



Corrosion Inhibition of Mild Steel in Orange Juice Using Benzamide as an Inhibitor

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ABSTRACT

The corrosion inhibition of mild steel in orange juice using Benzamide as an inhibitor was undertaken using the weight loss method of corrosion measurement. This is aimed at investigating the efficiency of Benzamide as an inhibitor in orange juice. The results showed that the corrosion rate in orange juice extract without any inhibitor was higher compared to orange juice containing various concentration of the inhibitor except at 4.0 g/L of the inhibitor. The inhibition efficiency of the inhibitor increased with concentration up to a certain point, after which it began to decline. Maximum inhibition efficiency of 88.14% was obtained at inhibitor concentration of 6.0 g/L. The optimum concentration for good corrosion inhibition performance is 6.0 g/L.

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Introduction

An assessment of most orange processing centers revealed that the problem of corrosion is very severe. The main acid in citrus fruits is citric acid (80-90% of the total acid) and others are malic, tartaric, benzoic, succinic, quinic, oxalic and formic acid (Abiola *et al.*, 2004 as cited in [1]). During the processing of fruit juice, there is an interaction between the machine components and the juice being extracted. Several studies have been conducted to reveal the effect of fruit juice (orange juice) on metals.

Oladele and Okoro [2] reported that mild steels are corrosive in fruit juice environments due to the evolution of hydrogen gas (a cathodic reaction product) at low pH resulting in the possibility of the removal of protective formation of hydrogen. Tin coated steel cans were observed to be corrosive in fruit juice environments due to the evolution of hydrogen gas at low pH resulting in the possible removal of the protective tin layer [1].

Afolabi *et al* [3] carried out a comparative analysis of the corrosion behavior of mild steel in apple, orange, mango and mixture of the juice for 60 days exposure time at 5-day interval using the weight loss method of corrosion measurement. The highest corrosion rate was in grape fruit losing about 4.69 g, 4.18 g loss in orange juice, 4.15 g loss in mixture of fruit juice, 4.10 g loss in apple and mango has the lowest corrosion rate with weight loss of about 2.25 g loss.

Based on the research works mentioned above, it is evident that orange juice has an adverse effect on metals and little or nothing has

been done to mitigate the corrosion of mild steel in orange juice using inhibitors. Therefore, this research work focuses attention on the use of corrosion inhibitors to mitigate the corrosion of mild steel in orange juice. The aim of this work is to investigate the effectiveness of Benzamide as an inhibitor for the corrosion of mild steel in orange juice.

Materials and Method

The materials used for this study include: mild steel sheet, plastic containers (one liter size), strings, cotton wool, emery paper (P60 and P220), distilled water (40 liters), polyethene gloves, bowl, filter paper, orange juice, ethanol, sieve and Benzamide. The equipment and tools used are: drilling machine, weighing balance, orange squeezer, hand file and hacksaw.

Twelve (12) rectangular test specimens each of dimensions (40 mm x 30 mm x 3 mm) were prepared from a mild steel sheet. The percentage chemical composition of the mild steel sheet used for the preparation of the corrosion test specimens is: 98.82 wt% Fe, 0.143 wt% C, 0.124 wt% Si, 0.541 wt% Mn, 0.0204 wt% P, 0.307 wt% Cr, 0.00097 wt% Mo, 0.00788 wt% Ni, 0.0158 wt% Cu, 0.0224 wt% Al, 0.00027 wt% Nb, 0.00339 wt% Ti and 0.00134 wt% V. A 3 mm diameter hole was drilled at the longitudinal end for suspension of the metal sample in the corrodent as shown in Figure 1. The sharp edges formed during the cutting and drilling operations were smoothed using a hand file. The surfaces of the test specimens were further polished with abrasive paper using water as a lubricant,

to produce smooth surfaces and to remove any trace of contaminants. The test specimens were degreased in ethanol, washed thoroughly in deionized water and rinsed. The washed specimen were cleaned with cotton wool and sun dried for thirty minutes to remove any moisture that might be present on the test specimens. After weighing, the test specimens were kept in a desiccator until needed for corrosion studies.

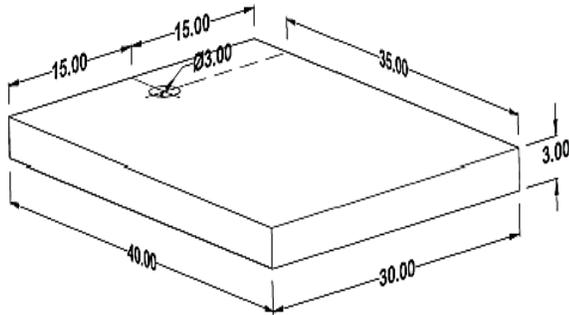


Fig. 1: Corrosion test specimen (coupon)

Orange fruits were obtained from MutumBiyu, Gassol LGA of Taraba State. The fruits were thoroughly washed in water to remove dust and particles of sand. The fruits were peeled using a knife. The peeled orange fruits were further washed in distilled water. The juice was extracted from the fruits using a juice extractor. The resulting juice was sieved using a nylon cloth and stored in a refrigerator until needed for corrosion studies.

