INVESTIGATION OF CORROSION INHIBITION MECHANISM OF MUSA PARADISCA PEELS IN A CARBONATED DRINK (SPRITE) IN NIGERIA.

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Abstract
Corrosion inhibition of mild steel - a certified material used in production of crown cork of carbonated drink solution was investigated using musa paradisiaca. This was done by the method of gravimetric technique in which two extraction methods of ethanol extraction and reflux method were adopted. The work was also subjected to scanning electron microscopy imaging test. The gravimetric studies were carried out at the temperatures of – 3^oC, 5^oC and 25^oC which correspond to the temperatures of the freezer, fridge and the ambient temperature corresponding to the environments where the carbonated drinks are kept. MP showed inhibition efficiency of 68% and 61.4% respectively for Sprite extract and ethanol extract at – 3^oC, 63% and 59% respectively for Sprite extract and ethanol extract at 5^oC and 50% and 49.2% respectively for Sprite extract and ethanol extract at 25^oC after 1008 hours of immersion. All these values show that inhibitor extracted by refluxing Sprite yielded better values of inhibition efficiencies in comparison with ethanol extraction method.

Introduction

Carbonated Drinks constitute a great proportion of food consumed in homes all round the world. Most of these drinks come in glass bottle which are corked using crown corks. These crown corks repeatedly make contact with the drinks and become slightly acidic due to dissolved carbon IV oxide ($C0_2$) dissolved in the solution and as well are subjected to variation in temperature.

Spark analysis has shown that crown corks are made of alloys of iron and precisely mild steel. Iron and its alloys are extensively used in industries. Their usage varies with the environment in which they are used. Excessive corrosion attack is known to occur on metals 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, silicates, borates, tungstates, molybdates and arsenates have been found effective as inhibitors of metal corrosion (Oguzie, 2008).

As such crown cork of carbonated drinks corrode with time under storage conditions and this can lead to negative impact on the product and consequently, decline in the demand of this product (Akoma et al, 2015). A careful observation on the trend of corrosion studies shows that the studies overtime had been centered on aggressive environment such as acid solutions and alkaline solution (Nnanna et al, 2011).

Corrosion cannot be eliminated totally. However efforts have been made to reduce corrosion. In-organic substance such as chromates, phosphates, dichromate's, silicates, borates, tungstates, mollyberates and arsenates have been found effective as inhibitor of metal corrosion (Oguzie, 2008). Some of these in-organic inhibitors have been mixed with their oxides to protect the surface of crown corks. These inorganic inhibitors are poisonous hence they portend severe health challenge to the consumers.

Consequently it became a challenge to provide alternatives to this in-organic inhibitor which will be free from poison and are eco friendly. This gave birth to green corrosion inhibitors which are inhibitors derived from plant extracts. Plant extracts have been found to be rich in tannin, flavonoids, alkaloids and saponin. These phytochemical compounds have proven to be good inhibitors of corrosion.

Corrosion studies on inhibition of crown cork in Sprite (a carbonated drink in Nigeria) have earlier been carried out at different temperatures using dialum Guinness (velvet tamarind - a tropical fruit bearing shrub) by Akoma and Osarolube, (2017). The result of the two extraction techniques used showed that a maximum inhibition effectively of 71% was obtained. In furtherance to the investigation of green corrosion inhibitors, this work seeks to investigate the corrosion pathway of inhibition using unripe peels of Musa Paradisiaca (MP), otherwise known as plantain.

The plantain plant is rich in insulin, alkaloids, tannins and noradrenalin They are reported to be active against dysentery, ulcer, skin infections, prostitis, diabetes and gonorrheal/syphilis (Grand, Wondergen, and Peter, 1990: Adodo, 2002). Therefore, incorporation of MP into the drink is inferred to increase the health benefit unlike the in-organic compounds. More so, Ighodaro (2012) and Nwankwo and Osaro-Mathew, (2014) noted that the root extract of plantain and unripe plantain peels possess biologically active substances such as tannins, saponins, alkaloids, glycosides and anthraquinones (Nwankwo and Osaro-Mathew, 2014).

