Journal of the Korean Chemical Society
2012, *Vol. 56, No. 4*
Printed in the Republic of Korea
http://dx.doi.org/10.5012/jkcs.2012.56.4.401

Study on Corrosion Inhibition Efficiency of Stem Alkaloid Extract of Different Varieties of Holy Basil on Aluminium in HCl Solution

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(Received January 10, 2012; Accepted June 3, 2012)

ABSTRACT. Corrosion inhibition efficiencies of holy basil on Al in HCl solution were studied by weight loss and thermometric methods in presence and in absence of stem extract of three different varieties of holy basil viz. *ocimum basilicum* (E_B), *ocimum canum* (E_C) and *ocimum sanctum* (E_S). Inhibition efficiency increases with the increasing concentration of stem extract and decreases with increases in acid strength. Results show that all varieties under study are good corrosion inhibitors, among which, E_B is most effective. Maximum inhibition efficiency was found 97.09% in 0.5N HCl solution with 0.6% stem extract. The Langmuir adsorption isotherm indicates that surface coverage also increases with increasing in the concentration of extract of stem in HCl solution.

Key words: Inhibitors, Aluminium metal, Weight loss, Surface coverage

INTRODUCTION

Aluminium, being an industrially important metal, is subjected to corrosion in service by various corrosive agents of which the aqueous acids are the most dangerous. The corrosion of aluminium and its alloys in HCl solution has been extensively studied.[1-4] Pure aluminium is very soft and weak but it can be alloyed to increase its mechanical properties. For example, high strength aluminium alloy containing about 4% copper. Hence aluminium alloy are used for building purpose, motors and in cement products. It is also widely used as the structural material for various internal fitting in various industries.

The corrosion inhibitive properties of ocimum sanctum,[5] ricinus communis[6] and ficus virens[7] were studied on mild steel. Some other naturally occurring substances like argemone maxicana,[8] delonix regia,[9] caparis deciduas,[10] prosopis julifforar,[11] sansevieria trifascinata,[12] phylanthus amarus,[13] have been evaluated as effective corrosion inhibitors.

In the present investigation the inhibitive effect of three varieties of holy basil viz. ocimum basilicum (E_B), ocimum canum (E_C) and ocimum sanctum (E_S) have been studied.

EXPERIMENTAL

The extract of stem of all three species of holy basil obtained by refluxing the dried stem in soxhelt in ethanol. Resulting extract was dried and collected. Rectangular specimens of aluminium of dimensions 2.0 cm×2.0 cm× 0.045 cm containing a small hole of about 2 mm diameter near the upper edge were used for studying the corrosion rate. The chemical composition of the test specimen was 98.5% Al, 0.2% Fe, 0.2% Cu, 0.08% Zn, 0.08% Ti. Specimens were cleaned by buffing to produce a mirror finish and were then degreased. The solutions of HCl were prepared using double distilled water. All chemical used were of analytical reagent grade.

Each specimen was suspended by glass hook made of fine capillary tube in a beaker containing 50 mL of the test solution at 273±0.1 K. After the sufficient exposure, of time specimens were cleaned by running water. Duplicate experiments were performed in each case and mean values of the weight loss were calculated.

The percentage inhibition efficiency was calculated[16] as

$$\eta\% = \frac{\Delta W_u - \Delta W_i}{\Delta W_u} \times 100$$

Where, ΔW_u and ΔW_i are the weight loss of the metal in uninhibited acid and in inhibited acidic solution, respectively.

The corrosion rate (CR) in mm/yr can be obtained by the following equation.

$$\text{Corrosion rate (mm/yr)} = \frac{\Delta W \times 87.6}{A \times T \times d}$$

Where, ΔW is weight loss in mg, A is area of specimen in cm^2, T is time of exposure in hours and d is density of metal in g/cm^3

The degree of surface coverage q can be calculated as[17]

$$\theta = \frac{\Delta W_u - \Delta W_i}{\Delta W_u}$$

Where, ΔW_u and ΔW_i are the weight loss of the metal in uninhibited acid and in inhibited acidic solution, respectively.