Due to the advantages of the weight loss method, it was adopted for evaluating the corrosion rates of mild steel samples in orange juice. The experiment was performed twice. The pH of the orange juice was measured before the commencement of the test. In each set of weight loss measurement, six rubber containers were arranged on a table in Faculty of Engineering Laboratory, Taraba State University, Jalingo. 1000 mL of the orange juice was measured and poured into each of the labeled plastic containers in each set. The required concentrations (2.0 g/L, 4.0 g/L, 6.0 g/L, 8.0 g/L and 10.0 g/L) of Benzamide were measured with the aid of a weighing balance. After measurement, they were respectively added to each of the containers containing the corrodent in each set. No inhibitor was added to the sixth container in each set. Each of the pre-weighed test specimens were totally immersed in each of the plastic containers containing both the corrodent and the inhibitor. Samples were retrieved after every five (5) days from the corrodent, observed and washed thoroughly in water with a sponge and brush to remove corrosion products. Samples were again subjected to washing in absolute ethanol with cotton wool, dried under the sun and weighed to determine the final weight. The difference in weight of the coupon

was taken as the weight loss. The average weight loss value was determined by adding the weight loss value obtained from the first experiment to the corresponding value of weight loss in the second experiment for each coupon divided by two (2). The average weight loss value was recorded as the weight loss. The corrosion rate was computed using Equation 1 [4].

$$CR = \frac{534W}{DA t} \quad (1)$$

where CR is the corrosion rate, W is the weight loss, A is the sectional area, D is density of the metal sample and t is the exposure time of the mild steel coupon in days.

The inhibition efficiency (IE %) was computed using Equation 2 [5]

$$IE = \frac{CR_{uninhibited} - CR_{inhibited}}{CR_{uninhibited}} \times 100 \quad (2)$$

Results and Discussion

Effect of Exposure Time on Corrosion Rate

Presented in Figure 2 is the result of the effect of exposure time on the corrosion rate of mild steel in orange juice without and with different concentrations of Benzamide.

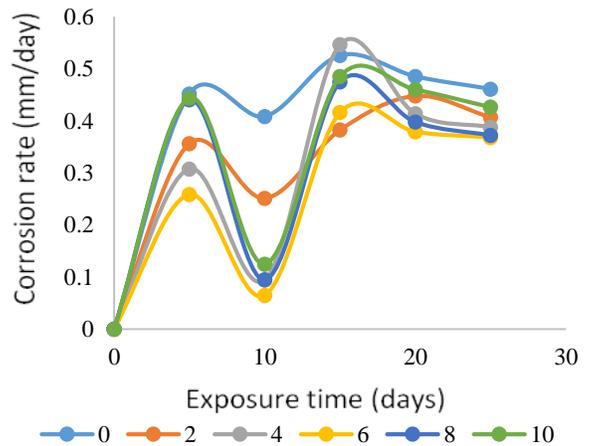


Fig. 2: Effect of exposure time on the corrosion rate of mild steel in orange juice with Benzamide as an inhibitor

The Figure revealed that the corrosion rates at 0.0 g/L (solution without extract) were higher compared to the corrosion rates at 2 g/L, 6 g/L, 8 g/L and 10 g/L of the inhibitor. This is an indication that the inhibitor (Benzamide) inhibited the corrosion of mild steel in orange juice. Corrosion rate at 4 g/L of the inhibitor was observed to be slightly higher compared to the corrosion at 0.0 g/L on the same day of immersion. This could be likely due to an increase in the acidity of the orange juice extract due to fermentation [6, 7] on

that day of immersion. An inspection of the Figure further revealed that the corrosion rate increased from day zero (0) reaching a peak on the fifth day; it decreased as the exposure time increased from day ten (10) to fifteen (15) and finally corrosion rate decreased till the end of the exposure time. The high corrosion rate observed at all extract concentrations on day zero to five and day ten to fifteen could be attributed to the increased acidity of the environment due to fermentation [6, 7]. The fermentation increases the aggressiveness of the environment (orange juice). Therefore corrosion rates were higher on day zero to five and day ten to fifteen. Also, the decrease in corrosion rates observed on day five to ten and day fifteen to twenty five could be attributed to the dilution of the orange juice due to reaction of the acid (s) present in it with the mild steel. The dilution reduces the acidity of the acid, therefore a reduction in corrosion rate.

