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# Investigation of the Inhibitive Influence of Theobroma Cacao and Cola Acuminata Leaves Extracts on the Corrosion of a Mild Steel in Sea Water

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**Abstract:** The inhibitive effect of cocoa (*Theobroma Cacao*) and kolanut (*Cola Acuminata*) extracts on the corrosion of mild steel in seawater at roomtemperature has been investigated. The study was carried out using the gravimetric technique. The results showed kola and cocoa leaves extracts as potential inhibitors of mild steel corrosion in seawater and marine environment. The highest inhibition efficiency was obtained when the concentration of the inhibitors was increased up to optimum. There was a sign of synergismwhen 4% of each of the extracts were used to inhibit corrosion in the seawater.

**Key words:** Corrosion, mild steel, inhibitors, theobroma cacao, cola acuminata, inhibition efficiency, seawater

## INTRODUCTION

The tendency for high energy states to transfer into low energy states is a paramount law of thermodynamics that give corrosion one of its numerous definition: "tendency of metals to revert to their natural states"[1]. Attempts to halt this natural phenomenon can cost fortune. Several techniques abound for preventing or controlling corrosion in metals or engineering components. Some attempts to modify the properties of the metals in an environment while some try to alter or modify the environment with the aim of curtailing the corrosive effect of the environment on metals. Many years ago man has succeeded in modifying the environments among other methods through the injection of substances that can reduce the rate of corrosion. These substances, which are sometimes referred to as retarding catalyst, are generally called inhibitors. They function by one of several mechanism. Among these are inhibitions through adsorption on metal surfaces to form an invisibly thin film or perhaps visibly bulky precipitates. Some inhibitors cause metals to corrode in such a way that a combination of adsorption and corrosion products forms a protective layer. The use of inhibitors for corrosion prevention has been well established and numerous inhibitors have been documented. The interest to use plants juice extracts, as inhibitor is still recent. It is believed that there are some active inhibiting chemicals and/or chemical compounds in plants that inhibit corrosion in aqueous or acidic environment. Tannin, for instance has been known to be an effective inhibitor for metals [5]. Empirical results from the work of Loto[3] has shown juice extracts from cashew tree (anacardium accidentale) notable for its tannin content as been capable of inhibiting corrosion of mild steel in 0.5M HCl at 28°C. The inhibitive effect of Jasminumauriculatum and cordia latifolia on corrosion of mild steel in 3% NaCl water has also been studied by Farooqui and Quarishi[4] with positive results. The gentlemen in their paper observed that the plant extracts followed the Langmuir and Freudlich adsorption isotherm, i.e. they inhibit corrosion by adsorption. In this work, the influence of juices extracted from kolanut tree (cola acuminata) and cocoa tree (Theobroma cacao) on the corrosion inhibition of mild steel specimen immersed in sea water has been evaluated. The dianodic influence of the mild steel have also been investigated. This study is expected to contribute meaningfully to the present interest in elucidating the corrosion inhibitive effectiveness of plants.

**Experimental:** The mild steel sample used was obtained from Universal Steel Nigeria Limited situated at industrial Estate in Ikeja, Lagos state. It was obtained in the form of a steel sheet of 0.5mm thick. A spectrometric analysis run in the company gave chemical composition of the steel as :95.44%Fe, 0.17%C, 0.42% Mn, 0.017Cr 0.008%V0.04%P, 0.17%C, 0.04%S.0.66Ni% and 0.025N. Seventy-seven coupons of 50mm x 50mm x 0.5mm were cut with a 3mm hole drilled in each sample for the purpose of suspension in the media. The coupons surfaces polished to 600grit, thoroughly washed under tap, swabbed with acetone and then dried. Subsequently, the initial weight of the coupons were measured on a metler balance to 0.001g accuracy. Immediately

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afterwards, the coupons were immersed completely in the freshly prepared corrosion media.

**Preparation of corrosion media:** Methanol was used in obtaining the aqueous extracts of the plant. After shredding into small sizes, methanol was poured on the leaves of kola and cocoa separately and left for three days to obtain the solution extracts needed for the corrosion inhibition experiment. The extracts were first filtered from the leaves and later vaporized.

