Inhibiting Corrosion of Crown Corks of Fanta Using an Eco-Friendly Inhibitor

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ABSTRACT: *The inhibiting effect of the plant extract of Dialum guinnesse (D.G) on mild steel (a low carbon steel and the material used in the production of crown corks of carbonated drinks) was investigated at three temperatures: 25°C (ambient), 5°C (fridge) and -3°C (freezer) using Fanta, a carbonated drink as the corroding environment by method of gravimetric technique. The fruit extract was extracted using two methods: refluxing using Fanta and cold ethanol extract and thereafter, metal coupons (20mm X 20mm) were dipped into the solutions so as to form a thin film of the plant extract on the surface of the coupon. The experimental set up consisting of the coupons treated with inhibitors and those uninhibited were dipped into plastic bottles of Fanta and allowed to stand for six weeks at these temperature conditions. The weight losses of the metal coupons were deduced from which corrosion rates and inhibition efficiencies were calculated. The result showed that the reflux extract, hereinafter called the Fanta extract had a better inhibitive property as can be deduced from the plots of weight loss, corrosion rates and inhibition efficiency. Inhibition efficiencies for ethanol extract were 61%, 64% and 70% for 25°C, 5°C and -3°C respectively and 59%, 64% and 71% for the Fanta extract. SEM surface morphology validated the result as the inhibited metal coupon appeared better protected than the uninhibited coupons.*

Keywords: ***Dialum guinnesse*, corrosion inhibition, crown cork, carbonated drink, mild steel**

INTRODUCTION

The crown cork (also known as a crown seal, crown cap or just a cap), the first form of bottle cap, was invented by William Painter in 1892 in Baltimore. It is made of tinplate, electrolytically lined with tin, or TFS steel, chromium plated sheet metal. The crown cork was the first highly successful disposable product. Inasmuch as it is highly disposable, it forms part of a consumable that when it corrodes, it affects the consumer of the products. Iron and its alloys have found its use in the making of crown corks. Excessive corrosion attack is known to occur on this metal deployed in service in aggressive environments. A significant method to protect such metals is the introduction of corrosion inhibitors that hinder the corrosion reaction and thus reduce the corrosion rate. Inorganic substances such as phosphates, chromates, dichromates, silicates, borates, tungstates, molybdates and arsenates have been found effective as inhibitors of metal corrosion [1]. Many synthetic compounds have shown good anticorrosive activities. Most of them are highly toxic to both human beings and environment. The safety and issues of corrosion inhibitors arising in industries have always been a global concern. Such inhibitors may cause reversible or irreversible change to the organs, disturb a biochemical process or an enzymatic system at some sites in the body. The toxicity may manifest either during the synthesis of the compound or during its application [2].

Plant extracts have become important as an environmentally acceptable, readily available and renewable source for wide range of inhibitors. They are the rich sources of ingredients which have very high inhibition efficiency [3]. Acid solutions are widely used in many industrial processes, besides Hydrochloric acid, Phosphoric and Sulphuric acids are regular aggressive solutions for acid cleaning and acid descaling due to their special chemical properties. The use of corrosion inhibitors is one of the most practical methods of protecting the corrosion of metal and decreasing hydrogen evolution [4, 5].*Dialium guinnesse* (Velvet tamarind) is a tall tropical fruit bearing tree. It belongs to the leguminosae family and has small typically grape sized edible fruit with brown hard edible shells. It grows in dense forests in Africa along the southern edge of the Sahel. It can be found in West African countries like Ghana, where it is known as "yoyi", Sierra Leone, Senegal and Nigeria, where it is known as Awin in Yoruba, Icheku in Igbo and Tsamiyar and Kurm in Hausa. The leaves have medicinal properties and are used against several diseases, its pulp is edible and may be eaten raw or soaked in water and consumed as beverage [6](www.wikipedia.org). The extract of *Dialum guinnesse* was found to have Carbohydrate, reducing sugars, tannins, phobatannins, flavonoids, saponins, Cardiac glycoside, steroids/triterpenes and alkaloids. With the presence of these active and heterocyclic compounds on the plants to be used (*Dialum guinnesse*), adsorption of the plant constituents on the metal surface is facilitated and hence, inhibition of the corrosion of the metal is expected [7].

