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COMPARATIVE STUDY OF CORROSION PERFORMANCE OF ALUMINIUM- ZINC COATED, GALVANIZED AND ELECTROPLATED STEELS IN TOMATO JUICE

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ABSTRACT
Metallic materials are given prominent considerations in agro-based machinery especially in fruit juice processing, storage and use as disposable cans. Such metallic materials include Electroplated Steel (ES), Galvanized Steel (GS) and Aluminum-zinc coated steel (Aluzinc). This study evaluated the corrosion performance of Aluzinc, GS and ES in tomato juice. The medium was chosen due to its social and economic importance. Samples of Aluzinc, GS and ES were prepared by cutting into 3 x 3 cm^2 from 1 mm thick plate. Three of each of the prepared samples were used for Potentiostatic Polarization Experiments (PPE) while 18 samples each were used for Weight Loss Method (WLM). Each of the prepared samples for WLM was cleaned, weighed and immersed in the media for 30 days. The samples were removed at the end of immersion, cleaned and reweighed. The results obtained for the corrosion rates in mm/y using PPE in tomato juices were 0.0061, 0.0065 and 0.0148 for Aluzinc, GS and ES respectively. The measured pH values for the media ranged from 4.1 to 8.3. Aluzinc had the lowest corrosion rate in tomato juice followed by GS and ES after 30 days of immersion using WLM.

Keywords: **corrosion rate, potentiostatic polarization, weight loss, coatings, fruit juice**

1.0 INTRODUCTION

Scully(1990) stated that corrosion is the deterioration of a material, usually a metal, because of a reaction with its environment and which requires the presence of an anode, a cathode, an electrolyte, and an electrical circuit. To understand the application of protective coatings or cathodic protection in corrosion control, the basic concepts of corrosion of metals in the presence of moisture needs to be reviewed.

Metallic materials are given prominent considerations in agro based machinery especially in fruit juice processing. Such metallic materials include Aluzinc, electroplated steel and galvanized steel. The corrosion performance differs even when they are exposed to the same environment. Adequate protection of steel is therefore a necessary consideration in its wide applications including fruit juice processing, storage and waste fruits disposable cans. Highly industrialized nations often vote about five percent of annual budget to combat the menace of corrosion of facilities and infrastructures. (Adetunji and Aiyedun, 2012).

Galvanized steel which account for a great deal of metallic material in the construction industries, industrial process equipment and allied industries is susceptible to various forms of corrosion such as pitting corrosion, uniform corrosion, intergranular corrosion, stress corrosion cracking and fatigue corrosion (Afolabi, 2005 and Adetunji *et al*.2011).

Tomato is one of the most widely consumed vegetable crops in the world, not only because of its volume, but also because of its overall contribution to nutrition and its important role in human health (David *et al*., 2002 and Okori *et al.* 2004).

Corrosion has been a major problem in food processing industries, where in the loss of production time for maintenance and equipment failure, there exists the additional risk of product contamination by corrosion products which may results in food poisoning. Corrosive effects are of remarkable consequence in the food processing industry as fruits contain corrosion aggressive substances, thereby causing significant impact on the degradation of constructional materials and the maintenance or replacement of products lost or contaminated as a result of corrosion reactions. (Nestor, 2004)

This research work focused on the comparative study of corrosion performance of Aluzinc, Galvanized and electroplated steel in tomato juice.

2.0 MATERIALS AND METHODS

Aluzinc, Galvanized steel and electroplated steel samples were sourced from Kolorkote, Otta. The samples thickness is 0.5 mm. Fresh fruits of Tomato were sorted and the juice were extracted. The plastic containers were first washed with detergent, rinsed in distilled water and were cleaned and allowed to dry for hours. Each of the measured samples was deeply inserted into identified plastic container containing tomato juice.

The sourced samples were cut into sizes 3cm by 3cm using a shearing machine, scriber, steel rule and engineer's try square. The cut samples were 56 pieces of the same thickness for the sample. The prepared samples for WLM was cleaned, weighed and immersed in Tomato Juice for 30 days.

2.1 Direct measurement of corrosion rate from weight loss

The samples were measured at the end of given time by weighing balance to determine the weight loss directly (as the final weight) and corrosion rate was also calculated mathematically according to Fontana (1987) as follows:

$$CR = \frac{87.6W}{\rho AT} \text{ (mm/yr)}$$

Where, CR = corrosion rate in millimeter per year,
W = weight loss in mg, this was done by subtracting the final weight measured from initial weight which gave the weight loss (weight difference)
ρ = density of each sample in mg/m^3,
A = Area, the area of each samples was determined by calculating the total surface area in cm^2 and T = Time, this was an exposure time in hours of each of the samples spent inside the different concentrations of the fruit juice.

2.2 Experimental Setup and Process for Potentiostatic Polarization

Corrosion analysis involves the particular surface of interest, and other surfaces that were not required for the corrosion analysis were isolated. This was done using synthetic epoxy. Connecting wires were place at one side of the sample and covered with a tape. Epoxy was prepared and placed all over the surface that were not required for the corrosion analysis. The epoxy was then also to solidify. This required a day to solidify. Continuity of the connection was checked to ensure proper connection between the wires and samples. The results obtained were shown in Figures 3-5.