Afterwards, the corrosion media were prepared with seawater having different levels of inhibitor concentrations: viz., 0%, 4% and 8% kola extracts, 4% and 8% cocoa extracts and finally 4% and 8% of equal proportions of kola and cocoa leaves extracts as inhibitors. Coupons were suspended in corrosion media by using nylon thread and a rack. To avoid crevice corrosion due to suspension threads the parts of the coupons with holes were painted off before weighing and partial immersion in the corrosion media. The experiment was put under close monitoring as the experiment lasts. On the completion of each exposure test, the coupons were cleaned with wire brush, rinsed under tap and air dried prior to second weighing of samples to determine weight losses due to corrosion.

## RESULTS AND DISCUSSIONS

Figure 1 shows the variation of the weight losses in the corrosion coupon exposed to seawater and the differently inhibited seawater media with time. In general, the weight losses in the exposed coupons increased with time, an indication of progressive increase in corrosion rates of the mild steel in all the media with time. Relatively, the losses in weight with time are more pronounced in the samples exposed in ordinary seawater without inhibitors. Fig. 2 is the graphical illustration of the corrosion rates of mild steel in the media with time. Here the corrosion rate is presented in mils per year. Just like in Fig. 1 the media containing the cocoa leaves extracts exhibited much lower corrosion rates than the uninhibited seawater medium. Fig. 3 depicts exclusively the variation of corrosion rates with time for the seawater inhibited with kola leaves extracts. The inhibition efficiency as can be seen increased with increase in concentration of inhibitors from 4% to 8% especially from the 9$^{th}$ day (216 hours) of exposure. The same type of characteristics were displayed for the corrosion of mild steel in the seawater inhibited with cocoa leaves extract (Fig. 4). The exception to the common behaviour exhibited in Figs. 3 and 4 is the relatively negligible corrosion rates shown during the first 10 days of exposure in the latter inhibited with 8% cocoa leaves extracts. Beyond 10 days, the corrosion of the mild steel increased but not more than the rate shown in the medium with 4% cocoa extracts. It is clear from both Figs. 3 and 4 that the 2 leaves extracts will inhibit the corrosion of mild steel in seawater. Fig. 5 depicts the dianodic influence of the two leaves extracts (kola and cocoa) on the seawater corrosion of the mild steel. When 2% of each of them were combined ( i.e 4% of both) to inhibit the corrosion of mild steel, the corrosion rates were reduced appreciably. But when 4% of each were combined to inhibit the same corrosion phenomenon, the result as shown in Fig. 5 was very positive. The corrosion rates reduced drastically to an all time low. It was less than one mil per year throughout the duration of exposure. The dianodic inhibition exhibited by the cocoa and kola leaves extracts at 4% level of concentration each is synergistic.

**Uninhibited sea water:** Fig.1 shows the curve of weight loss versus exposure time. The curve shows an increase in weight loss as exposure time increases. The increase in corrosion rate could be adduced to the loss of electrons from the coupon. It was observed that thick reddish-brown corrosion debris formed on the coupon sheet. There was also a slimy suspension that appeared as corrosion product. Observation during the experiment showed that the uninhibited seawater solution showed progressive colour change from transparent solution to brownish solution due to the release of various forms of corrosion products suspected to be $Fe_2O_3$, Fe $(OH)_3$ and $Fe_3O_4$ that were formed on the surface of the corroded surface The high corrosion rates obtained during the tests is most probably due to break down of the oxide film on the coupon by chloride ions from the sea water environment.

**Inhibition with 4% Acuminata leaf extracts:** The corrosion rate reduced after 72 hrs and fluctuated at a particular high range. The corrosion rate then increased to the higher values up to the end of the eighth day. This sudden decrease in corrosion rate as shown in Fig 3 could be due to the inhibitive film formed on the surface of the coupon but as exposure time increased the chloride ions present in the seawater penetrated the film and allowed corrosion to occur. This became apparent after exposure time when the rust formed was removed with a wire brush during descaling. The increase in corrosion rate values shows that the inhibitor efficiency at 4% dosage is insufficient for any reasonable inhibition of the coupon.