Most corrosion inhibition research work have been centred on aggressive environment such as in acids or alkaline solutions and the application has not been at food industries such as carbonated drinks bottling companies. Crown corks of Fanta corrode over time because of presence of carbon dioxide – an acid gas used in preserving the drinks. The crown corks is made of low carbon steel mostly electroplated with chromate which serve as a surface finisher and a corrosion inhibitor. In spite of the surface coatings, most times the crown corks get corroded. This has led to negative word of mouth effect on the product and consequently, decline in the demand of the product. This also has led to consumer dissatisfaction; hence producers of Fanta have drifted to the use of plastic containers for its production.

This work therefore seeks to create the possibility of using the extract of *Dialum guinnessse* as an effective corrosion inhibitor for use in the inhibition of crown corks of carbonated drinks (Fanta) by bottling industries.

MATERIALS AND METHOD

MATERIALS

The materials required to carry out this experimental research are mild steel, *Dialum guinnesse*, silicon emery paper (grade nos 200, 400, 600), digital weighing balance, refrigerator with freezer and fridge compartments, thread, filter paper, vernier callipers, micrometer screw guage, desiccators, hydrochloric acid, acetone, ethanol, distilled water, SEM machine.

METHOD

Preparation of coupons

The mild steel sheet was purchased from the materials marked in Aba South LGA of Abia State and the spark analysis was conducted at Petroleum Training Institute, Effurun, Warri, Nigeria. The percentage mild steel compositions are C = 0.05, Mn = 1.13, Si = 0.05, P = 0.91, S = 0.85, Cu = 0.09, Pb = 0.15, Ve = 0.13, Mo = 0.08 and Fe = 96.56.

The mild steel sheet was cut into coupons of dimensions 20 mm X 20 mm and a hole of 2.5 mm was drilled at the centre but to one end of the coupon. The hole was drilled on the coupon to enable for insertion into the corrosive media. The metal specimens were polished with silicon emery abrasive paper, degreased with ethanol and dried in acetone.

Corrosive environment

The corrosive media used for this experiment was a carbonated drink – Fanta which is a product of Nigerian Bottling Company (NBC).

Preparation of Plant extract

Dialum guinnesse had it black seed cover removed to reveal the sweet edible region (pulp) which was air dried, pulverized and stored in a bottle. Two different methods of extraction were used for extracting. Firstly, the inhibitor was put into a mixture of ethanol and water with ratio 40: 60 and left to stay for 24 hours before filtration. Secondly reflux method was used in which inhibitors were inserted into the corrosive media (Sprite, Fanta and Coke) in the ratio of 1:24 for sap and corrosive media respectively and heated in a refluxing machine for three hours.

Dipping of Coupons

The blank experiment was conducted by dipping the air dried coupons into the drink and letting them remain in the medium for six weeks. They were checked and retrieved on weekly basis to obtain the weight of the uninhibited metal. This served as the control experiment [9 – 11].

The main experiment was conducted by first dipping the cleaned and weighed metal coupon in to the *Dialum guinnesse* plant extract for 5 minutes. This was to form a protective thin film of the inhibitor on the metal coupon. The coupons were retrieved after the 5 minutes and allowed to air dry. These coupons were then introduced into the corrosive media – Fanta. The set up was such that six of each medium were placed at temperatures of 25°C (ambient), 5°C (fridge) and -3°C (freezer). The experimental set up were allowed to stand for six weeks of which identified coupons were retrieved weekly and subsequently washed, dried and reweighed to obtain the weight loss.

