

The Inhibitive Effect of *Gnetum Africanum*, *Gongronema Latifolium* and *Chromolena Odaratum* Extracts on Corrosion of Stainless Steel in 1 M HCl and H₂SO₄ Solutions

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Abstract. Extract of various plants; Okazi leaf (*Gnetum africanum*), Utazi leaf (*Gongronema latifolium*) and Elizabeth leaf (*Chromolena odaratum*) was investigated as corrosion inhibitor of stainless steel in 1M HCL and H₂SO₄ using conventional weight loss. Results were obtained at intervals of 24, 48, 72 and 96 hours respectively. The corrosion rate and inhibition efficiency were calculated. The results revealed that all the plant extract act as inhibitors in the acid environments while Elizabeth leaf (*Chromolena odaratum*) proved to be better corrosion inhibitor than Okazi plant (*Gnetum africanum*) and Utazi plant (*Gongronema latifolium*) extract as it recorded the highest inhibition efficiency of 90.95% in 1M HCL for 20 ml concentration.

Introduction

Acid solutions are widely used in acid pickling and industrial cleaning. Hydrochloric acid and sulphuric acid are widely used for this purpose and most acid media cause metal corrosion [1, 2, 3]. Since aggressive acid solutions are widely used for industrial purposes, inhibitors are commonly used to reduce the corrosive attack on metallic materials. Corrosion inhibitors will reduce the rate of either anodic oxidation or cathodic reduction or both. This will give us anodic, cathodic or a mixed type of inhibition. Most of the potential corrosion inhibitors possess an active functional group, such as a nitro (-NO₂) or a hydroxyl (-OH) [4, 5] group. The inhibition of steel corrosion by acids was previously studied by some sulfur- and/or nitrogencontaining compounds [6]. A corrosion inhibition is a substance which when added in small concentration of an environment, effectively reduces the corrosion rate of a metal exposed to the environment [7]. In an attempt to find corrosion inhibitors that are environmentally safe and readily available, there has been a growing trend in the use of natural products such as leaves or plant extracts as corrosion inhibitors for metals in acid cleaning processes. Several corrosion inhibition studies of mild steel by plant extracts in acidic media has been carried out and reported. Hui *et al.* [8] has proved the use of herbs as new type of green inhibitors for acidic corrosion of steel. Elyn Amira *et al.* [9] have contributed significantly to the green mitigation by investigating several plants and their different body parts as corrosion inhibitors. Most researchers are focusing on natural products as corrosion inhibitors viz., *Gossypium hirsutum* L. [10], *Cola acuminata* and *Camellia sinensis* [11], *Citrullus vulgaris* Peel [12] and *Rogrophis paniculata*, *Jatropha curcas* [13], *Stevia rebaudiana* [14], *Hibiscus sabdariffa* calyx [15] Rosemary Extract [16] Eggplant Peel [17], *Psidium guajava* [18] *Azadirachta indica* [19], *Strychnos nuxvomica* [20]. This study was done to evaluate the inhibitive effect of ethyl acetate extract of *Gnetum africanum*, *Gongronema latifolium* and *Chromolena odaratum* as a green corrosion inhibitor of stainless steel in aqueous solution. Okazi leaf (*Gnetum africanum*) is traditionally a wild vine and is considered to be a wild vegetable. It is widely distributed in Nigeria, Cameroun, Central Africa Republic, Equitorial Guinea and Gabon. This vegetable is important ingredients in preparing soup in many homes in the South-south and Southeast of Nigeria. Utazi leaf (*Gongronema latifolium*) is an herbaceous shrub, with flowers usually yellow and the stem yields

characteristic milky exudates. It is commonly grown in Nigeria and is locally called utasi by the Efiks, Ibibios. The assessment of the corrosion behaviour was studied using weight loss.

Material and Method

The steel rod was tested in the present study with a length of 50 mm and a diameter of 12 mm. The test aqueous solutions contained HCL and H₂SO₄ with 1 M concentrations. Triple distilled water was used for preparing all solutions. In all measurements, mechanically polished electrode was used. Polishing was affected using successively finer grade of emery papers (600-1200 grade). About 25 g of dried and powdered leaves of each plant; Okazi leaf (*Gnetum africanum*), Utazi leaf (*Gongronema latifolium*) and Elizabeth leaf (*Chromolena odoratum*) were refluxed with ethanol for about 5 h and was kept overnight to completely extract the basic components. The insoluble residues were removed and the ethanol evaporated. The resultant material obtained was dried, powdered and weighed accurately by digital micro-balance. From the weight of extracted mass as above, different concentrations of 5, 10, 15 and 20 mL, respectively of the plant extracts were separately put into four beakers. The first beaker was kept plain, without any extract addition (control experiment). 20 pieces of the steel rod were then weighed for initial weight and immersed in each of the 1M HCL and H₂SO₄ concentration. Four coupons were then suspended with rope in each of the beakers and were left for various time intervals (24, 48, 72 and 96 h, respectively). This process was repeated for the Utazi leaf (*Gongronema latifolium*) and Elizabeth leaf (*Chromolena odoratum*) extracts. The above procedure was also carried out for mild steel [21]. The weight loss was used to calculate the Corrosion Rate (CR) in milligrams per square centimeter per hour.

Results and Discussion

Okazi leaf (*Gnetum africanum*) in 1M H₂SO₄ for stainless steel. The results obtained for the variation of weight loss with exposure time for the stainless steel specimens immersed in 1M H₂SO₄ with varied concentrations of added okazi leaf (*Gnetum africanum*) extract is presented in Fig.1.

