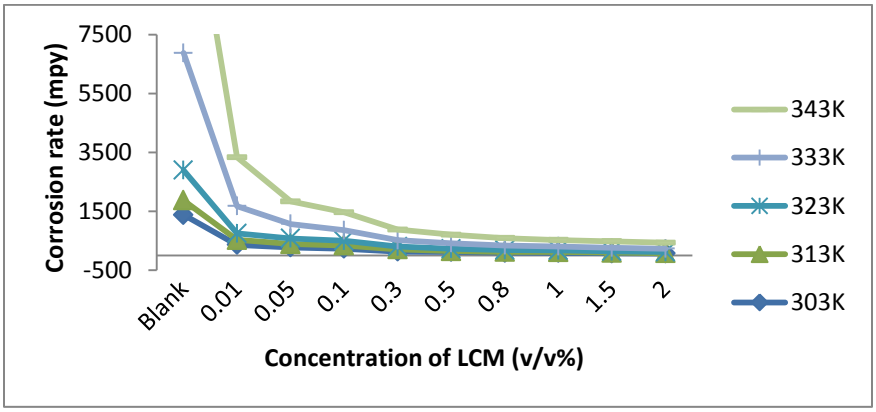

Fig 3 Effect of temperature on corrosion rate of mild steel with various concentrations

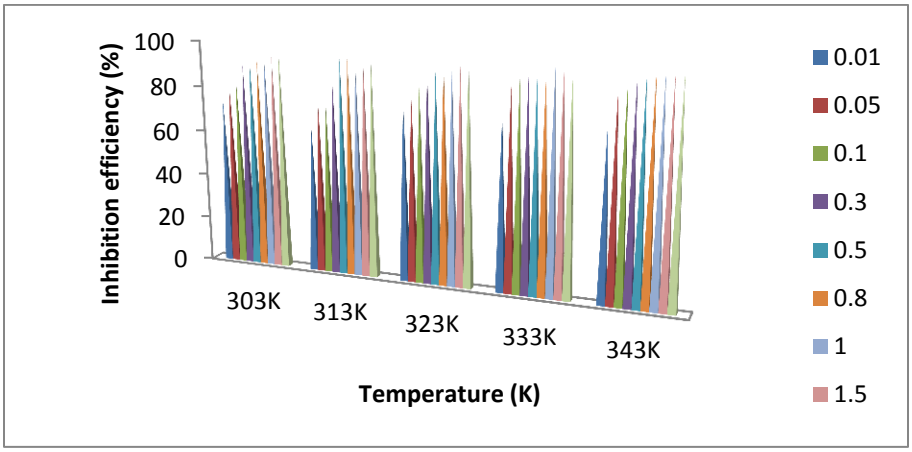

Fig 4 Effect of temperature on inhibition efficiency of PCM with various concentrations

Adsorption isotherms

The information about the interaction between inhibitor and MS surface can be provided by the adsorption isotherm. Here Temkin and Langmuir adsorption isotherms were applied in order to explain the adsorption process of LCM on the MS surface [21, 22].

$$\text{Langmuir: } C/\theta = 1/K + C \quad (3)$$

Temkin: $\text{Log } \theta/C = \text{Log } K - g\,\theta$ (4)

Where C is the concentration of inhibitor, K the adsorptive equilibrium constant, θ is the surface coverage and g is the adsorbate parameter. The plot of C/θ against C yields straight lines as shown in the Fig 5. It is evident that the linear correlation coefficient value is almost equal to 1, indicating the adsorption of LCM on MS surface obeys Langmuir adsorption isotherm in 1N HCl. The plot of θ versus Log C at different concentrations of LCM shows a straight line indicating that the adsorption of the inhibitor on mild steel surface follows the Temkin adsorption isotherm. Fig. 6 shows the Temkins adsorption isotherm plot of MS in 1N HCl with different concentrations of LCM.