The corrosion rates were calculated using the formula in equation 1 [12 – 15]:

$$CR = \frac{k\Delta w}{\rho A t} \quad (1)$$

Where
CR = Corrosion rate in mm/yr
k = Corrosion rate constant (534 mpy; mils per year).
Δw = Weight loss in grams
ρ = Density of the steel (g/cm^3)
A = The exposed area of the coupon (cm^2)
t = Immersion time (hrs)

The inhibition efficiency which is the percentage of reduction of corrosion rate without and with the inhibitor was calculated using the formula [7, 18, 19]:

$$I\% = \left(1 - \frac{W_1}{W_2}\right) \times 100 \quad (2)$$

where W_1 and W_2 are the corrosion rates of inhibited coupons and uninhibited coupons respectively.

SCANNING ELECTRON MICROSCOPY

The XL-30FEG Scanning Electron Microscope was used to study the surface morphology of the metal specimen before and after immersion in the different corrosive media in the absence and presence of CA. The mild steel specimens were those used in the gravimetric analysis.

RESULTS AND DISCUSSION

Corrosion Inhibition by *Dialum guinnesse* extracts

The obtained results for the use of *Dialum guinnesse* as a corrosion inhibitor are presented in Figures 1 – 6. The obtained results reveal graphical information on the corrosion inhibition effect of DG in Fanta. It shows that in the presence of *Dialum guinnesse*, the corrosion rate values reduced considerably. Subsequently, a plot of the weight loss reveals that the loss was reduced as the exposure time increased. This indicates that particles of the *Dialum guinnesse* extract which had become attached to the surface of the metal protects sucuh surface from interactions and charge transfer, hence reducing weight loss. This result conforms to the results gotten by several researchers [18-20].

Effect of Temperature

Temperature has a pronounced effect on the corrosion behavior of metals [22]. It was observed that the higher the level of temperature of the corrosive solution, the higher the corrosion rate and vice versa. The change of the corrosion rate with the temperature was studied in these environments; both in the absence and in the presence of DG at the various temperatures studied and the results are presented in Fig. 4 to 6. The obtained results revealed that at higher temperatures both weight loss and corrosion rates values was more compared to the obtained values at lower temperatures studied indicating that corrosion rates are higher with higher temperatures. This result complies to results gotten by several researchers [9, 11, 22].

Inhibition Efficiency

The values of inhibition efficiency obtained for *Dialum guinnesse* in the aggressive environments studied are presented in graphs as shown in Figures 7 to 9. This was determined using the relation presented in equation 2. The obtained results also reveal that inhibition efficiency of *Dialum guinnesse* was better at lower temperature compared to higher temperatures: the maximum value of inhibition efficiency obtained for DG at – 3°C and at 1008 hrs of immersion is 74%, while those obtained at higher temperatures of 5°Cand 25°Care 63.8% and 66.6%, respectively. The result also showed that the ethanol extract had a better inhibitive property producing an inhibition of 61% against 59% from the Fanta extract at 25°C, 64% for both extracts at 5°C and 70% against 71% at -3°C.

Effect of Immersion Time

The Figures presented in 1 to 6 again, show that immersion time has a significant effect on the corrosion of mild steel. In the presence of DG, it was observed that inhibition efficiency reduced with an increase in immersion time. Also, the values of weight loss increased considerably, but the rate/magnitude of corrosion gradually reduced. The observed reduction could be due to the gradual adsorption of more *Dialum guinnesse* species onto the mild steel surface with over time and also the formation of corrosion products especially in the uninhibited environment. The presence of more inhibitor species and corrosion products helped to resist the penetration of these corrosive species onto the metal surface. The observed effect also accounts for the reduction of corrosion rates over time as shown in Figures 4 – 6.

The obtained results for the use of *Dialum guinnesse* as a corrosion inhibitor are presented in the figures 1-9 below. The results obtained reveal that *Dialum guinnesse* afforded a significant effect on the corrosion inhibition of mild steel in Fanta. In the presence of *Dialum guinnesse*, both the weight loss and corrosion rate values reduced as well and better protection of the mild steel surface was observed also.