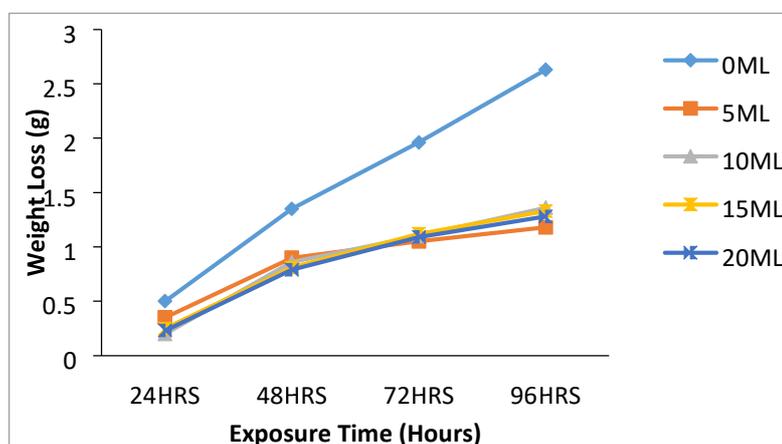


Fig. 1. Variation of weight loss with exposure time for Okazi leaf (*Gnetum africanum*)

From the figure, low weight losses were recorded for 5ml, 10ml, 15ml and 20ml concentrations of the *Gnetum africanum* extracts with values of 0.35, 0.20, 0.25 and 0.23g respectively at the beginning and 1.18, 1.36, 1.33 and 1.28g respectively at the 4th day of the experiment. The concentrations with the *Gnetum africanum* extract performed better throughout the experimental period than the test in which there was no extracts addition showing that the plant extract exhibited corrosion inhibition and also proved effective in corrosion inhibition.

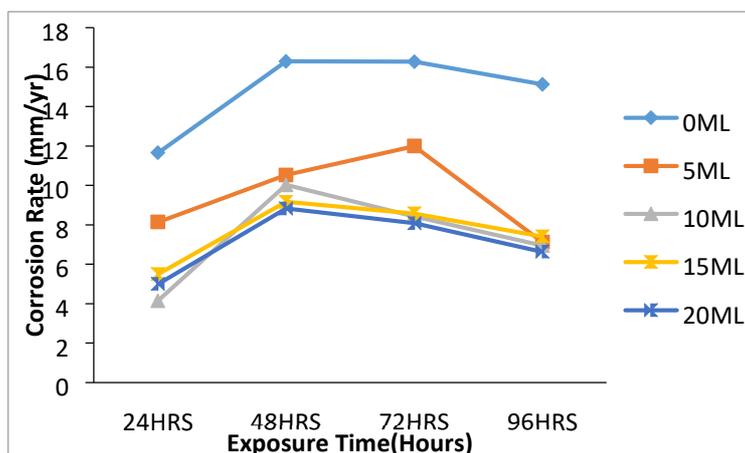


Fig. 2. Variation of corrosion rate with exposure time for Okazi leaf (*Gnetum africanum*)

Figure 2 shows the corrosion rate for the test media with and without the *Gnetum africanum* extracts. Corrosion rate value of 8.14, 4.15, 5.50 and 5.00mm/yr for 5ml, 10ml, 15ml and 20ml respectively were recorded after 24 hours of the experiment and rose to 10.53, 10.03, 9.17 and 8.83mm/yr after 48 hours. 7.13, 6.95, 7.41 and 6.63mm/yr was recorded after 96 hours of the experiment. The lowest recorded corrosion rate was achieved with the 20ml concentration of the *Gnetum africanum* extracts with values ranging between 5.00mm/yr after 24 hours of the experiment and 8.83 / 8.08/ 6.63 mm/yr on 48 hours, 72 hours, and 96 hours of the experiment respectively.

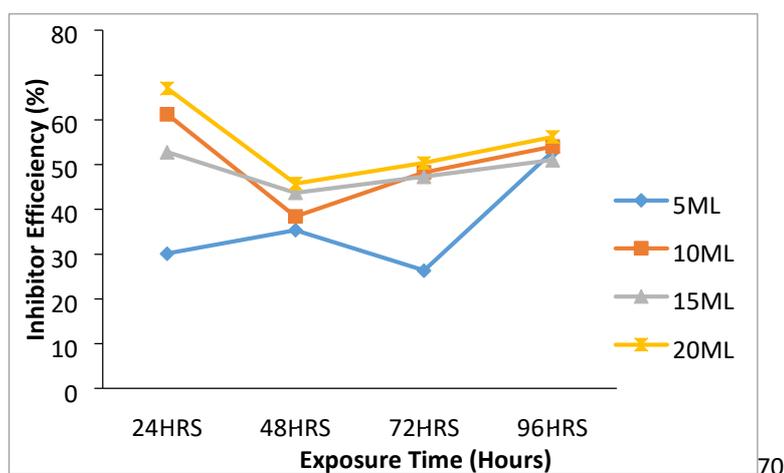


Fig. 3. Variation of inhibitor efficiency with exposure time for okazi leaf (*Gnetum africanum*)

From fig. 3, the inhibition efficiency slightly decreases after 24 hours for the four concentrations, after 48 hours there were slight increase in inhibition efficiency among the four concentrations. The 10ml, 15ml and 20ml achieved their highest value of inhibition efficiency after 24 hours at 61.29, 52.79 and 67.08% respectively whereas that of 5ml achieved its value after 96 hours at 52.88%. The inhibition efficiencies for the four concentrations all have values of similar range which falls at the end of the experiment (96 hours).

