Research Article

Pipali (*Piper longum)* and Brahmi (*Bacopa monnieri*) extracts as green corrosion inhibitor for aluminum in NaOH solution

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ABSTRACT

The corrosion inhibition properties of Piper longum fruit extract and Bacopa monnieri stem extract in 1 M sodium hydroxide (NaOH) solution was studied using chemical technique. Both extracts inhibited the corrosion of aluminium in NaOH solution. The inhibition efficiency increased with increasing concentration of the extracts. The Piper longum fruit extract was found to be more effective. The Piper longum extract gave 95% inhibition efficiency.

Keywords: Aluminium; plant extracts; weight loss.
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INTRODUCTION

The investigation of the corrosion behaviour of aluminium in different aggressive environments has continued to attract considerable attention because of the many important applications of the metal. Aluminium relies on the formation of a compact, adherent passive oxide film for its corrosion immunity in various environments. This surface film is amphoteric and dissolves substantially when the metal is exposed to high concentrations of acids or bases [1]. Bared metal surface sites become exposed to the corrodent after the breakdown of the oxide film, leading to a sequence of electrochemical reactions as the metal dissolves. Corrosion is accompanied by many conjugate cathodic processes in which hydrogen gas evolution is often predominant in strong acid or alkaline solutions [2]. Apart from the deleterious effects of hydrogen uptake by a corroding metal, the H_2 gas evolution agitates the interface, dispersing the corrosion product thereby preventing self-inhibition.

Aluminum depends on the presence of natural surface oxide film for its high corrosion resistance in several media, but alkaline solutions are known to render the oxide film non-protective; because OH- ion dissolves the protective oxide and the aluminum surface establishes a very negative potential, with the formation of aluminate ion [3–9].

The corrosion behaviour of pure aluminium and its alloys in aqueous alkaline solutions have been extensively studied in the development of the aluminium anode for the aluminium/air battery [10-14]. Aluminium corrosion within the batteries cause many problems: (i) it passivates the cathode active material, (ii) its solid products increase the electrical resistance, (iii) its soluble products contaminate the electrolyte and increase the self-discharge rate, and (iv) the dissolved Al^{3+} ions migrate to the counter anode and reductively deposit [15].

Attention has been focused on the corrosion inhibiting properties of plant extracts [16–22] because plant extracts serve as incredibly rich sources of naturally synthesized chemical compounds that are environmentally acceptable, inexpensive, readily available and renewable sources of materials and can be extracted by simple procedures.

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Recently, Gossipium hirsutum L. [23] extracts were found to have significant retarding effect on the dissolution of aluminum in alkaline solutions using chemical technique and that the inhibitive action was due to adsorption of the inhibitor molecules onto the metal surface. This paper reports the effect of fruit extract of *Piper longum* and stem extract of *Bacopa monnieri* on the corrosion of aluminium in 1 M NaOH solution using gravimetric technique.

EXPERIMENTAL SECTION

Material preparations
The corrosion tests were performed on aluminum alloy specimens of 2.5 cm×2.0 cm × 0.25 cm sizes. The exposed surface was abraded with silicon carbide abrasive paper from 400 to 1200, degreased with absolute ethanol, rinsed in distilled water, and dried in warm air. The NaOH was BDH grade, used without further purification and 1 M NaOH solution was employed as the corrodent for this study. Stock solutions of *Piper longum* fruit extract and *Bacopa Monnieri* stem extract were prepared as follows: it were dried and blended to powder form; 10 g powder was refluxed in 400 ml double distilled water for 5 h. The refluxed solution was allowed to stand for 8 h, filtered and stored. The obtained filtrate was reduced to 10 ml.

Weight loss determination
The coupons were weighed and their initial weight recorded before immersion in 150 ml open beakers containing 100 ml of 1 M NaOH as corrodent and the addition of different concentrations of the extract at 308 K. The variation of weight loss was monitored after 1 h immersion per coupon at 308 K. After 1 h, the coupons were taken out, dried and reweighed. Percentage inhibition efficiency (%η) was calculated using the following equation:

$$\eta(\%) = \frac{W_o - W_i}{W_o} \times 100 \qquad (1)$$

where, w_i and w_o are the weight loss values of aluminium coupon in presence and absence of inhibitor at 308 K, respectively.

$$\theta = \frac{W_o - W_i}{W_o} \qquad (2)$$

where, w_i and w_o are the weight loss value in presence and absence of inhibitor, respectively.

Fig. 1 Variation of inhibition efficiency of *Piper longum* fruit extract and *Bacopa monnieri* seed extract in 1 M NaOH.

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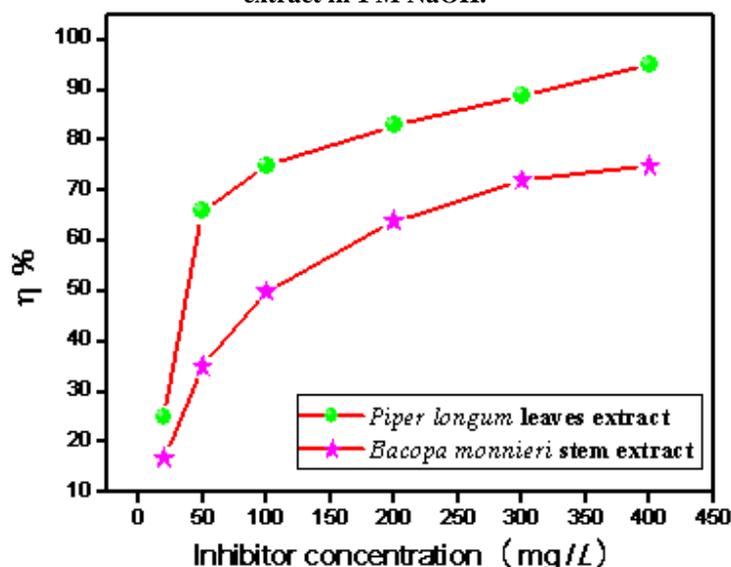
The corrosion rate (C_R) of mild steel was calculated using the relation:

$$C_R \, (mm/y) = \frac{87.6 \times w}{ATD} \tag{3}$$

where w is corrosion weight loss of mild steel (mg), A the area of the coupon (cm^2), T is the exposure time (h) and D the density of mild steel (g cm^{-3}).