SEM analysis

Scanning Electron microscopic images (Fig. 10 i & ii) of the mild steel immersed without and with the inhibitor respectively was captured. Careful observation of the images which showed the fact that the uninhibited metal had a smoother surface than the inhibited coupon implied the presence of the constituents of DG molecules (alkaloids, tannin, saponin, Anthraquinones, flavonoids, terpenoids, steroids and cardiac glycoside) which reduced the active dissolution of the mild steel by formation of a protective film, which accounts for a different layer, adsorbed on the surface of the metal.

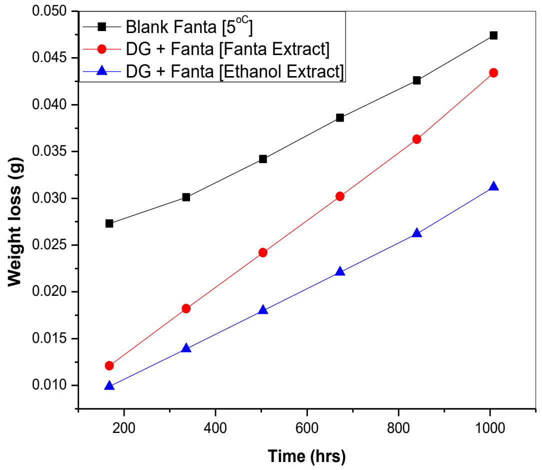

Fig. 1: Variation of weight losses of DG in Fanta solution at 5°C.

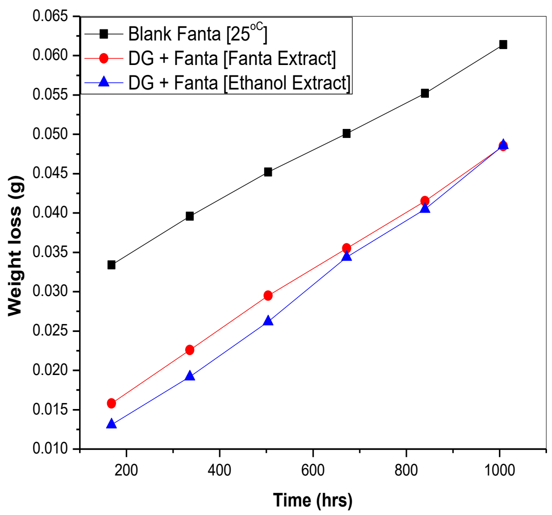

Fig. 2: Variation of weight losses of DG in Fanta solution at 25°C.

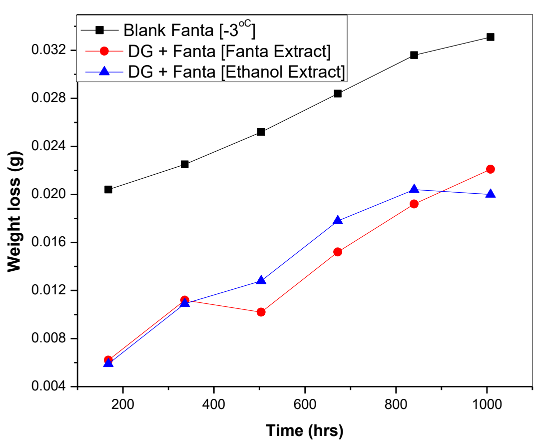

Fig. 3: Variation of weight losses of DG in Fanta solution at - 3°C.