2.3 Microstructural Analysis

The metallic samples from WLM were prepared for microstructural examination using the optical microscope. The results obtained were shown in Figures 6-8.

3.0 RESULTS

The weight loss per unit area of aluzinc steel in tomato juice with reference to time of immersion had an average increasing trend (Table 1). Its pH values increased between the first five and ten days and later changed from acidity to neutral over the time of immersion. The corrosion rate of aluzinc in tomato juice with reference to time had an averagely decreasing trend. Effect of pH on tomato juice averagely decreased from acidity to neutral over the time of immersion that implies that the tomato juice was less aggressive on the protective sample.

The weight loss per surface area of galvanized steel in tomato juice with reference to time of immersion had an average decreasing trend to certain level before increasing. The pH of tomato juice decreased from acidity to neutral over the time of immersion (Table 2). The trends of corrosion rates of metallic samples over immersion time were shown in Figure 1.

The corrosion rate of galvanized steel in tomato juice with reference to time of immersion had an averagely decreasing trend. The tomato juice had lesser aggression on the material after longer duration of immersion and as pH value averagely decreases steadily in the level of acidity over the time of immersion. The corrosion rate of galvanized steel in tomato juice reduced over the time of immersion.

The weight loss per surface area of electroplated steel in tomato juice with reference to time of immersion had an average decreasing trend to certain level before increasing. The pH of tomato juice decreased from acidity to neutral over the time of immersion (Table 3). The relationship between weight loss per surface area and time of immersion is shown Figure 2.

The corrosion rate of electroplated steel in tomato juice with reference to time of immersion had an averagely decreasing trend (Table 3). The tomato juice had lesser aggression on the material after longer duration of immersion and as pH value averagely decreased to neutral over the time of immersion. The corrosion rate of electroplated steel in tomato juice reduced over the time of immersion (Table 3).

Table 1: Corrosion Performance of Aluzinc in Tomato Juice.

Time of Immersion (Days)	Wi (g)	Wf (g)	WL (g)	WL/A (g/m2)	pH	CR (mm/yr.)
5	2.3087	2.3019	0.0068	7.555±0.00545	5.20±0.01	0.091926±0.07368
10	2.2814	2.2769	0.0045	5.000±0.0042	7.39±0.0503	0.030417±0.02841
15	2.1962	2.1871	0.0091	10.111±0.0063	6.15±0.0208	0.041006±0.02836
20	2.2382	2.2246	0.0136	15.111±0.0042	5.26±0.0404	0.045963±0.01433
25	2.2219	2.2145	0.0074	8.222±0.00127	5.40±0.0361	0.020007±0.00342
30	2.2864	2.2681	0.0183	20.333±0.00661	6.43±0..00	0.041231±0.01787

Table 2: Corrosion Performance of Galvanized Steel in Tomato Juice.

Time of Immersion (Days)	Wi (g)	Wf (g)	WL (g)	WL/A (g/m^2)	pH	CR (mm/yr.)
5	1.0543	1.0317	0.0226	25.111±0.0130	5.18±0.015	0.0262623±0.14841
10	1.0526	1.0406	0.0120	13.333±0.0068	7.74±0.0115	0.069723±0.03869
15	1.1019	1.0944	0.0075	8.333±0.0021	7.62±0.0264	0.029051±0.00781
20	1.0436	1.0239	0.0197	21.889±0.0075	7.52±0.00	0.057231±0.02132
25	1.1016	1.0723	0.0293	32.556±0.0105	7.45±0.00	0.068096±0.02423
30	1.0389	1.0162	0.0227	25.222±0.0127	7.55±0.021	0.043964±0.02421

Table 3: Corrosion Performance of Electroplated Steel in Tomato Juice

Time of Immersion (Days)	Wi (g)	Wf (g)	WL (g)	WL/A (g/m^2)	pH	CR (mm/yr.)
5	1.3536	1.3517	0.0019	2.111±0.0012	4.96±0.0153	0.022079±0.01319
10	1.3819	1.3808	0.0011	1.222±0.0003	5.40±0.2646	0.006391±0.00144
15	1.4225	1.3832	0.0393	43.667±0.0531	5.63±0.0208	0.152229±0.02021
20	1.3085	1.2704	0.0381	42.333±0.0464	8.14±0.01	0.110685±0.01394
25	1.3358	1.3094	0.0264	29.333±0.019	8.33±0.00	0.061356±0.04351
30	1.3624	1.2695	0.0929	103.222±0.0921	8.38±0.0010	0.179924±0.00712