**Inhibition in 8 % acuminata leaf extracts:** There was a gradual improvement in inhibitor efficiency at 8 % dosage. The tests here showed low corrosion rate values after 72 hrs of exposure. The inhibitor efficiency of the kola extract increased with inhibitor dosage. The increase in inhibitor efficiency can be

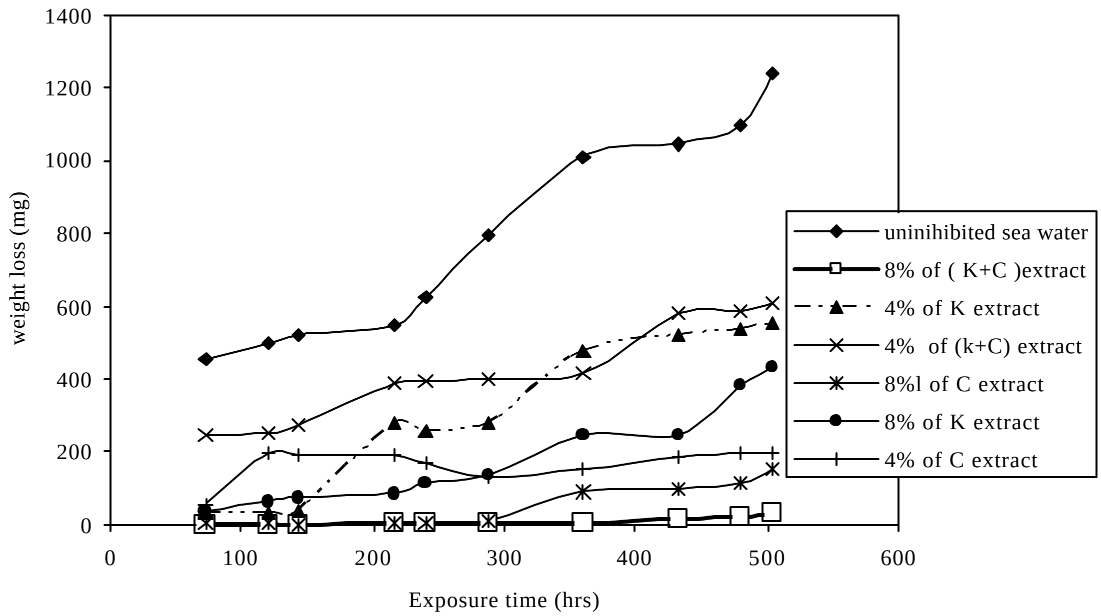


**Fig. 1:** Variation of weight loss verus exposure time(hrs) for mild steel in sea water with leaf extracts.

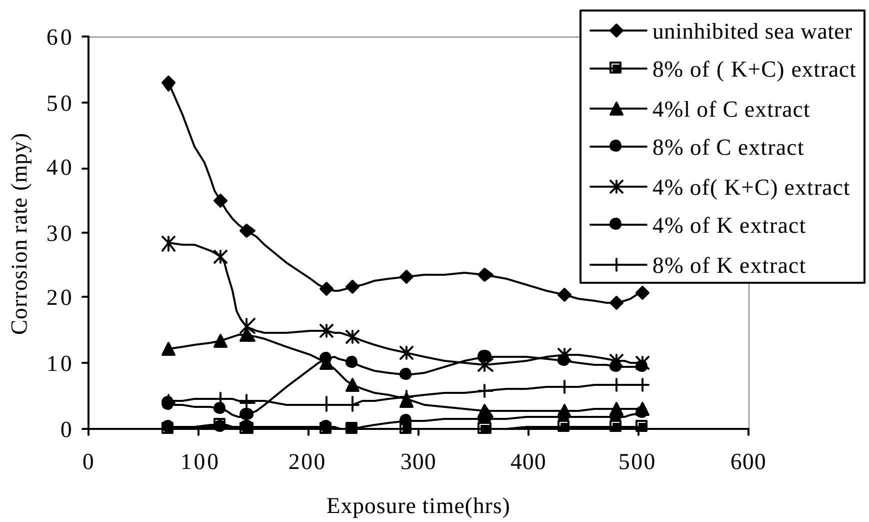


**Fig. 2:** Variation of corrosion rate with exposure time for mild steel in sea water with the leaf extracts.

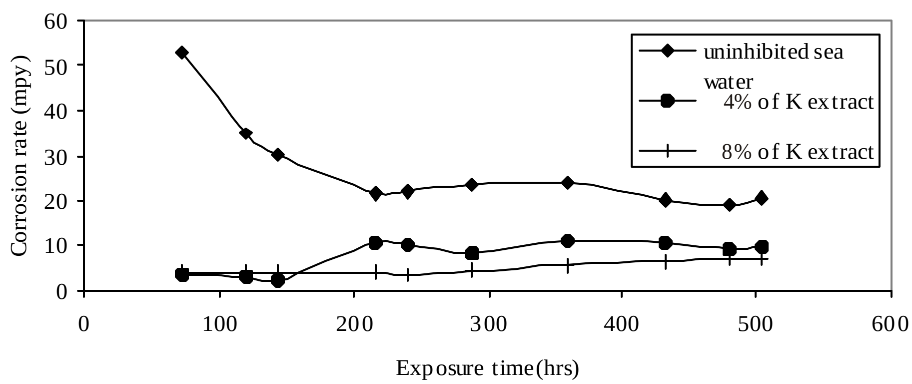


**Fig. 3:** Variation of corrosion rate with exposure time for mild steel in sea water with the leaf extracts.

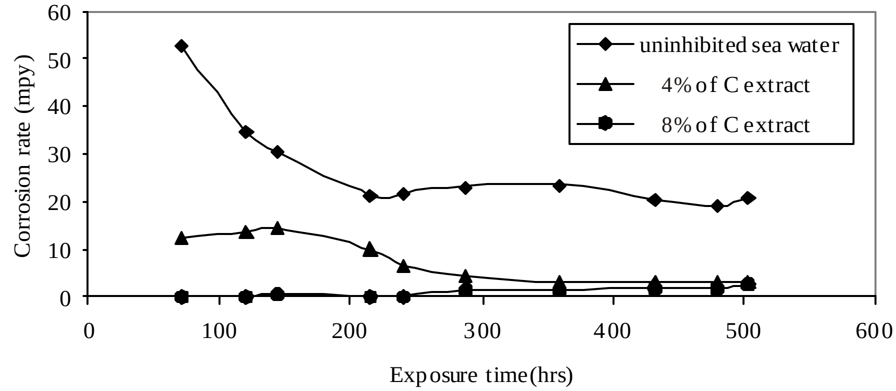


**Fig. 4:** Variation of corrosion rate with exposure time for mild steel in sea water with the leaf extracts.

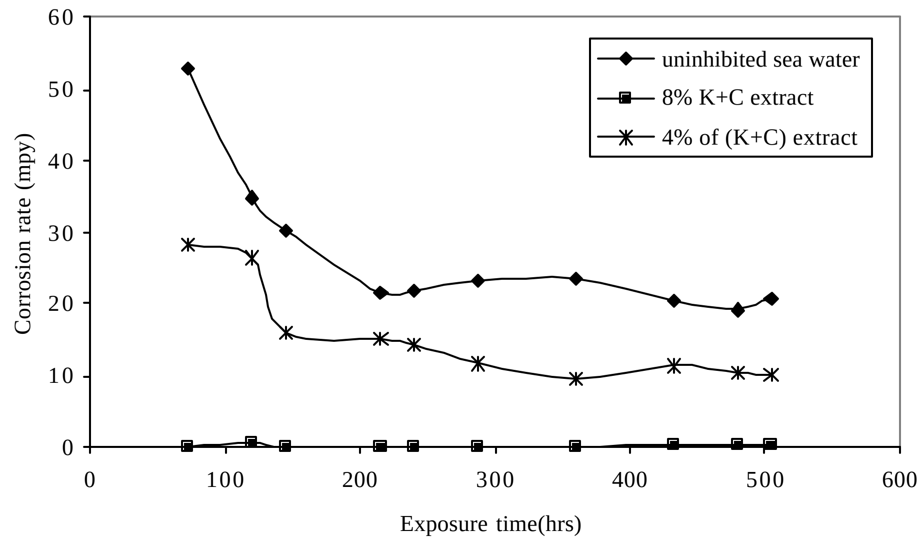


**Fig. 5:** Variation of corrosion rate with exposure time for mild steel in sea water with the leaf extracts.

adduced to the widerspread of the passive film formed on the coupon surface by the leaf extract.

**Inhibition with 4% theobroma leaf extracts:** The weight loss of the coupons here only became noticeable after 240 hrs. The corrosion rates of the coupon was initially high in the first few hrs of the experiment. The corrosion rate curves also showed a decrease in corrosion rate after 360hrs and then a slightly increasing corrosion rate as can be seen in Fig 4. This can be adduced to the fact that the inhibitor and the corrosion product combined to form a passive film on the surface of the coupon.