Inhibition efficiencies were also determined by using thermometric technique. This involved the immersion of single specimen measuring 2.0 cm×2.0 cm×0.045 cm in a reaction chamber containing 50 mL of solution at an initial temperature of 273±0.1 K. Temperature changes were measured at intervals of 5 min. using a thermometer with a precision of 273±0.1 K. The temperature increased slowly at first, then rapidly and attained a maximum value before falling. The maximum temperature was recorded.

Percentage inhibition efficiencies ($\eta\%$) were calculated[18] as

$$\eta\% = \frac{100(RN_f - RN_i)}{RN_f}$$

Where RN_f and RN_i are the reaction number in free and in presence of inhibitor, respectively and RN (Kmin^{-1}) is defined as

$$RN = \left(\frac{Tm - Ti}{t}\right)$$

Where T_m and T_i are the maximum and initial temperature respectively and t is the time (in min.) required to reach the maximum temperature.

RESULT AND DISCUSSION

Loss in weight and percentage inhibition efficiency for various concentrations of acid and inhibitors are given in *Table* 1. It can be seen that the inhibition efficiency increases with increase in concentration of inhibitor. It is also evident from the *Table* 1 that inhibition efficiency decreases with increasing concentration of acid strength and that all inhibitors display maximum efficiency at the lower concentration of acid used (i.e. 0.5N). All the inhibitors reduce corrosion rate to a significant extent. The highest efficiency was shows by E_B for which a maximum value of 97.09% was obtained at an inhibitor concentration of 0.6% in 0.5N HCl. The corresponding values of surface coverage are shown in *Table* 2. The variation of inhibition efficiency with inhibitor concentration presented graphically in *Fig*. 1 for 0.5N HCl which shows almost linear behaviour with the positive slope indicating that the inhibition efficiency increases with increasing inhibitor concentration.

Generally, the adsorption of organic molecules on metallic surface involves oxygen, nitrogen and sulphur atom and in some cases selenium and phosphorus. In the present investigation plant extract contains oxygen atom which is responsible for the adsorption. This process may block active sites on metallic surface and hence decreases

***Table* 1.** Weight loss (ΔW) and percentage inhibition efficiency (η%) for Aluminium in HCl solution with given inhibitor addition at 273±0.1 K

Inhibitor addition	0.5N HCl (70 min.)		1 N HCl (12 min.)		2 N HCl (4 min.)		3 N HCl (3 min.)	
	ΔW, mg	η%	ΔW, mg	η%	ΔW, mg	η%	ΔW, mg	η%
Uninhibited	275	-	283	-	286	-	290	-
E_B								
0.1%	40	85.45	50	82.33	60	79.02	79	72.75
0.2%	31	88.72	41	85.51	46	83.91	51	82.41
0.4%	19	93.09	26	90.81	36	87.41	40	86.20
0.6%	8	97.09	11	96.11	25	91.25	37	87.24
E_C								
0.1%	46	83.27	56	80.21	62	78.32	83	71.37
0.2%	34	87.63	44	84.45	56	80.41	73	74.82
0.4%	22	92.00	28	90.10	42	85.31	60	79.31
0.6%	13	95.27	18	93.63	27	90.55	49	83.01
E_S								
0.1%	50	81.81	57	79.85	64	77.62	87	70.00
0.2%	38	86.18	46	83.74	59	79.37	97	72.75
0.4%	26	90.54	30	89.39	48	83.21	64	77.93
0.6%	17	93.81	20	92.93	33	88.46	55	81.03

***Table* 2.** Percentage inhibition efficiency (η%) and surface coverage (θ) for Aluminium in HCl solution with given inhibitor addition at 273±0.1 K