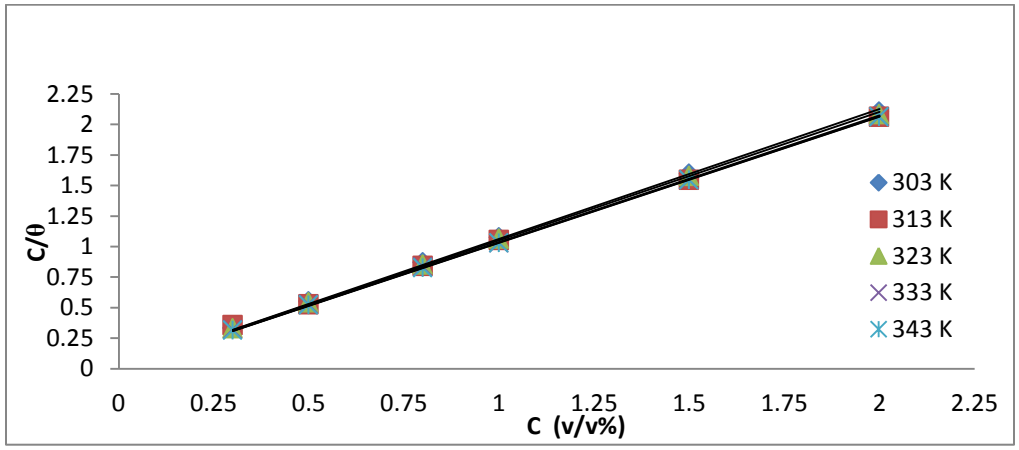

Fig :5 Langmuir plot for mild steel in 1N HCl containing different concentrations of LCM

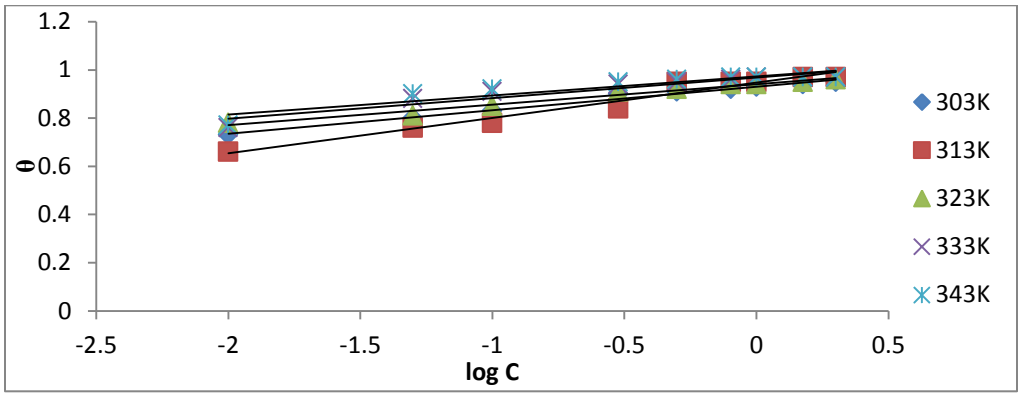

Fig 6: Temkin adsorption isotherm for corrosion behavior of mild steel in 1N HCl in the presence of LCM

FTIR Analysis

The FTIR instrument is used to determine the type of bonding for organic inhibitors adsorbed on the metal surface. FTIR spectra have been used to analyze the protective film formed on metal surface. FTIR spectrum of crude LCM extract is shown in Fig 7a. Fig 7b shows FTIR spectrum of mild steel in 1N HCl. The FTIR spectrum of mild steel in 1N HCl containing 2% v/v concentration of LCM, shown in Fig7c.From Fig 7a and Fig 7c , it was found that OH stretch at 3387 cm^{-1} was shifted to 3618 cm^{-1}, the C=O stretch at 1635.64 cm^{-1} was shifted to 1743.65 cm^{-1} and -NO_2 shoulder band at 1365.60 cm^{-1} shifted to strong band with same spectral region and -NH band at 1211.01 cm^{-1} was shifted to 1219.30 cm^{-1}indicating that there is interaction between the inhibitor and mild steel surface[23-26]. In fig 7b the peak at 1365 cm^{-1} and 771 cm^{-1} indicating the presence of α FeOOH, and OH bending for γ FeOOH respectively [27] . The absence of 771 cm^{-1} band in Fig 7c indicating the adsorption of inhibitor molecules on mild steel surface. FTIR peak values are listed in table 4.

Table 4 FTIR peak values for plant extract, mild steel in 1N HCl and MS in 1N HCl with 2% LCM

FTIR peak values (cm^{-1})			Possible groups	Reference Number
MS in 1N HCl	Plant Extract	MS in 1N HCl with 2%LCM		
-	3387	-	Stretching mode of OH from plant extract	24,25
3001.24	-	3008.95	Stretching mode of OH from adsorbed water	24,26
1735.93	-	1743.65	C=O stretch	23
-	1635	-	C=C stretching band for aromatic ring	23
1527.62	-	1527.62	$-NO_2$ group	23
1365	-	-	α FeOOH	27
-	1211.01	1219.01	amines	23
771	-	-	OH bending for γ FeOOH	27

