



Inhibitive effect by natural *Cyperus esculentus L.* oil on the corrosion of A356.0-type Al-Si-Mg alloy in simulated seawater environment

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Abstract

The effect of *Cyperus esculentus L.* oil as a corrosion inhibitor on the corrosion rate of A356.0-type Al-Si-Mg alloy in simulated seawater environment was investigated using gravimetric method. The corrosion rates were studied in different concentrations of *Cyperus esculentus L.* oil (0.2, 0.4, 0.6, and 0.8 g/v) at temperatures of 30, 50, and 70°C. The results revealed that *Cyperus esculentus L.* oil in 3.5% NaCl-aluminium environment decreased the corrosion rate at various concentrations considered. Results also showed that *Cyperus esculentus L.* oil decreased the corrosion rate of Al-Si-Mg alloy immersion time considered. The minimum inhibition efficiency was obtained at 70°C while the maximum inhibition efficiency of 69.97% was achieved with 0.8g/v inhibitor concentration at 30°C. *Cyperus esculentus L.* oil acted as an effective corrosion inhibitor for Al-Si-Mg alloy within the temperature and concentration range studied. The results demonstrated that *Cyperus esculentus L.* oil adsorbed on the surface of Al-Si-Mg alloy and obeyed Langmuir adsorption isotherm.

Keywords: Al-Si-Mg alloy, gravimetric, adsorption mechanism, interface, thin film.

1. Introduction

Aluminium and its alloys are known to find application in many industries due to their high strength-to-weight ratios, good corrosion resistance, excellent workability, high thermal/electrical conductivity [1-11]. However, the ability of aluminium and its alloy to resist corrosion attack in aggressive environment have been reported to be poor and insufficient [12]. Corrosion of this alloy has been subject of interest among researchers because of the aforementioned importance. Although, in recent years and continuously, various methods, have been put forward to address this limitations: such as alloying addition [13]; thermal treatment [14-17]; composite/nano-composite formation [18,19]. Equally, corrosion resistance of aluminium and its alloys using inhibitors have also been investigated in various environments [5,6,10,11,20-24]. However, some synthetic corrosion inhibitors have been identified to be toxic and non eco-friendly [25,26]. In view of this, search for an eco-friendly and non-toxic corrosion inhibitors have received focus among researchers in recent time. The use of plant extract and oils; otherwise known as green corrosion inhibitors has gained recognition due to their availability, non toxicity and renewable source of materials for wide range of corrosion control [11,27]. The non-toxic nature and edibility of tiger nut oil has been reported [28-32]. In this paper, an attempt was made to investigate the inhibitive effect by natural *Tigernut oil (Cyperus esculentus L.)* on the corrosion of A356.0-type Al-Si-Mg alloy in seawater environment.

2. Experimental procedures

2.1 Materials and sample preparation

An aluminium alloy specimen of cylindrical dimension 20 x 10 mm with chemical composition: 7%Si, 0.3%Mg and 92.7% Al was used as coupons for the corrosion study in 3.5% NaCl solution (simulated seawater). Initially, the coupons were mechanically polished with emery papers down to 600. The samples were degreased by using acetone to remove fatty or oily matters on the metal surface, dried, weighed and stored in a desiccator. The initial weight of each sample was taken and recorded. In each experiment, 3.5% NaCl solution was prepared fresh as required. The natural tiger nut oil (*Cyperus esculentus L.*) used was

obtained from local market in Nigeria in which its physical, chemical properties and fatty acid analysis have been reported (see Tables 1-3). Corrosion studies were conducted independently at variable temperatures of 30, 50 and 70°C.