Inhibitor addition	0.5N HCl (70 min.)			1 N HCl (12 min.)			2N HCl (4 min.)			3N HCl (3 min.)		
	η%	θ	$\log\left(\frac{\theta}{1-\theta}\right)$	η%	θ	$\log\left(\frac{\theta}{1-\theta}\right)$	η%	θ	$\log\left(\frac{\theta}{1-\theta}\right)$	η%	θ	$\log\left(\frac{\theta}{1-\theta}\right)$
Uninhibited	-	-	-	-	-	-	-	-	-	-	-	-
E_B												
0.1%	85.45	0.8545	0.7688	82.33	0.8233	0.6683	79.02	0.7902	0.5759	72.75	0.7275	0.4264
0.2%	88.72	0.8872	0.8957	85.51	0.8551	0.7709	83.91	0.8391	0.7172	82.41	0.8241	0.6707
0.4%	93.09	0.9309	1.1294	90.81	0.9081	0.9948	87.41	0.8741	0.8415	86.20	0.8620	0.7956
0.6%	97.09	0.9709	1.5232	96.11	0.9611	1.3928	91.25	0.9125	1.0182	87.24	0.8724	0.8348
E_C												
0.1%	83.27	0.8327	0.6969	80.21	0.8021	0.6077	78.32	0.7832	0.5578	71.37	0.7137	0.3966
0.2%	87.63	0.8763	0.8502	84.45	0.8445	0.7348	80.41	0.8041	0.6132	74.82	0.7482	0.4729
0.4%	92.00	0.9200	1.0606	90.10	0.9010	0.9590	85.31	0.8531	0.7639	79.31	0.7931	0.5835
0.6%	95.27	0.9527	1.3040	93.63	0.9363	1.1672	90.55	0.9055	0.9814	83.01	0.8301	0.6889
E_S												
0.1%	81.81	0.8181	0.6529	79.85	0.7985	0.5979	77.62	0.7762	0.5401	70.00	0.7000	0.3679
0.2%	86.18	0.8618	0.7948	83.74	0.8374	0.7118	79.37	0.7937	0.5851	72.75	0.7275	0.4264
0.4%	90.54	0.9054	0.9809	89.39	0.8939	0.9255	83.21	0.8321	0.6951	77.93	0.7793	0.5479
0.6%	93.81	0.9381	1.1805	92.93	0.9293	1.1187	88.46	0.8846	0.8845	81.03	0.8103	0.6305

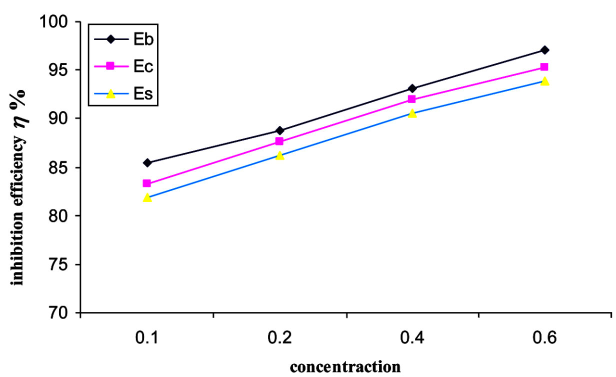
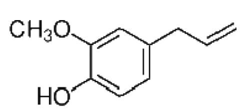


***Fig.* 1.** Variation of inhibition efficiency with stem extract for Al in 0.5N HCl.

the corrosion of the metal. The oxygen atom of terpenoids present in extract of holy basil acts as the reaction centre (polar function) because of its higher electron density resulting in the formation of a monolayer on the metal surface.



Ursolic acid

The $-OCH_3$ group present in ursolic acid exerts a positive mesomeric effect (+M>-I), which increases the electron density at the oxygen atom. This explains the higher inhibition efficiencies displayed by ocimum basilicum (E_B). It has been observed that the inhibition efficiency increasse as the inhibitor concentration increases.

Adsorption plays an important role in the inhibition of metallic corrosion by organic inhibitors. Many investigators have used the Langmuir adsorption isotherm to study inhibitor characteristics.[14,15] Assuming that the inhibitors adsorbed on the metal surface decrease the surface area available for cathodic and anodic reaction to take place. Hoar and Holliday[14] have shown that the Langmuir isotherm,

$$\text{Log}\ [\theta/1-\theta] = \log A + \log C - [Q/2.303\ RT]$$

should give a straight line of unit gradient for the plot of log [θ/1-θ] versus log C, where A is a temperature independent constant, C is the bulk concentration of the inhibitor (percentage) and Q is the heat evolved during adsorption.