Okazi leaf (*Gnetum africanum*) in 1M HCL for stainless steel. The results obtained for the variation of weight loss with exposure time for the stainless steel specimens immersed in 1M HCL with varied concentrations of added okazi leaf (*Gnetum africanum*) extract is presented Fig. 4.

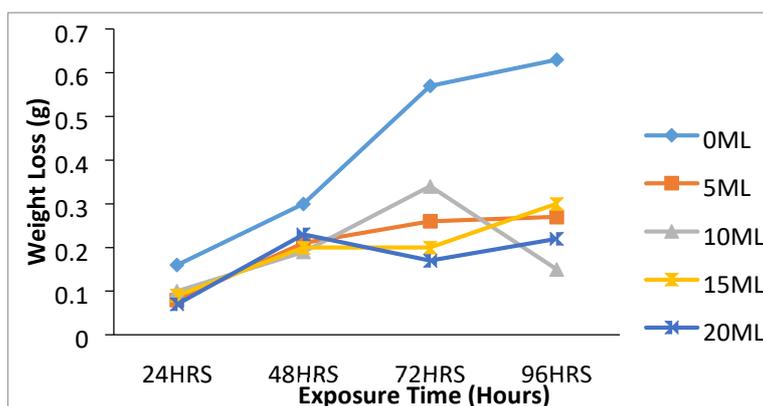


Fig. 4. Variation of weight loss with exposure time for Okazi leaf (*Gnetum africanum*)

The curve specimen without any *Gnetum africanum* extract addition recorded the highest weight loss values, achieving 0.16, 0.30, 0.57 and 0.63g, after 24, 48, 72 and 96 hours of the experiment respectively. The addition of the suitable concentration of the *Gnetum africanum* extract shows significant reduction in the recorded weight loss values, which indicate the magnitude of corrosion. In this case, it may be concluded that a reasonable degree of corrosion inhibition of the test specimen in the acid medium was provided. All the four different concentrations of the *Gnetum africanum* extract had an initial better performance after 48 hours of the experiment, after that they all showed unstable performance after 72 and 96 hours of the experimental period.

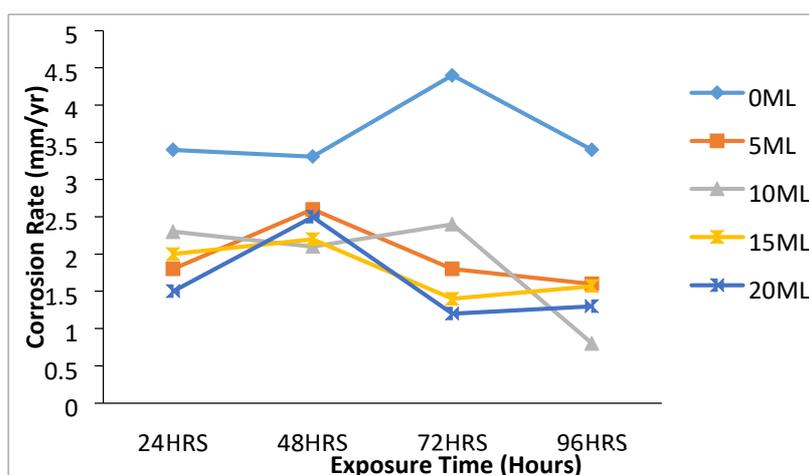


Fig. 5. Variation of corrosion rate with exposure time for Okazi leaf (*Gnetum africanum*)

From Fig. 5, the test without *Gnetum africanum* addition has a high corrosion rate. The decreasing corrosion rates with the exposure time the four different concentrations was due to the presence of the *Gnetum africanum* extract introduced. Corrosion rate value 3.40mm/yr for the medium without *Gnetum africanum* was recorded after 24 hours a decrease after 96 hours. The media with the plant extract all showed a reducing rate in corrosion at unstable manner in different time interval. This was also noticed in the test media without *Gnetum africanum*.

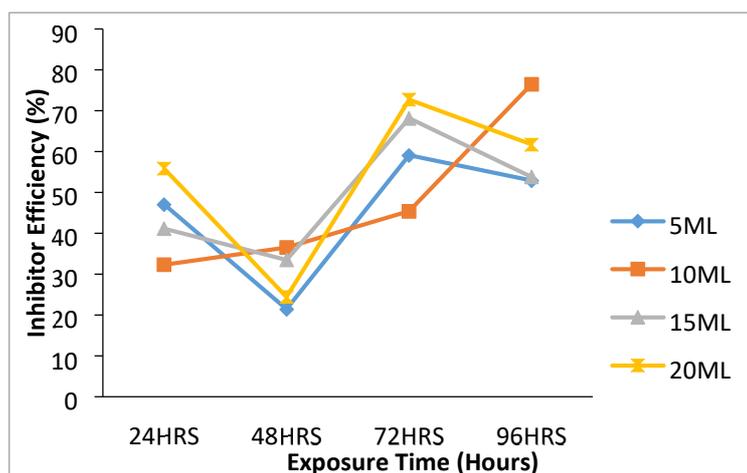


Fig. 6. Variation of inhibitor efficiency with exposure time Okazi leaf (*Gnetum africanum*)

From fig. 6, the highest inhibitor efficiency of 76.47% for the concentration of extracts was obtained with the 10ml concentration of *Gnetum africanum* after 96 hours of the experiment. An increasing trend was recorded from the 24 hours of the experiment to the 96 hours. The other concentration 5ml, 15ml and 20ml showed similar trend at different days of the experimental period. First with a decreasing trend from 24-48 hours, an increasing trend from 48-72 hours and finally a decreasing trend from 72-96 hours.