Materials and Methods

The materials used in carrying out this experimental research are mild steel, Musa Paradisiaca peels (powder), silicon emery paper (grade nos. 200,400, 600) digital weighing balance, refrigerator, thread filter paper, vernier calipers, micrometer screw gauge, distill water, ethanol, acetone hydrochloric acid and SEM. The experiment was carried out at the Physics Laboratory of Abia State Polytechnic, Aba.

The mild steel was sourced at Aba. Spark analysis was carried at Petroleum Tracing Institute Effurun, Warri Nigeria. This analysis revealed the composition of the mild steel as Fe = 96.56, c = 0.05, Mn = 1:13, Si = 0.05, P = 0.91, S = 0.85, Cu = 0.09, Pb = 0.15, Va = 0.13 and Mu = 0.08. The mild steel was machined in small square sheets of dimension 20mm x 20mm and a hole of diameter 2.5mm was drilled at a point a little off the center. The small sheets of mild steel are hereafter referred to as coupons. The essence of the hole was to provide access for attachment of a thread so that the coupon can stand in the corrosive media. The silicon emery paper were used to remove rusts and dirt on the surface of the metal. Thereafter the coupons were washed in ethanol for degreasing and quick drying was achieved using acetone. Then each of the coupons was weighed using digital weighing balance. The masses were recorded and the coupons were properly tagged or labeled.

Corrosive Environment

The corrosive media used in this experiment is Sprite, a carbonated drink, product of Nigeria Bottling Company Lagos. This drink is carbonated hence slightly acidic with a pH of 5.

Musa paradisiaca have high moisture content. Fresh peels of the MP were pounded using clean mortar and pestle and the sap was squeezed out using a press. 10ml of the juice was refluxed in equal volume of the corroding medium (Sprite) hereafter referred as Sprite extract. Also it was refluxed in alcohol to obtain the ethanol extract. The mild steel coupons after proper identification and weighing were dipped in the extracts to provide inhibitive coating. The coupons were retrieved from the extracts after 3 hours and allowed to dry in air. A total of 72 coupons were used. The coupons were kept in desiccators to avoid interaction with other environmental factors.

Dipping of the Coupons:

The blank experiment which stood as the control was conducted by dipping coupons that were not initially dipped in the plant extract. Thirty six coupons were used for each of the extraction method. Out of the 36 coupons,12 coupons were kept at ambient temperature corresponding to temperature of the drinks stored in open air environment (25°C). 12 coupons were kept in refrigerating compartment at 5°C and the last 12 coupons were kept in the freezer at -3°C. Thereafter, all of the coupons were dipped in corroding medium (Sprite). The experiment was allowed to stand for a minimum of six weeks. A coupon is retrieved weekly from the bottles and used for further extraction methods. The control experiments were conducted by using the coupons which were initially dipped in the plant extracts that had been refluxed in corroding media or ethanol to form inhibitive films. The coupons for each medium were kept at the temperature of 25°C, 5°C, and -3°C for a minimum of six weeks, making it a total number of 1008hrs as in the case of the control. A coupon was retrieved on weekly bases and subsequently washed, dried and reweighed to ascertain the weight lossin accordance to the method of Akoma and Osarolube,(2017).

The corrosion rate (C.R) for corroding media was calculated at the three temperatures in accordance to Oguzie, (2008) using eqn. 1:

$$C.R = \frac{k\,\Delta w}{\rho A t} \quad \text{..... (1)}$$

Where

C.R = corrosion rate in mm/yr K = corrosion rate constant (534 mild per year)

ΔW = weight loss in grams ρ = density of the steel (g/cm^3)

The inhibition efficiency which is the ratio percentage of reduction of corrosion rate in the blank (in the absence of the inhibitor) to corrosion rate in the inhibitor was calculated in accordance with Akpa and Offiong, (2013) using eq. 2.