The corresponding plots, shown in *Fig*. 2 for 0.5N HCl are linear but the gradients are not equal to unity as would be expected for the ideal Langmuir adsorption isotherm equation. This deviation from unity may be explained on the basis of the interaction among the adsorbed species on the metal surface. It has been postulated in the derivation of the Langmuir isotherm equation that the adsorbed molecules do not interact with one another, but this is not true in the case of organic molecule having polar atoms or groups which are adsorbed on the anodic and cathodic sites of the metal surface. Such adsorbed species may interact by mutual repulsion or attraction. Thus, it is also possible for

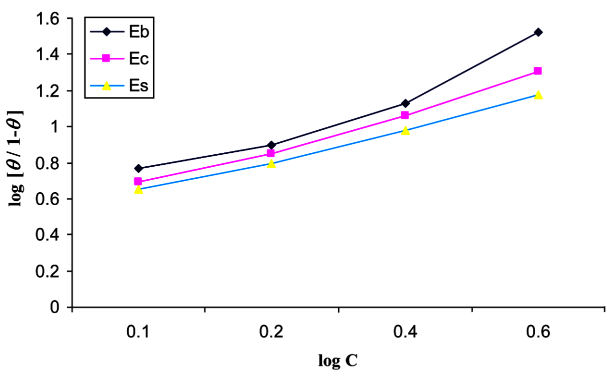


***Fig.* 2.** Langmuir adsorption isotherm for aluminium in 0.5N HCl with inhibition addition.

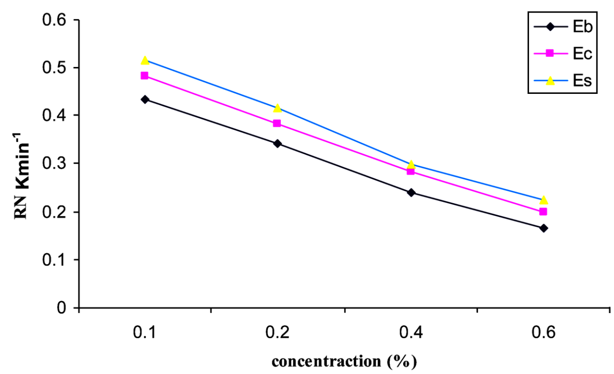


***Fig.* 3.** Variation of reaction number with stem extract for Al in 1.0N HCl.

inhibitor molecule those are adsorbed on anodic and cathodic sites to interact with metallic surface as well as with each other.

Inhibition efficiencies were also determined using the thermometric method. Temperature change for Al in 1N, 2N and 3N HCl were recorded both in presence and in absence of the different concentration of inhibitors. However, no significant temperature changes were recorded in 0.5N concentration. Results summarized in *Table* 3 for HCl show a good agreement with the results obtained by weight loss method. The maximum inhibition efficiency was obtained with highest concentration (0.6%) of inhibitor and with highest concentration of HCl (1.0N). The variation of reaction number (RN) with inhibitor concentration is depicted graphically in *Fig*. 3 for HCl. Figures show a linear deviation which indicates that the reaction number decreases with increasing inhibitor concentration.

CONCLUSION

A study of three different varieties (E_B, E_C and E_S) has shown them to be effective corrosion inhibitors for aluminium in HCl solution. Weight loss method has shown that the inhibition efficiency of holy basil increases with increasing concentration of inhibitor.