Result for Utazi leaf (*Gongronema latifolium*) in 1M H₂SO₄ for stainless steel. The results obtained for the variation of weight loss with exposure time for the stainless steel specimens immersed in 1M H₂SO₄ with varied concentrations of Utazi leaf (*Gongronema latifolium*) added extract is presented Fig. 7.

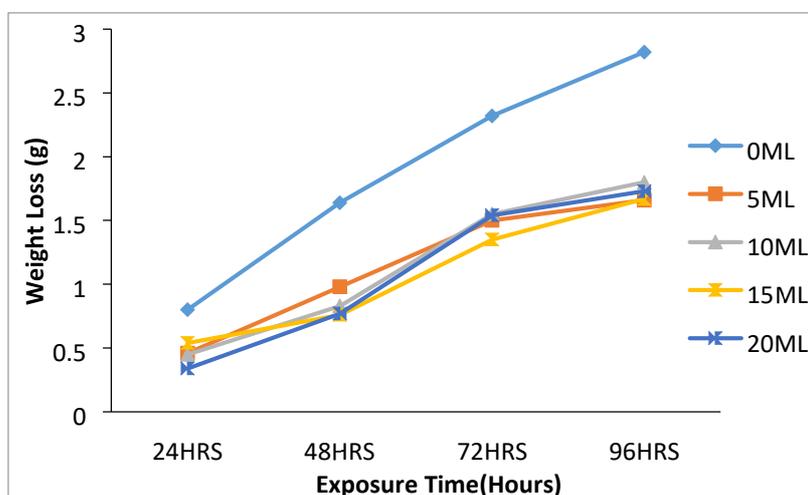


Fig. 7. Variation of weight loss with exposure time for Utazi leaf (*Gongronema latifolium*)

The weight loss curve for the test medium without the concentration of the plant juice extracts addition showed high weight loss throughout the hours of the experiment. Weight loss value of 0.80g was recorded after 24 hours of the experiment which rose up to 2.82g after 96 hours of the experiment. The lowest recorded weight loss achieved was with the 15ml concentrations of the *Gongronema latifolium* extracts with values ranging between 0.54g after 24 hours of the experiment and 0.76, 1.35, 1.67g after 48, 74 and 96 hours of the experiment respectively. The four concentrations with the juice extract showed a closed range of weight loss values from the first day through the last day of the experiment.

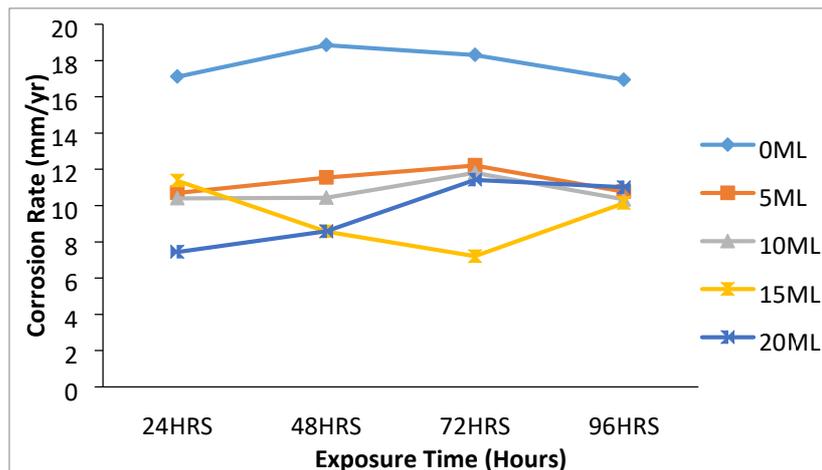


Fig. 8. Variation of corrosion rate with exposure time Utazi leaf (*Gongronema latifolium*)

From Fig. 8, the corrosion rates are very low, with the four different *Gnetum africanum* extract concentrations achieving values which range from 10.70, 11.55, 12.22 and 10.77mm/yr (for 5ml), 10.40, 10.44, 11.80 and 10.34mm/yr (for 10ml), 11.37, 8.57, 7.20 and 10.14mm/yr (for 15ml) to 7.44, 8.58, 11.42 and 11.01mm/yr (for 20ml extract per 1M H₂SO₄ acid). The test without any *Gnetum africanum* extract addition had higher corrosion rate values throughout the experimental period. These results thus confirm that the plant extract of the *Gnetum africanum* possesses corrosion-inhibiting property. It is not certain, however, whether the optimum concentration needed for more effective corrosion inhibition have been reached with any of the three concentrations used.

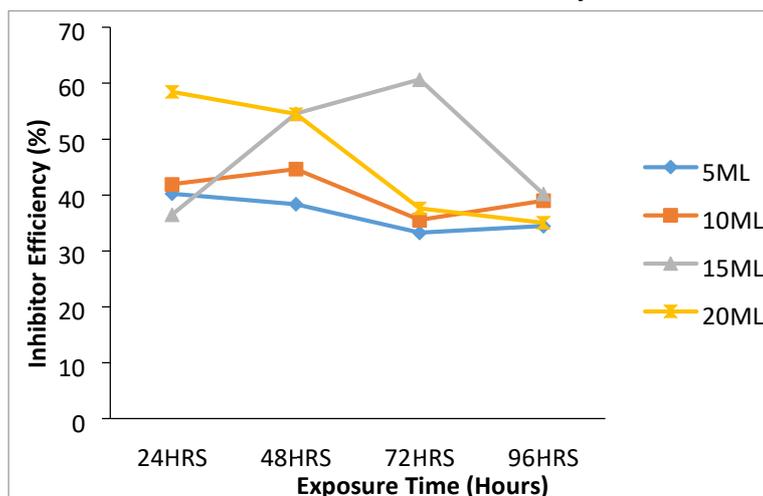


Fig. 9. Variation of inhibitor efficiency with exposure time for Utazi leaf (*Gongronema latifolium*)

From fig. 9, it will be observed that 5ml, 10ml and 20ml concentration of *Gongronema latifolium* reduce from 24 hours of the experiment to 72 hours of the experiment and slight increase on the 96 hours of the experiment. While the 15ml concentration of *Gongronema latifolium* increase from 24 hours to 72 hours and then a reduction on the 96 hours of the experiment. The highest inhibition efficiency of 60.68% was recorded after 72 hours for the 15 ml concentration of *Gongronema latifolium*. The 15ml concentration of extract was recorded to be most effective followed by the 20 ml, 10 ml and 5 ml concentration of extract respectively.