Table 1: Physical properties of *Cyperus esculentus L.* oil used [33]

S/No	Physical Properties	Value(s)	Units
1	Colour	Golden brown	---
2	Taste	Nutty taste	---
3	Density	914	g/m ³
4	Refractive index at 25°C	1.47	---
5	Specific gravity	0.914	---
6	Percentage Yield of oil	26	%

Table 2: Chemical properties of *Cyperus esculentus L.* oil used [33]

S/No	Chemical Properties	Determined Value(s)	Units
1	Acid number	1.40	%
2	Iodine number	11.74	---
3	pH	3.51	---
4	Saponification number	169	mgKOH/g
5	Free fatty acid number	3.15	---
6	Peroxide number	0.5	Mg/equivalent/Kg

Table 3: Fatty acid analysis of *Cyperus esculentus L.* oil used [33]

S/N	Constituents	% Composition
1	Myristic	0.08
2	Palmitic	13.19
3	Palmitoleic	0.25
4	Margaric	0.08
5	Margaroleic	0.05
6	Stearic	4.32
7	Oleic	68.83
8	Linoleic	11.70
9	Linolenic	0.15
10	Araquic	0.61
11	Gadoleic	0.23
12	Behenic	0.13
13	Lignoceric	0.19

2.2 Gravimetric measurement

The gravimetric corrosion test was carried out on the previous weighed samples with and without inhibitor at 30, 50 and 70°C. The volume of the solution was 150mL with and without the addition of *Cyperus esculentus L.* inhibitor. The *Cyperus esculentus L.* inhibitor concentration was varied from 0.2, 0.4, 0.6 and 0.8 g/v in 3.5% NaCl solution. For each sample, using gravimetric method, the samples were washed, dried and weight taken at interval of 1, 2, 3, 4, 5 h of immersion time. The corrosion rate and inhibitor efficiency were determined along with the degree of surface coverage for each inhibitor concentration at 30, 50 and 70°C.

3. Result and Discussion

3.1 Results

The variation in corrosion rate with immersion time at different immersion temperatures are shown in Figures 1-3. Figure 4 represents the corrosion rate with concentration of inhibitor at different immersion temperatures for 2 h exposure. The variation in percentage inhibition efficiency (% IE) with concentration of inhibitor (C,

g/v) is shown in Figure 5. While the %IE with immersion temperatures for 0.8g/v 1-5 h can be found in Figure 6. Figure 7 shows the adsorption isotherm for the inhibitor in 3.5% NaCl/aluminium condition.

3.2 Discussion

3.2.1 Corrosion rate and inhibitor efficiency

From the results, the corrosion rate of the Al-Si-Mg alloy in simulated seawater environment decreased with addition of inhibitor and immersion time (Figures 1-3). In Figures 1, the sample in NaCl/0.8g/v *Cyperus esculentus L.* oil exhibited an excellent corrosion resistance. Similar trends can be observed in Figures 2 and 3. For example, corrosion rate decreased from 3.83×10^{-8} g/cm²/sec (control) to 1.15×10^{-8} g/cm²/sec (0.8g/v) at 30°C for 2 h immersion time (Figures 1). While at 50°C/70°C (0.8g/v) for 2 h immersion time, corrosion rate decreased from 7.56×10^{-8} / 8.33×10^{-8} g/cm²/sec to 2.68×10^{-8} / 6.70×10^{-8} g/cm²/sec. Also it can be seen that corrosion rate of the aluminium alloy decreased at any immersion temperature used for along with the inhibitor's concentrations (Figure 4). The results show that % IE of the *Cyperus esculentus L.* oil natural oil increases with an increase in the inhibitor concentrations. The reason been that, as the inhibitor concentration increases, the surface area covered by this inhibitor increased hence higher IE was achieved.