Table 1. Corrosion parameters for aluminium in aqueous solution of 1 M NaoH in absence and presence of different concentrations of *Piper longum* and *Bacopa monnieri* from weight loss measurements at 308 K for 1 hrs

	Inhibitor conc. (mg/L)	Weight loss (mg cm^{-2})	η (%)	C_R (mm/y)
Blank	1 M NaoH	15	-	56
Pipali	20	11	25	42
	50	5	66	19
	100	4	75	14
	200	1	83	5
	300	1	89	4
	400	0.8	95	3
Brahmi	20	13	17	47
	50	10	35	36
	100	8	50	28
	200	5	64	20
	300	4	72	16
	400	4	75	14

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Fig. 2 (a) Structures of main constituents of *Piper longum* fruit extract.

a　　　**Piplartine**　　　　　　　　　　　　　　b　　　**Rutin**
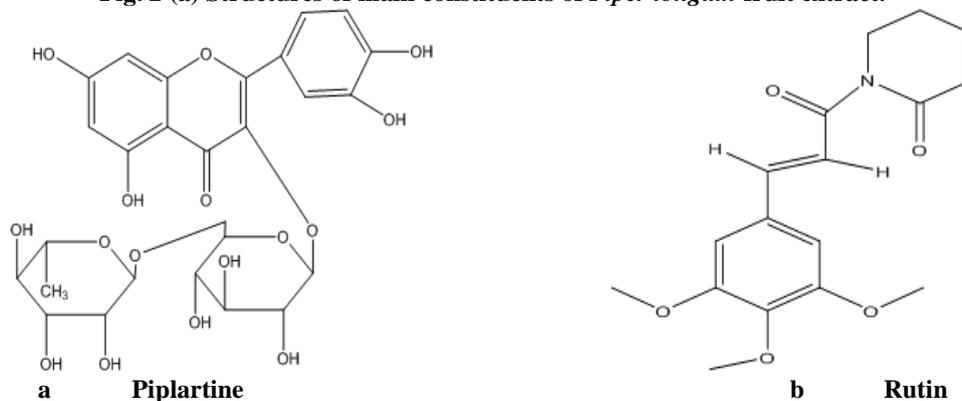
Fig. 2 (b) Structures of main constituents of *Bacopa monnieri* stem extract.

c　　　**Bacoside-A**　　　　　　　　　　　　　　d　　　**Bacoside-B**

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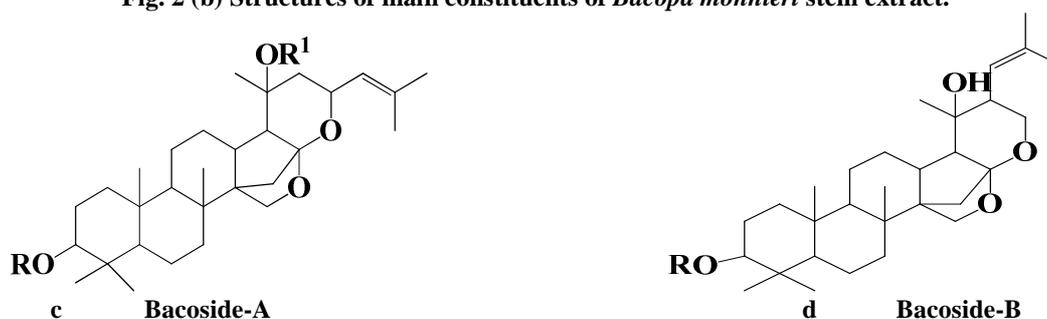
RESULTS AND DISCUSSION

Fig.1a represents the effect of inhibitor concentration on inhibition efficiency in NaoH .The *Piper longum* fruit extract showed maximum inhibition efficiency of 95 % at a optimum concentration of 400 mg/l whereas *Bacopa monnieri* stem extract showed maximum inhibition efficiency of 75% at 400 mg/l. Further increase in extract concentration did not cause any significant change in the performance of the extracts .The values of percentage inhibition efficiency (% η) and corrosion rate (C_R) obtained from weight loss method at different concentrations of *Piper longum* and *Bacopa monnieri* at 308 K are summarized in table 1 and is represented in Fig. 1.

The phytoconstituents of *Piper longum* fruits include several alkaloids such as piperine, piplartine, piperlongumine, piperlonguminine, pipernonaline and piperundecalidine etc., a few unidentified steroids and some reducing sugars and their glycosides [24, 25] are represented in Fig 2 (a). The active constituents of *Bacopa monnieri* stem extract includes Bacoside-A-B (*Bacopa monnieri*) whose structures are given in Fig. 2 (b). The high performance of *piper longum* extract could be due to large size of constituent's molecule which cover wide areas on the metal surface and thus retarding the corrosion. [26]

CONCLUSION

The examined fruit extracts of *Piper longum* and stem extract *Bacopa monnieri* inhibit the corrosion of aluminium in 1 M NaoH. The fruit extract of Piper longum was found to be more effective than stem extract of *Bacopa monnieri* in reducing the corrosion rate of Aluminium in 1 M NaOH. Both the extracts of *piper longum* and *Bacopa monnieri* inhibit corrosion of aluminium in alkali media by adsorption mechanism.

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