$$IE\,\% = (1 - \frac{W_1}{W_2}) \times 100 \quad \text{....(2)}$$

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

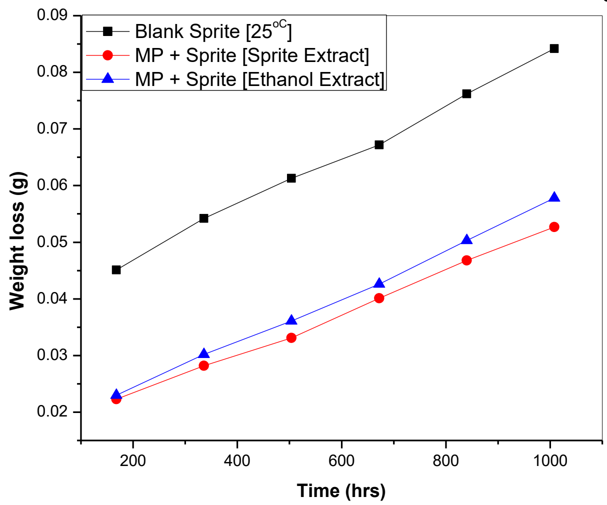
Scanning Electron Microscopy

In a bid to further investigate on the solid state properties so affected by the use of inhibitors, the coupons were subjected to surface morphology imaging test using XL – 30 FEG scanning Electron Microscopy. This enabled the comparison of the impact of inhibition on grain sizes and grain boundaries.

Results and Discussion

The result of the analyses are presented graphically in the Figures below.The figures show the weight loss, corrosive rate and inhibition efficiency of MP in the corrodants. The results show that MP significantly affected the corrosion process of mild steel in Sprite.

Effect of Temperature on Weight Loss



Temperature variation has great impact on corrosion considering the fact that carbonated drinks are stored at wide range o temperatures, it became expedient to carry out the investigation. It was observed that temperature has an great effect on the corrosion behaviour of the mild steel even after MP was introduced in Sprite a carbonated drinks.

Figures 1 - 3 show drastic decrease in weight losses at the three temperatures of 25°C, 5°C and -3°C respectively and for the different corroding media. The pattern of weight losses was similar for both Sprite extract and ethanol extract. Weigh loss decreased with temperature.

Fig. 1: Variation of weight loss (g) with time (hrs) for the corrosion of mild steel coated with MP in Sprite solution at 25°C

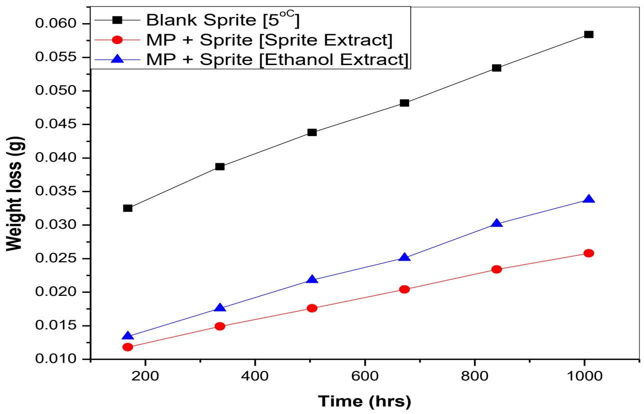


Fig. 2: Variation of weight loss (g) with time (hrs) for the corrosion of mild steel coated with MP in Sprite solution at 5°C

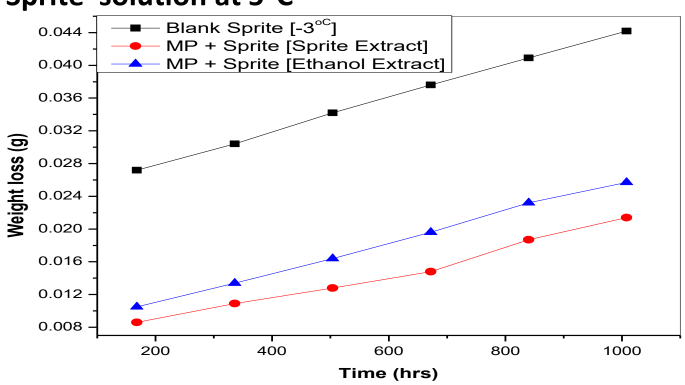


Fig. 3: Variation of weight loss (g) with time (hrs) for the corrosion of mild steel coated with MP in Sprite solution at -3°C