Result for Utazi leaf (*Gongronema latifolium*) in 1M HCL for stainless steel. The results obtained for the variation of weight loss with exposure time for the stainless steel specimens immersed in 1M HCL with varied concentrations of Utazi leaf (*Gongronema latifolium*) added extract is presented Fig. 10.

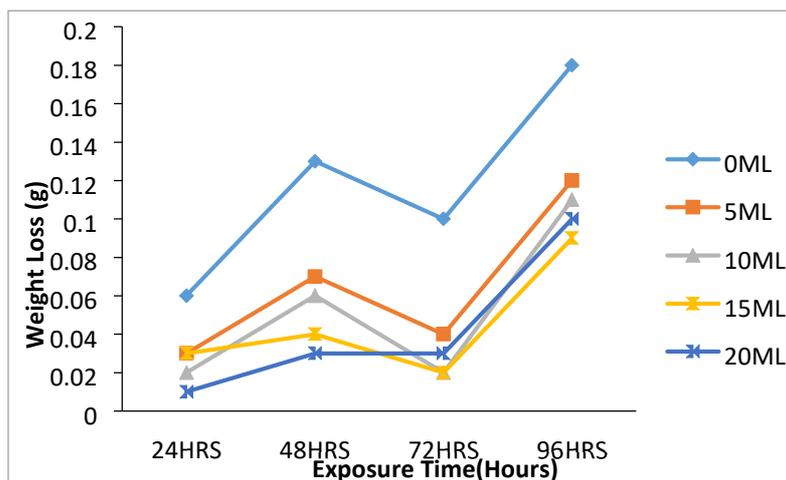


Fig. 10. Variation of weight loss with exposure time Utazi leaf (*Gongronema latifolium*)

The acid test medium with the four concentrations *Gongronema latifolium* of plant extracts addition in fig. 10 showed good weight loss inhibition effect of the immersed specimens, the four extracts concentration addition, achieved low weight loss values throughout the period of experiment. For most days of the experimental period, the extract with 20ml concentration addition to the test medium performed better than the 5ml, 10ml and 15ml concentration addition, though it achieved a comparative lower weight loss value of 0.01g after 24 hours, 0.03g after 48 hours and 0.1g after 96 hours of the experiment.

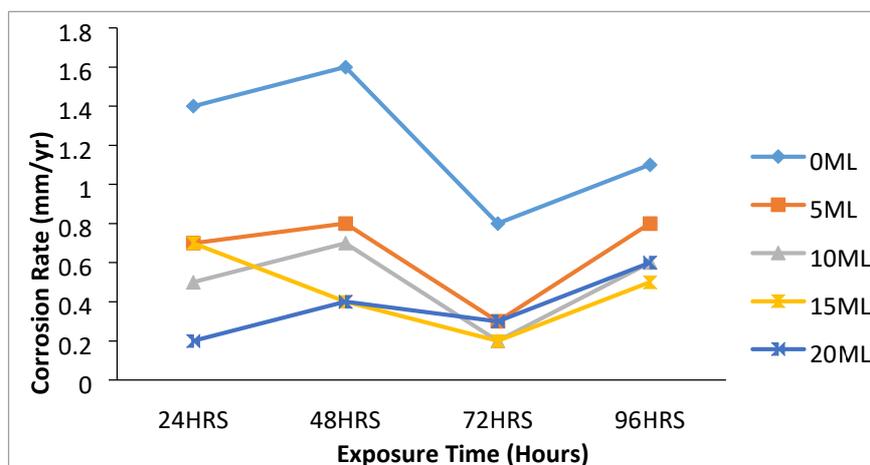


Fig. 11. Variation of corrosion rate with exposure time for Utazi leaf (*Gongronema latifolium*)

From Fig. 11, the height corrosion rate was recorded for the medium without *Gongronema latifolium* extract (control experiment). The curve of both the control experiment and the medium with different concentration of *Gongronema latifolium* extract had the same trend. The least corrosion rate was 0.2mm/yr after 24 hours and 0.4mm/yr after 48 hours was achieved with 20ml concentration of plant extraction. While the least corrosion rate of 0.2mm/yr after 72 hours was recorded for 15ml concentration of juice extract. In general the various concentration of *Gongronema latifolium* extract used showed good corrosion rate inhibition of the specimen when used in 1M hydrochloric media.