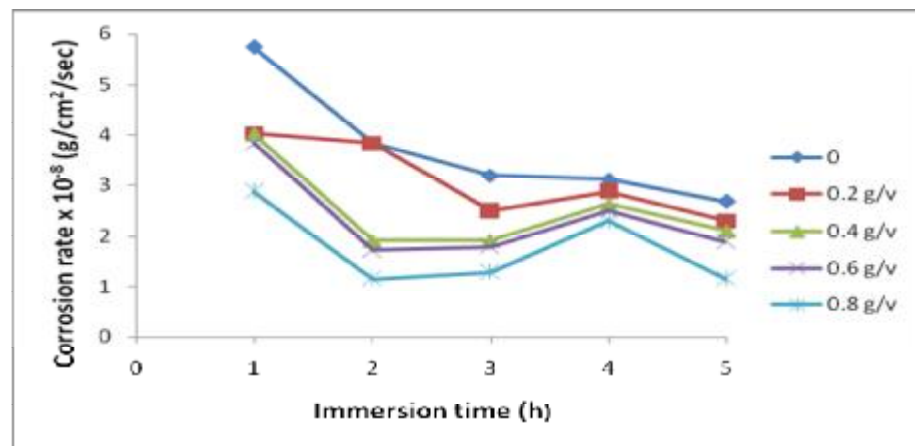


Figure 1: Variation of corrosion rate with immersion time for Al-Si-Mg alloy in 3.5% NaCl solution at 30°C

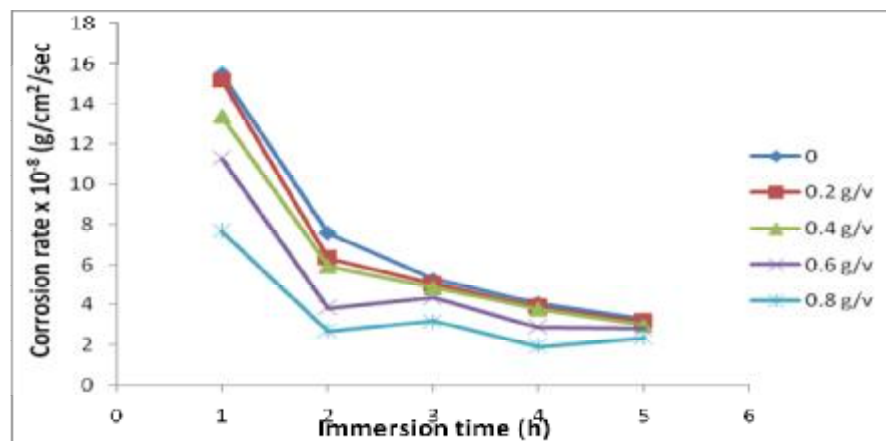


Figure 2: Variation of corrosion rate with immersion time for Al-Si-Mg alloy in 3.5% NaCl solution at 50°C

The results also indicate that the maximum inhibitor efficiency for tiger nut oil was obtained at a concentration of 0.8g/v with percentage inhibitor efficiency of 69.97% at 30°C. Considering Figure 5 at 50°C and 70°C, the maximum inhibitor efficiency was 64.55% and 19.57% respectively. From the trend in Figures 4-6 show that the highest inhibitor efficiency was at 2 h. Specifically, in Figure 6 the highest inhibitor efficiency was obtained at 2 h immersion time at the operating temperatures. From observation, even the maximum percentage inhibitor efficiency at each temperature 30, 50 and 70°C decreased from 30°C down to 70°C operating temperature. The decrease in inhibitor with increase in temperature for tiger nut oil could be attributed to the fact that, at lower temperature, the inhibitor molecules have the tendency to absorb themselves onto the surface of the alloy.