Effect of Concentration on Corrosion Rate

Presented in Figure 3 is the effect of concentration of Benzamide on the corrosion rate of mild steel in orange juice. Corrosion rate decreases as the concentration of the inhibitors increased from 0.0 g/L to 6.0 g/L and subsequently corrosion rate began to increase as the concentration of the inhibitor increases from 6 g/L to 10 g/L on day ten, twenty and twenty-five. The trend observed as the concentration of the inhibitor is increased from 0.0 g/L to 6.0 g/L could be attributed to adsorption of the inhibitor molecules on the corroding sites on the mild steel surface [8].

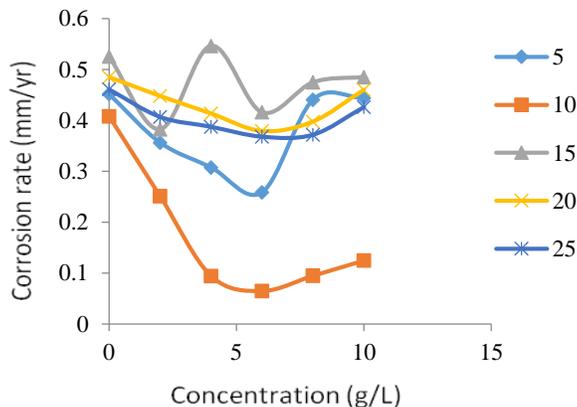


Fig. 3: Effect of concentration on corrosion rate of mild steel in orange juice with Benzamide as an inhibitor.

As the concentration of the inhibitor is increased, there is a reduction in the surface area of the metal available for direct attack [9] by the orange juice. Consequently, corrosion reaction is greatly reduced. The structure of Benzamide reveals the presence of a heteroatom (O) and aromatic ring system. The free electron pairs on the heteroatom from bond with electrons on the mild steel surface [10].

Therefore, a barrier is created between the metal and the corrodent which led to low corrosion rates as inhibitor concentration is increased from 0.0 g/L to 6.0 g/L. In addition, the π electrons present in the aromatic ring system present in the structure of Benzamide increases adsorption and consequently improve the inhibition efficiency of the inhibitors [11]. The trend observed as the concentration of the inhibitor increased from 6.0 g/L to 10 g/L could be attributed to the fact that the inhibitor can no longer be adsorbed onto the metal surface; therefore it dissolves in the corrodent and increases its acidity [12]. On day fifteen, corrosion rate decreased as concentration increased from 0.0 g/L to 2.0 g/L, after which it began to increase as concentration increased to 4.0 g/L. In addition, a decrease in corrosion rate was observed as concentration increased to 6.0 g/L, after which it increased with concentration.

Effect of Concentration on Inhibition Efficiency

The effect of concentration on inhibition efficiency is presented in Figure 4. Inhibition efficiency was observed to increase as the concentration of the inhibitor increased from 0.0 g/L to 6.0 g/L and subsequently it began to decline with increased concentration on day five (5), ten (10) and twenty (20) of immersion in the orange juice. The reason(s) stated for the trend(s) observed in the previous section also applies to the trends obtained here.

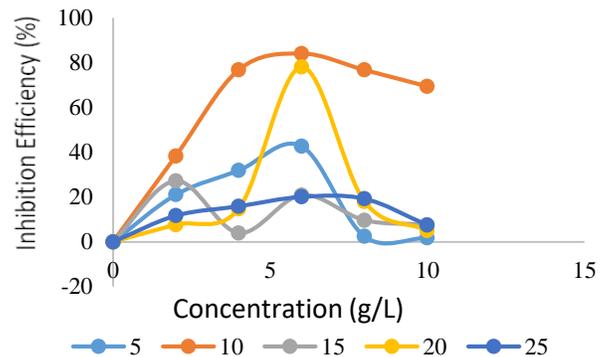


Fig. 4: Effect concentration on inhibition efficiency of mild steel in orange juice with Benzamide as an inhibitor

On day fifteen, inhibition efficiency increased with concentration after which it began to decrease as concentration increased to 4.0 g/L. In addition, inhibition efficiency increased as concentration increased from 4.0 g/L to 6.0 g/L after which it began to decrease with concentration. Inhibition efficiency was observed to increase as the concentration of the inhibitor increased from 0.0 g/L to 8.0 g/L, after which it began to decline on the twenty fifth day of immersion.



Conclusion

Benzamide inhibited the corrosion of mild steel in orange juice. Therefore, Benzamide was effective in mitigating the corrosion of mild steel in orange juice.

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