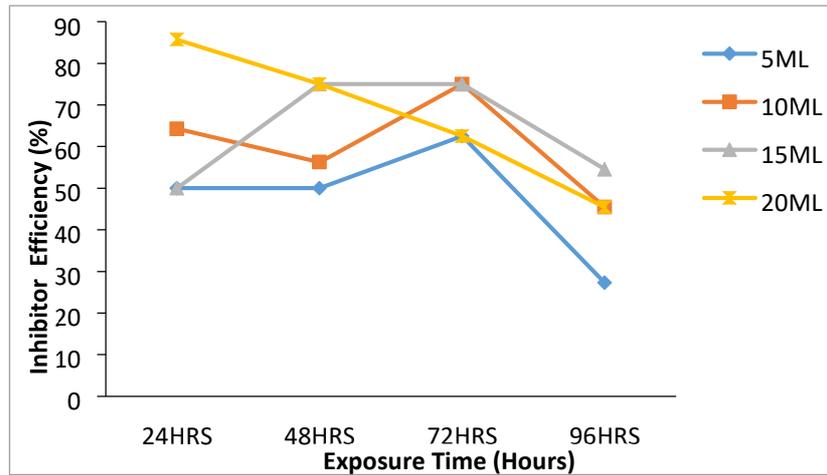


Fig. 12. Variation of inhibitor efficiency with exposure time for Utazi leaf (*Gongronema latifolium*)

From Fig. 12, the maximum inhibitor efficiency of 85.71% was recorded after 24 hours of the experiment when 20ml of *Gongronema latifolium* plant extract was used. The efficiency then reduced after 24 hours to the 96 hours. The 5 ml and 15 ml concentration of the juice extract had an increment in inhibition efficiency from 24 hours to 72 hours and encountered a reduction from 72 hours to 96 hours. In summary 15ml is the most effective concentration of *Gongronema latifolium* plant in 1M hydrochloric acid on stainless steel.

Result for Elizabeth leaf (*chromolena odoratum*) in 1M H₂SO₄ for stainless steel. The results obtained for the variation of weight loss with exposure time for the stainless steel specimens immersed in 1M H₂SO₄ with varied concentrations of Elizabeth leaf (*chromolena odoratum*) added extract is presented Fig. 13.

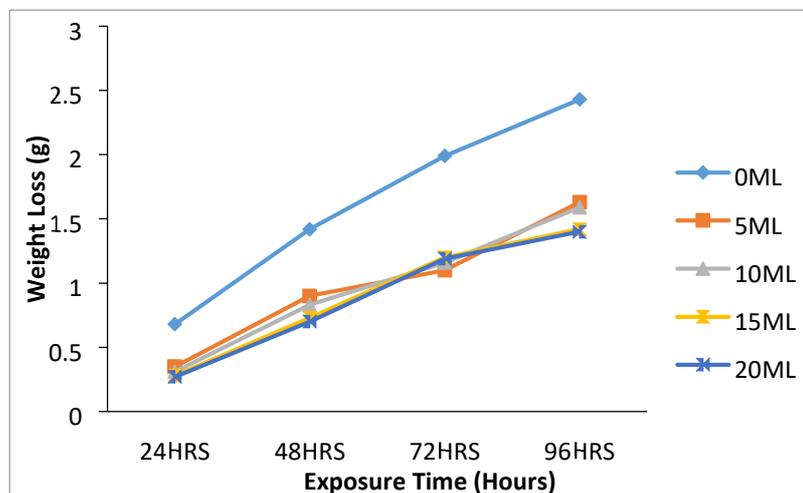


Fig. 13. Variation of weight loss with exposure time for Elizabeth leaf (*chromolena odoratum*)

From fig. 13, the concentration without *chromolena odoratum* juice showed a higher weight loss compared to the concentrations with *chromolena odoratum* plant extract. The results for the 5ml, 10ml, 15ml and 20ml plant extract concentrations were very close in weight loss values throughout the period of experiment. However, the results confirmed the effectiveness of the plant extract on the corrosion inhibition of stainless steel in sulphuric acid. The extract concentration of 20ml addition performed best throughout the hours of the experiment, achieving a weight loss value of 0.27, 0.7, 1.19, 1.4 g for 24, 48, 72, and 96 hours respectively.

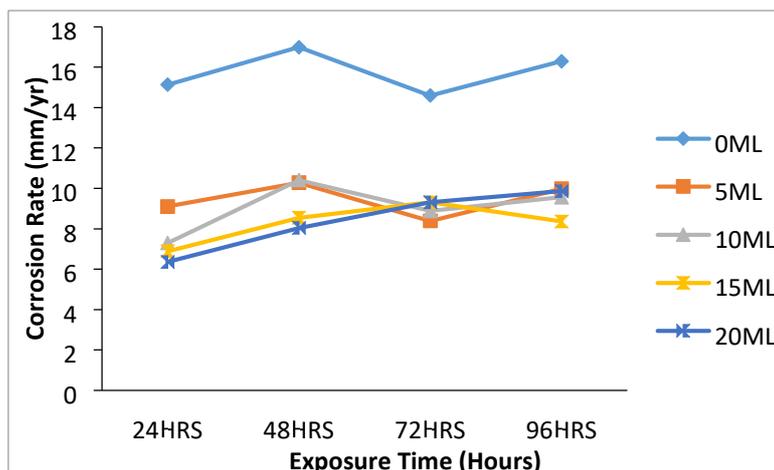


Fig. 14. Variation of corrosion rate with exposure time for Elizabeth leaf (*chromolena odoratum*)

Fig. 14 shows that the test without any extract addition clearly recorded the highest corrosion rate values, achieving 16.99mm/yr after 48 hours of the experiment. The addition of the various concentrations of the *chromolena odoratum* plant extract shows significant reduction in the recorded corrosion rate values, which indicate the magnitude of corrosion inhibition. In this case, it may be concluded that a reasonable degree of corrosion inhibition of the test specimen in the acid medium was provided. All the four different concentrations of the *chromolena odoratum* juice extract give very close values of corrosion rate after 72 and 96 hours. However, the 20ml addition had an initial better performance (6.35mm/yr CR) than the 15ml (6.88mm/yr CR), 10ml (7.29mm/yr CR) and 5ml juice (9.1mm/yr CR) additions.