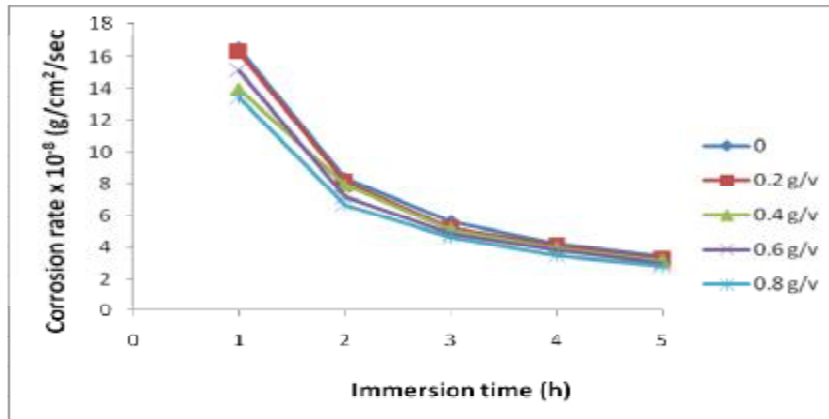


Figure 3: Variation of corrosion rate with immersion time for Al-Si-Mg alloy in 3.5% NaCl solution at 70°C

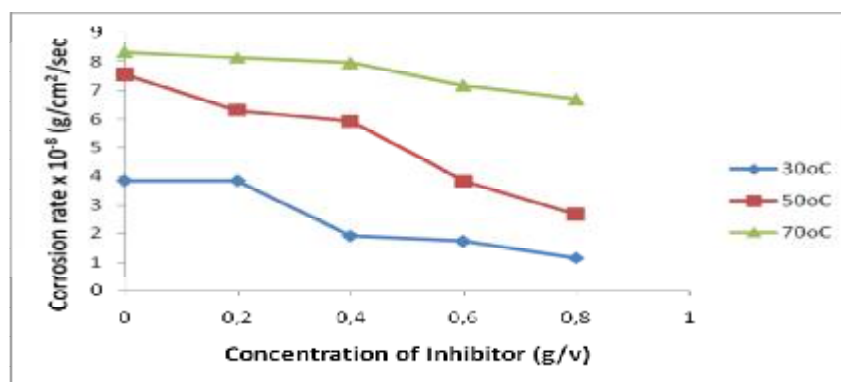


Figure 4: Variation of corrosion rate with concentration of inhibitor at different operating temperatures for immersion time of 2 h

While at a higher temperature, there is desorption of the molecules of the inhibitor from the surface of the alloy due to dissociation of the constituents of the inhibiting substance [34]. From this occurrence, it can be said that the decrease in inhibitor efficiency with increase in temperature could be traceable to the fact that, at lower temperature (30°C and 50°C), inhibitor molecules have the tendency to absorb themselves on the aluminium surface. However, this occurrence is contrary to the report given in [35]. In their work, the inhibition efficiency of Aloe extract and *Azadirachta indica* (AZI) extract for aluminium sample in 0.5 M HCl solution increased with rising temperature, this indicates that Aloe and AZI extracts are good inhibitors in acidic solutions at higher temperatures considered by the authors.

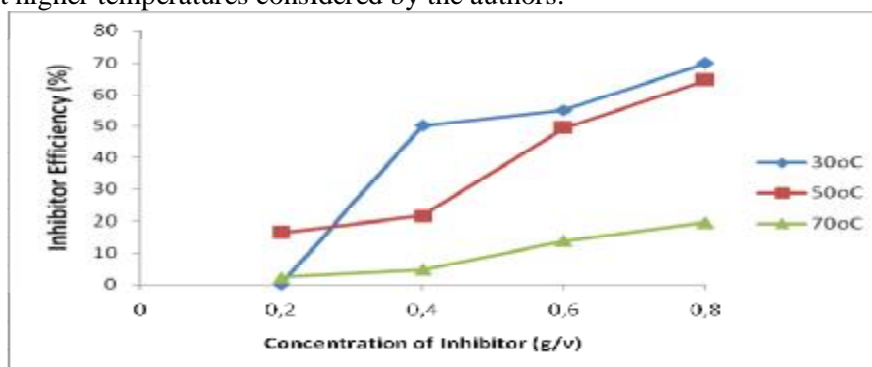


Figure 5: Variation of inhibitor efficiency with concentration of inhibitor for immersion time of 2 h at different operating temperatures

This is similar to the results obtained [18,36-38]. More so, at lower temperature, the inhibitor has the tendency to establish stronger interaction to the surface of the alloy than at higher temperature. Also the absorption of the *Cyperus esculentus L.* oil onto the surface of the alloy at lower temperature prevents the breakdown of the passive film, hence higher corrosion resistance of the aluminium alloy.