Among the extract of different varieties of Holy Basil under investigation, the highest inhibition efficiencies (up to 97.09% in 0.5N HCl) were shown by E_B at a concentration of 0.6%. Both methods (weight loss as well as thermometric) show same trends in corrosion efficiency and

***Table* 3.** Reaction Number (RN) and percentage inhibition efficiency (η%) for Aluminium in HCl solution with given inhibitor addition at 273±0.1 K

Inhibitor addition	1N HCl (12 min.)		2N HCl (4 min.)		3N HCl (3 min.)	
	RN, Kmin^{-1}	η%	RN, Kmin^{-1}	η%	RN, Kmin^{-1}	η%
Uninhibited	1.266	-	4.400	-	6.8	-
E_B						
0.1%	0.433	65.79	1.770	59.77	3.066	54.91
0.2%	0.341	73.06	1.450	68.96	2.700	60.29
0.4%	0.241	80.96	0.975	77.84	2.166	68.14
.0.6%	0.166	86.88	0.875	80.11	1.800	73.52
E_C						
0.1%	0.483	61.84	1.875	57.38	3.300	51.47
0.2%	0.383	69.74	1.575	64.20	2.933	56.86
0.4%	0.283	77.64	1.175	73.29	2.533	62.75
0.6%	0.200	84.20	1.000	77.27	2.000	70.58
E_S						
0.1%	0.516	59.24	1.975	55.11	3.500	48.52
0.2%	0.416	67.14	1.750	60.22	3.133	53.92
0.4%	0.300	76.30	1.425	67.61	2.733	59.80
0.6%	0.225	82.22	1.150	73.86	2.233	67.16

results are in good agreement with each others.

Acknowledgments. One of authors (Nutan Kumpawat) is greatful to R.G.N. fellowship from U.G.C. Govt. of India as J.R.F.

REFERENCES

1. Talati, J. D.; Patel, G. A. *Corrosion prevention and control* **1978**, *25*, 7.
2. Talati, J. D.; Pandaya, J. M.; Patel, G. A. *Proc. Semin. Electrochem. India* **1974**, *14*, 362.
3. Sampat, S. S.; Vogra, J. C. *Corros. Sci.* **1974**, *14*, 591.
4. Talati, J. D.; Patel, C. A. *Transaction of the SAEAST* **1978**, *13*, 139.
5. Kumpawat, N.; Chaturvedi, A.; Upadhyay, R. K. *Protection of Metals and Physical Chemistry of Surface* **2010**, *46*, 267.
6. Ananda Louise Salheyanathan R.; Maruthamuthu S.; Selvanayagan M.; *Indian Journal of Chemical Technology* **2005**, *12*, 356.
7. Jain, T.; Choudhary, R.; Mathur, S. P. *Materials and Corrosion* **2006**, *57*, 422.
8. Sharma, P., Upadhyay, R. K.; Chaturvedi, A.; Parashar, R. *J.T.R. Chem.* **2008**, *15*(1), 21.
9. Abiola, O. K.; Okafor, N. C.; Ebenso, E. E.; Nwinuka, N. M. *Anti-corrosion Methods and Materials* **2007**, *54*, 219.
10. Arora, P.; Kumar, S.; Sharma, M. K.; Mathur, S. P. *E-Journal of Chemistry* **2007**, *4*, 45.
11. Choudhary, R.; Jain, T.; Mathur, S. P. *Bull. Electrochem*. **2004**, *67*, 20.
12. Oguzei, E. E.; *Corros. Sci.* **2007**, *49*, 1527.
13. Okafor, P. C.; Ikpi, M. E.; Uwah, I. E.; Ebenso, E. E.; Elcpe, U. J.; Umoren, S. A. *Corros. Sci*. **2008**, 50.
14. Hoar, T. P.; Holliday, R. D. *J. Appl. Chem*. **1953**, *3*, 582.
15. Meakins, J. R. *J. Appl. Chem*. **1963**, *13*, 330.
16. Talati, J. D.; Gandhi, D. K. *Indian Journal of Technology* **1991**, *29*, 277.
17. Dubey, R. S.; Upadhyay, S. N. *J. Electrochem. Soc. (India*) **1993**, *43*, 239.
18. Aziz, K.; Shams, El-Din A. M. *Corros. Sci.* **1993**, *5*, 4.