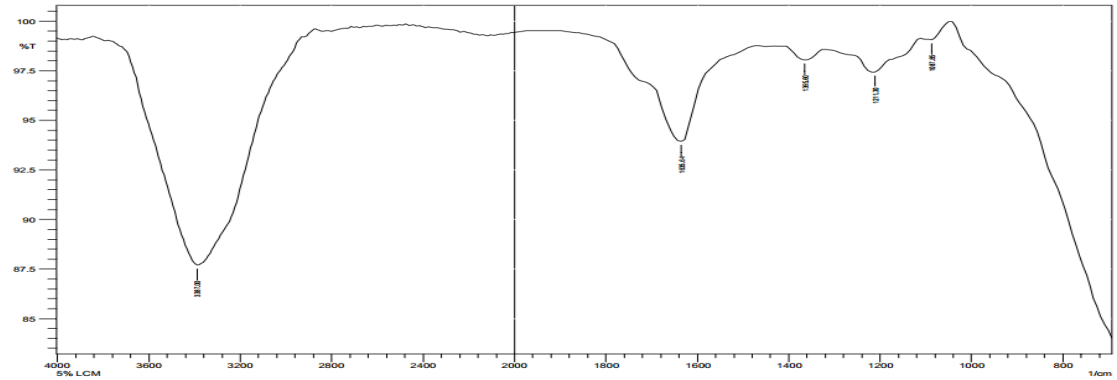

Fig 7a FTIR spectrum of crude LCM extract

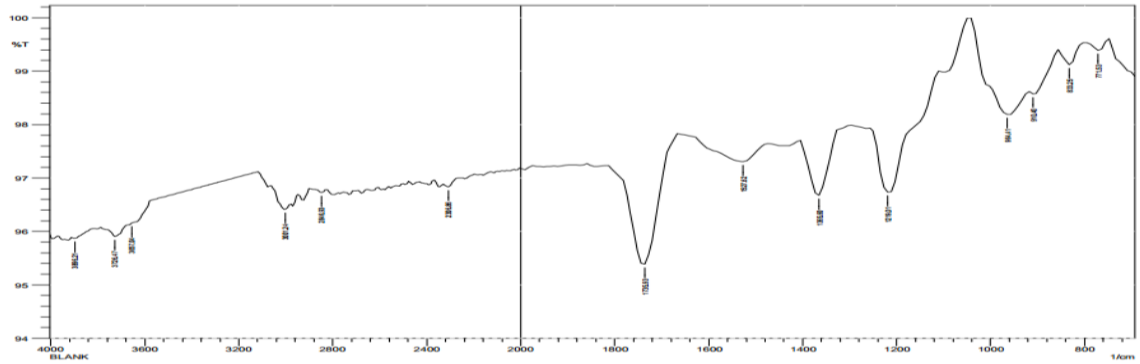

Fig 7b FTIR spectrum of mild steel in 1N HCl

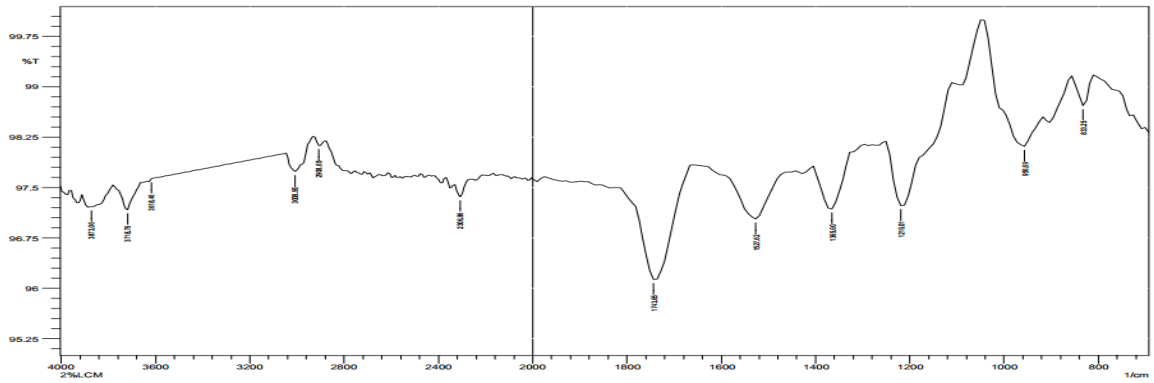

Fig 7c : FTIR spectrum of mild steel in 1N HCl containing 2% v/vconcentration of LCM

Conclusions

The following conclusions can be made on the basis of the results obtained:

1. LCM extract was found to be good green corrosion inhibitor of MS in 1N HCl solution.

2. The results of weight loss measurements for different immersion periods at room temperature show the maximum inhibition efficiency of 98% at 2% v/v of LCM.

3. The IE increased with an increase in LCM extract at different temperature range indicates the maximum inhibition efficiency of 97% at 2% v/v inhibitor concentration suggesting that it can acts as effective inhibitor even at higher temperature.

4. Adsorption of LCM on mild steel surface was found to obey Langmuir and Temkin adsorption isotherms.

5. FTIR analysis suggests the possibility of interaction of inhibitor constituents with mild steel surface and confirms the mechanism of inhibition to be adsorption.

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