Figure 1 to 3 shows that there was an appreciable decrease in weight of mild steel coupon when coated with thin filling of MP extracted in Sprite and that extracted with alcohol when compared with the uninhibited coupons.

Corrosion rate and effect of Immersion time

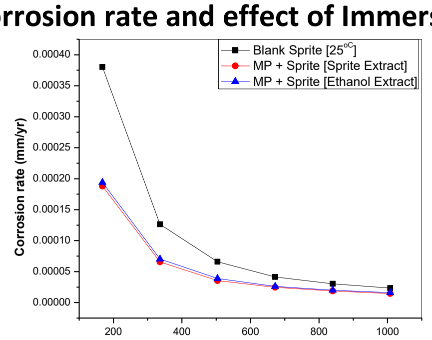


Fig. 4: Variation of corrosion rate (mm/yr) with time (hrs) for the corrosion of mild steel coated with MP in sprite solution at 25°C

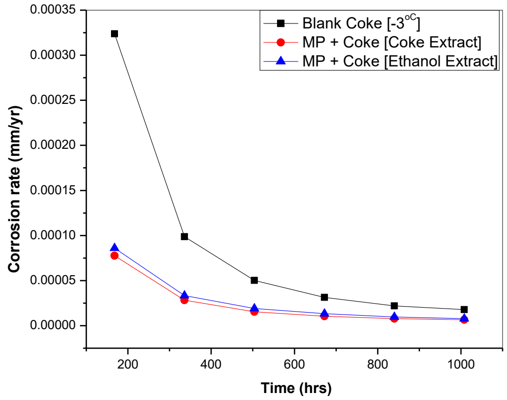


Fig. 5: Variation of corrosion rate (mm/yr) with time (hrs) for the corrosion of mild steel coated with MP in sprite solution 5°C

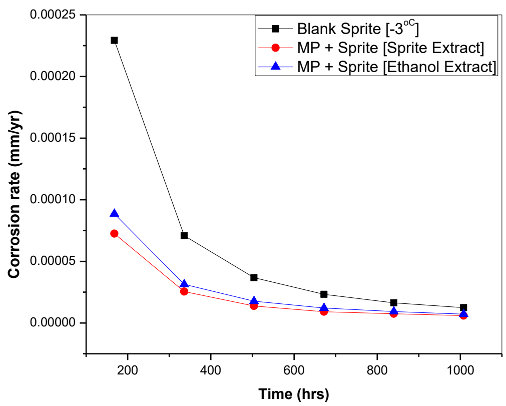


Fig. 6: Variation of corrosion rate of MP in Sprite solution at - 3^{oC} corrosion rate was higher in the uninhibited coupon than the inhibited coupon.

The results show that corrosion rate in the presence of MP reduced but passivited with increase immersion time. At the instant of immersion was considerable high with the blank /control experiment but reduced in the presence of MP and at each point the corrosion rate decreased with temperature.

Inhibition Efficiency

The inhibition efficiency was calculated using the formula as stated in question (2)

$$1\% = (1 - \frac{W_1}{W_2}) \times 100$$

It can be deduced from figure 7, 8, 9 that the highest inhibition efficiency was 68% and 61.4% at -3°C, 63% and 59% at 5°C and 50% and 49.2% for Sprite extract an ethanol extracts respectively. This result is far below the result obtained are lower than values obtained in the case chyrosphylum albidum (CA) as reported in Akoma *et al*., (2015).