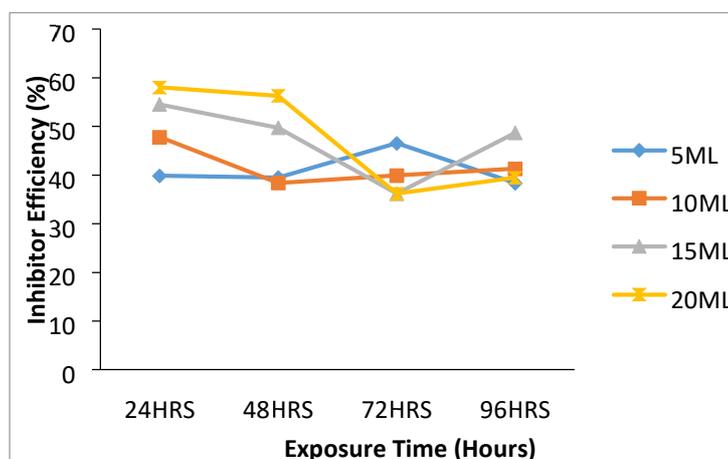


Fig. 15. Variation of inhibitor efficiency with exposure Elizabeth leaf (*chromolena odoratum*)

Fig. 15. The results obtained for the solution extract of *chromolena odoratum* at 20ml concentration gave very reasonable high inhibition efficiency at 58.03% for the 24hrs, and a reduction in efficiency down to 72 hours and a slight increase towards 96 hours, this phenomenon occurred for the 15ml concentration extract. The 10ml concentration has high inhibition efficiency at the 24 hours and then followed a decreasing trend to the end of the experiment showed, whereas the 5ml concentration has its highest value at the 72 hours and a lowest value at the start and end of the experiment.

Result for Elizabeth leaf (*chromolena odoratum*) in 1M HCL for stainless steel. The results obtained for the variation of weight loss with exposure time for the stainless steel specimens immersed in 1M HCL with varied concentrations of Elizabeth leaf (*chromolena odoratum*) added extract is presented Fig. 16.

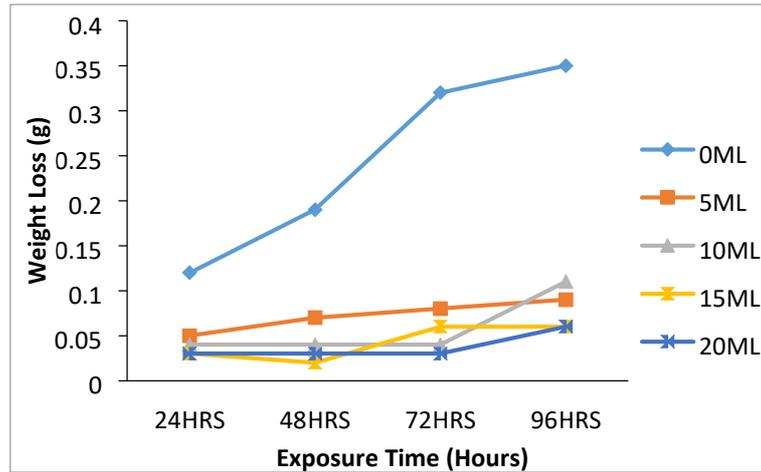


Fig. 16. Variation of weight loss with exposure time for Elizabeth leaf (*chromolena odoratum*)

The test media without inhibitor has the greatest weight loss during the experiment compared other concentrations of inhibitors. It was observed that the media with inhibitors had great effect on the weight loss of stainless steel in 1M HCL acid. The weight loss of the different extracts of the inhibitor was within the same range after 24 hours. It was also observed that the medium with 20 ml concentration of the *chromolena odoratum* extract had the least weight loss and thus the best inhibitor used in 1M hydrochloric acid on stainless steel.

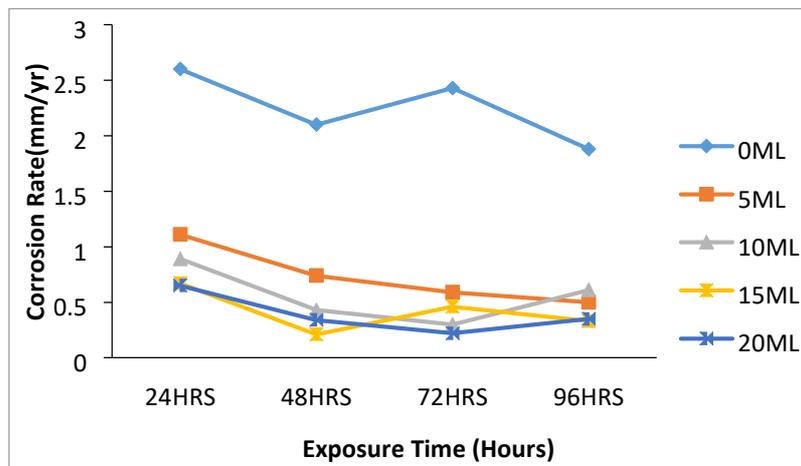


Fig. 17. Variation of corrosion rate with exposure time for Elizabeth leaf (*chromolena odoratum*)

From fig.17, the test media without inhibitor had the greatest corrosion rate through of the period of the experiment compared to those with different concentration of the plant juice. It was observed that the media with *chromolena odoratum* extract had great effect on the corrosion rate of stainless steel in 1M HCL acid. Corrosion rate value of 2.60 mm/yr was recorded after 24 hours of the experiment which decreased to 2.10mm/yr after 48 hours and increased to 2.43mm/yr after 72 hours and ended with a value of 1.88mm/yr after 96 hours of the experiment. The lowest recorded corrosion rate was achieved with the 20 ml concentrations of the *chromolena odoratum* extracts with values ranging between 0.22mm/yr at the 72 hours of the experiment and 0.34, 0.35, 0.65 mm/yr on the 48 hours, 96 hours and 24 hours of the experiment respectively.