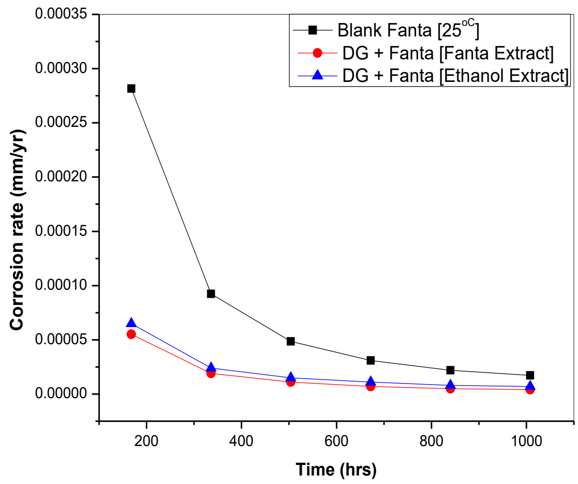

Fig. 4: Variation of corrosion rates of DG in Fanta solution at 25°C.

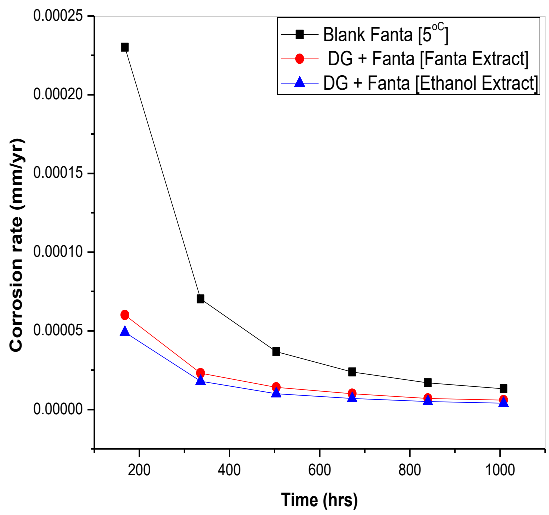

Fig. 5: Variation of corrosion rates of DG in Fanta solution at 5°C.

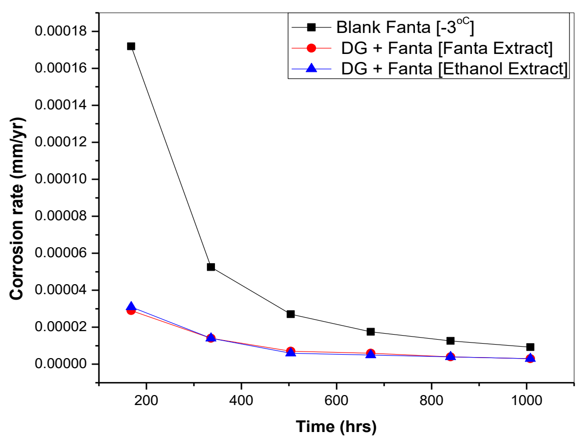

Fig. 6: Variation of corrosion rates of DG in Fanta solution at - 3°C.

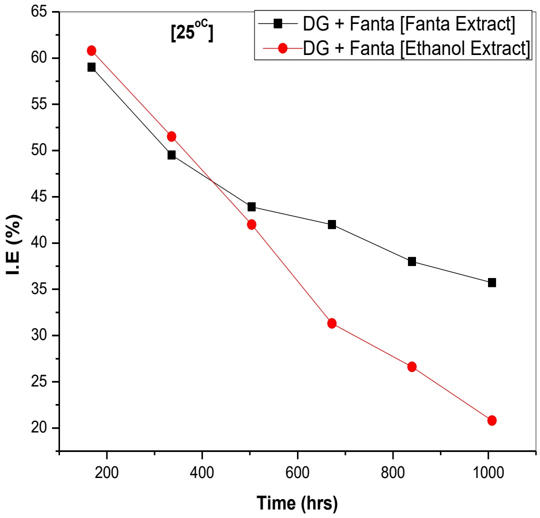

Fig. 7: Variation of inhibition efficiencies of DG in Fanta solution at 25°C.