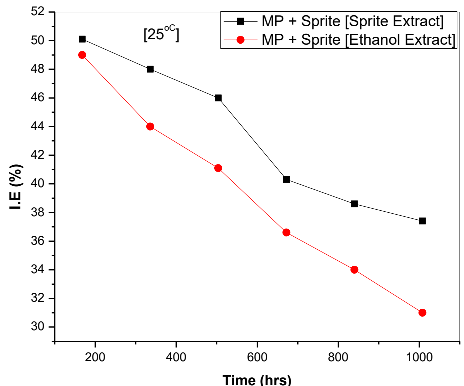


Fig. 7: Variation of inhibition efficiency (%) for the corrosion of mild steel coated with MP in sprite solution at 25^{oC}.

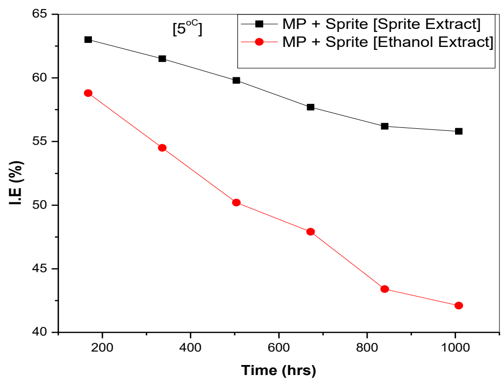


Fig. 8: Variation of inhibition efficiency (%) for the corrosion of mild steel coated with MP in sprite solutionat5^{oC}.

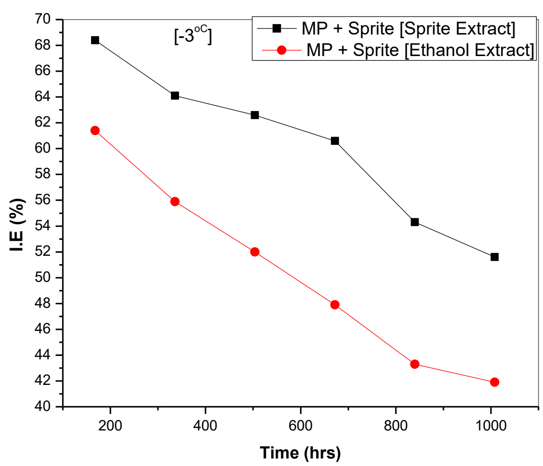


Fig. 9 Variation of inhibition efficiency (%) for the corrosion of mild steel coated with MP in sprite solution at -3^{oC}.

Scanning Electron Microscopy

This is an imaging mechanism of observing the surface morphology of specimens. Scanning Electron Microscopic image of the mild steel in the blank (without inhibitor) and with the inhibitor were obtained. The micro structure showed that grain sizes and grain boundaries were conspicuously established.

Figure 10 shows the grain size and boundaries of the mild steel without the MP as inhibitor while figure 11 shows the grain sizes and boundary after immersion time of 1008 hours for Sprite carbonated drink. A close look on un-inhibited sample show the boundaries were exposed but the presence of phytochemical composition of the inhibitor reduced the grain sizes and boundaries. The implication is that the mechanical properties of the mild steel were protected by the inhibitor.

Fig. 10: SEM images of the mild steel surface after 1008 hrs immersion at Sprite and in the absence of the various inhibitors studied.

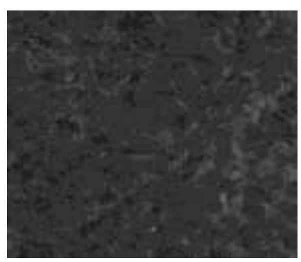


Fig. 11: SEM images of the mild steel surface after 1008 hrs immersion at 25°C in Sprite.

Summary and Conclusion

The result as presented show that the inhibition efficiency of *MP* at the variant temperatures are lower than results obtained in the case of chrysophyllum albidium as reported by Akoma *et al* .,(2015). It is therefore important that a continuous search for a better organic inhibitor for crown cork be made.

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