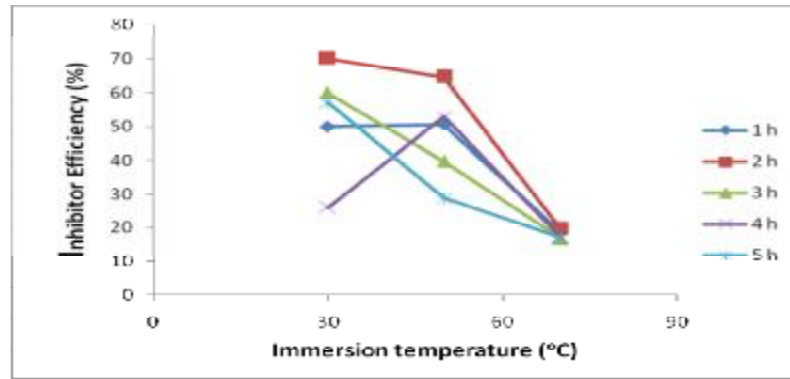


Figure 6: Variation of inhibitor efficiency with immersion temperature at different immersion time for 0.8 g/v inhibitor concentration

3.2.2 Adsorption behaviour

The percentage inhibitor efficiency (% IE) of the aluminium-*Cyperus esculentus L.* oil in NaCl solution were computed using the equation reported [11]. The variation in the %IE using gravimetric is presented in Figures 5 and 6. The results so that *Cyperus esculentus L.* oil can be said to be a good eco-friendly corrosion inhibitor. The adsorption mechanism has been demonstrated with a relationship between C/θ and C which shows linearity (Figure 7). Since the correction factors (R^2) is almost unity (0.9905.), the adsorption behaviour is believed to have obeyed Langmuir adsorption isotherms.

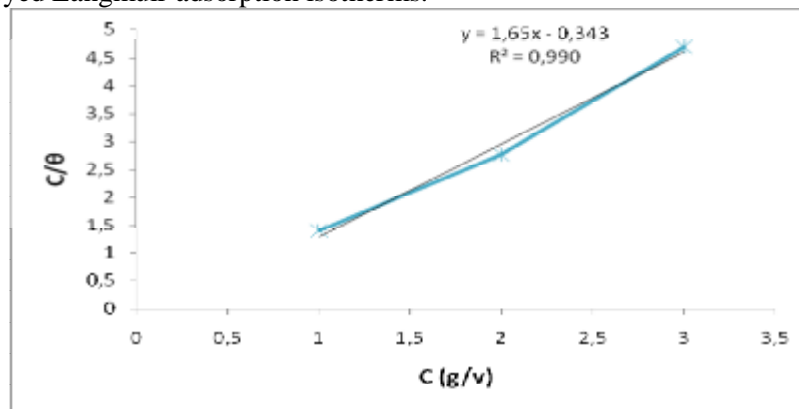


Figure 7: Langmuir isotherm for the adsorption of *Cyperus esculentus L.* oil compounds on the aluminium alloy surface in 3.5% NaCl solution at 5 h immersion time/temperatures

Conclusions

- *Cyperus esculentus L.* oil acted as an effective corrosion inhibitor for Al-Si-Mg alloy in seawater environment at temperature of 30°C
- The inhibitor efficiency of tiger nut oil decreases as temperature increases.
- It was established that the optimum concentration of *Cyperus esculentus L.* oil that should be used as corrosion inhibitor is 0.8 g/v at temperature of 30°C
- *Cyperus esculentus L.* oil acts as a mixed-type corrosion inhibitor and Langmuir adsorption isotherms were demonstrated for the aluminium alloy with correction factor of 0.9905.

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