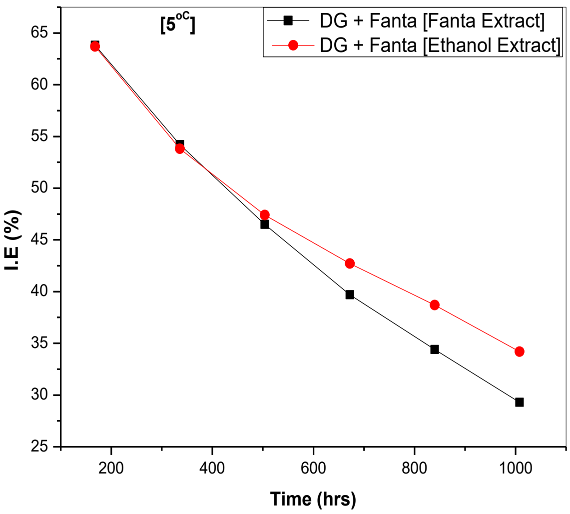

Fig. 8: Variation of inhibition efficiencies of DG in Fanta solution at 5°C.

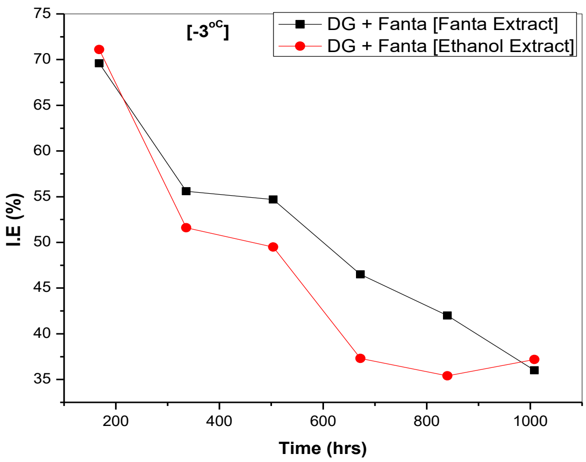

Fig. 9: Variation of inhibition efficiencies of DG in Fanta solution at - 3°C.

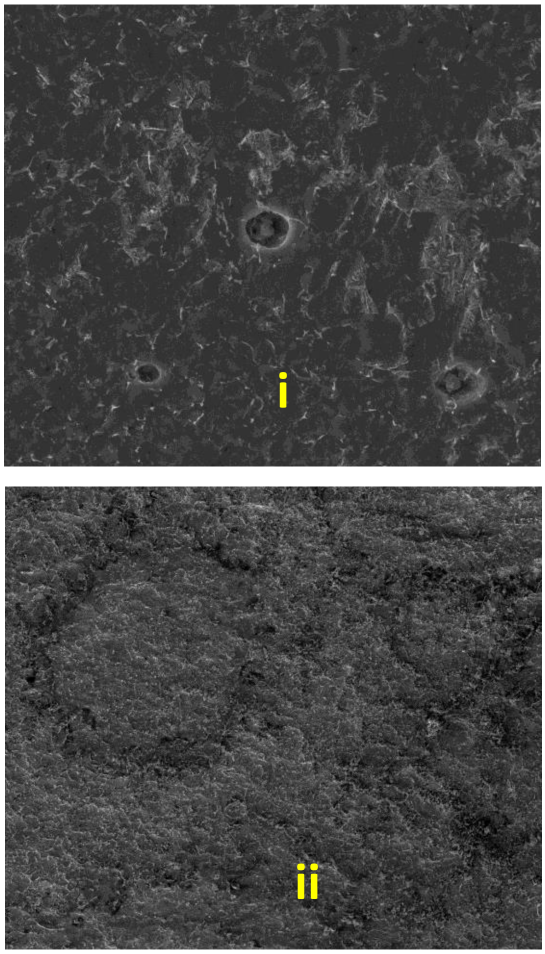

Fig. 10: SEM images of the mild steel surface after immersion at 25°C in Fanta in (i) the absence of the inhibitor (ii) the presence of DG

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