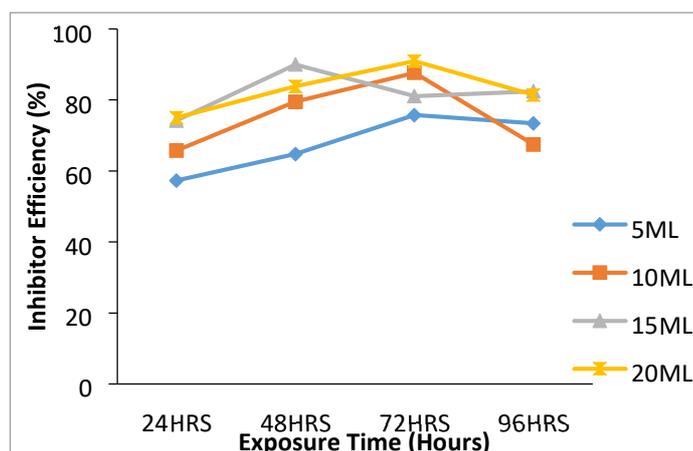


Fig. 18. Variation of inhibitor efficiency with exposure time for Elizabeth leaf (*chromolena odoratum*)

From fig. 18, the inhibitor efficiency of the 5ml, 10ml and 20ml showed an increasing trend from the 24 hours of the experiment up to 72hrs and then a decrease towards the end of the experiment. That of 15 ml which showed unstable inhibition efficiency throughout the experimental period. The highest inhibition efficiency from the graph is 90.95% was recorded at 72 hours for 20ml concentration of *chromolena odoratum*, while the least inhibition efficiency 57.30% was recorded at 24 hours for 5 ml concentration. The inhibition efficiency performance of the plant extract increased with increase in concentration used. Hence, it is concluded that the best concentration of the plant extract to use to obtain the best inhibition efficiency of the above medium was 20ml. Similar observations have been reported by Obiukwu et al [21] for the inhibitive effects of these plant extracts on mild steel in these acidic media. It is observed from comparison of the results that stainless steel has high rate of corrosion in H_2SO_4 than in Hydrochloric acid (HCL) thereby giving a low and unstable inhibition efficiencies on stainless steel compare to mild steel [21] whereas the corrosion rate of both steels (mild and stainless) in HCL was at a pleasant rate which showed a higher and stable inhibition efficiencies on both steels. In 1M HCL acid on mild steel [21] and stainless steel, a maximum of 87.97% and 76.47% inhibition efficiency was obtained using 15 ml concentration and 20ml concentration respectively, providing low inhibition weight loss and corrosion rate. In 1M H_2SO_4 acid on mild steel [21] and stainless steel, a maximum of 85.89% and 67.08% inhibition efficiency was obtained making use 20ml concentration and 10ml concentration respectively providing very low inhibition weight loss and corrosion rate. Among the various plant extracts used it was observed that Elizabeth leaf (*chromolena odoratum*) has the best inhibition efficiency on both mild steel [21] and stainless steel in both acidic media (HCL and H_2SO_4) followed by Okazi leaf (*Gnetum africanum*) and Utazi leaf (*Gongronema latifolium*) which also showed good inhibition efficiency.

Conclusions

Gnetum africanum, *Gongronema latifolium* and *Chromolena odoratum* extracts showed inhibitive effect on corrosion of stainless steel in acidic environment. Inhibition efficiency increase with an increase in inhibitor concentration for the extracts. Elizabeth plant (*chromolena odoratum*) extract proved to be better corrosion inhibitor than Okazi plant (*Gnetum africanum*) and Utazi plant (*Gongronema latifolium*) extract since it has higher inhibition efficiency. From the experimental results obtained, the different plant extracts can acts as good corrosion inhibitor and thus be used to retards the corrosion rate of stainless steel if the appropriate concentration is used. It was observed that stainless steel has higher rate of corrosion in sulphuric acid (H_2SO_4) than in hydrochloric acid (HCL). Corrosion rate increases with time of exposure to the corrosive medium (inhibited or non-inhibited). For 5ml, 10ml, 20ml, 20ml concentrations of of Okazi plant (*Gnetum africana*) extract at different time intervals in 1M H_2SO_4 acid, a maximum of 85.89% and 67.08% inhibition efficiency

was obtained for 20ml concentration and 10ml concentration. For 5ml, 10ml, 20ml, 20ml concentrations of Utazi leaf (*Gongronema latifolium*) plant extract at different time intervals, in 1M HCL acid, a maximum of 68.52% inhibition efficiency was obtained for 10ml concentration. In 1M H₂SO₄, a maximum of 60.68% inhibition efficiency was for 15ml concentration. For 5ml, 10ml, 20ml, 20ml concentrations of Elizabeth (chromolena odoratum) plant extract at different time intervals, in 1M HCL, a maximum of 68.50% and 90.95% inhibition efficiency was obtained for 15ml concentration and 20ml concentration respectively. In 1M H₂SO₄ acid, a maximum of 58.03% inhibition efficiency was obtained with 20ml concentration.

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