**Inhibition with 8% theobroma leaf extracts:** The weight loss versus exposure time as shown in Fig.1 indicate continued weight loss with time. The curves for the corrosion rates vs. exposure time for the 8% level of inhibition with theobroma cacao extracts decreased from the highest to the lowest rate(Fig. 4). The decrease in corrosion rate is an indication of the effectiveness of the inhibitor to slow down the corrosion rate of the coupon.

**Inhibition with 4% (acuminata + theobroma) leaf extract in 500ml of seawater:** This test has inhibited the seawater corrosion with extracts from both plant species with the objective of studying the dianodic influence of the two inhibitors on the corrosion of the mild steel.

There was high weight loss of the coupon especially when compared to the other coupons within the first 72 hrs when the coupon had lost 241mg. At the last day of the experiment the coupon had lost a total of 609mg. The corrosion rate versus exposure time showed a decrease in corrosion with exposure time, an indication that the combined inhibitors could reduce corrosion of the coupon. The relatively high corrosion rates can be attributed to the possible interaction between the 2 inhibitors leaving behind products that could not render effective inhibition due to non coverage of the surface of the specimens.

**Inhibition with 8% (kola acuminata + theobroma cacao) leaf extracts:** The weight loss of the coupon in this mixed leaves extract had the least values in test medium after 72hrs. The coupon lost between 1mg and 23mg after 504hrs The curves in Fig1 indicates weight loss versus exposure time. The corrosion rate curves had the least values as shown Fig 5. The curves showed the least corrosion rates and increased slightly with increased exposure time. The leaf extracts thus reduced the corrosion of the coupon.

It can be reasonably stated from the work of others that tannins present in acuminata and theobroma extracts are the agents responsible for the reduction of the rate of corrosion of mild steels in sea water. The active constituents of the extracts consist of mainly $N_2$ and $O_2$ compounds. Inhibition is said to be brought about by physical adsorption of the reactive constituents through their N and O active sites. These compounds form complexes with metallic cations. It is these complexes that probably cause the blocking of the micro-anodes and micro-cathodes that are generated on the metal surfaces when in contact with a corrodant, thus suppressing metal dissolution.

## Conclusions:

1. In summary the best result was obtained with 8% of acuminata and theobroma leaf extracts as inhibitors. The efficiency of the dianodic inhibition in seawater was 99.2%. The 4% extract of the same solution obtained inhibitor efficiency of 61.47%. The poorest inhibitor efficiency came from the seawater inhibited with 4% kola acuminata extracts.
2. It can be reasonably concluded that tannins present in acuminata and theobroma can reduce the rate of corrosion of a mild steel sheet in sea water.
3. The inhibitor efficiency of all the extracts increased with increase in extract concentration until maximum inhibitor efficiency was obtained.
4. The research also shows that the dianodic inhibition of mild steel corrosion in seawater by theobroma cacao and acuminata leaves extracts could afford reasonable protection at the right inhibitor dosage.
5. The inhibitive performance of the organic inhibitors is enhanced in synergism.

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