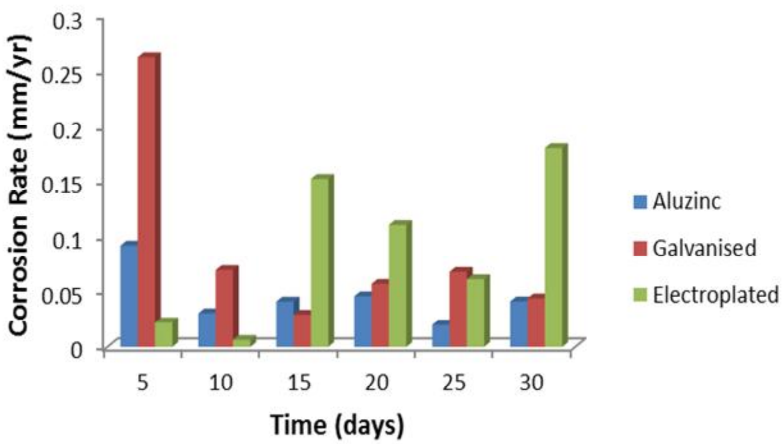


Fig. 1: Corrosion rate of galvanized and Electroplated Steel in Tomato Juice against time (days)

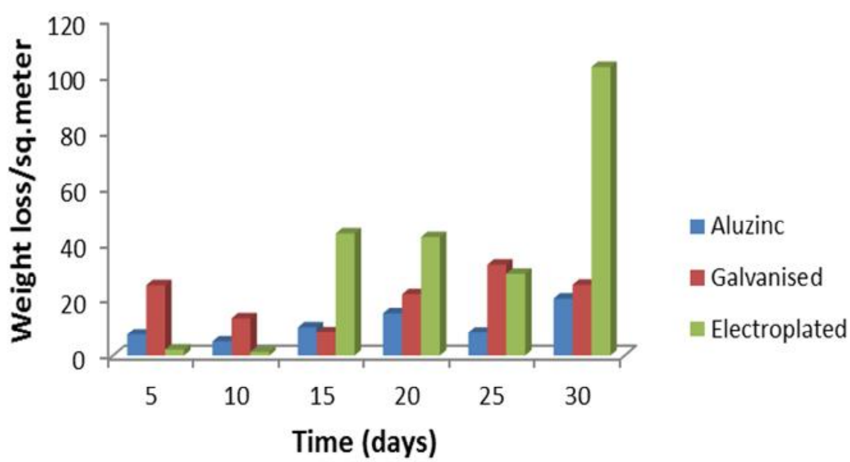


Fig. 2: Weight loss/sq. meter of galvanized and Electroplated Steel in Tomato Juice against time (days

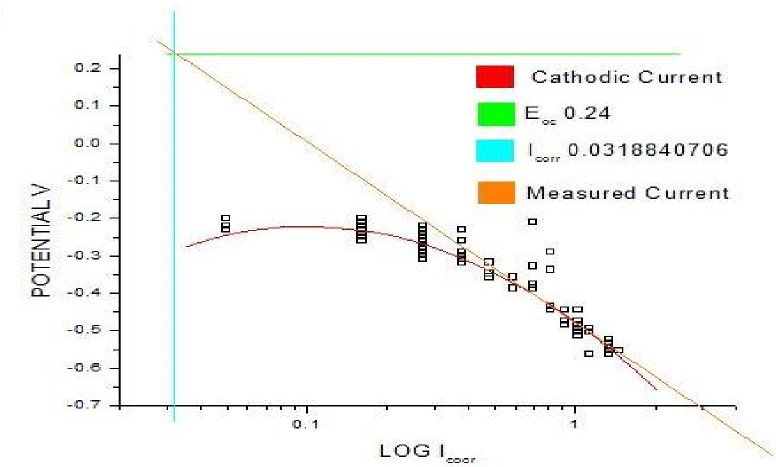


Figure 3: Potential V vs Log I_{corr} for Al - Zn Steel in Tomato Medium

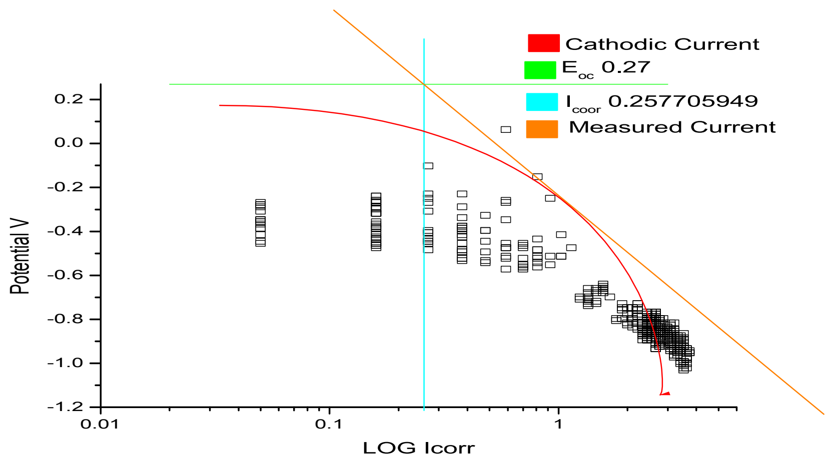


Figure 4: Potential V vs Log I_{corr} for Galvanized Steel in Tomato Medium

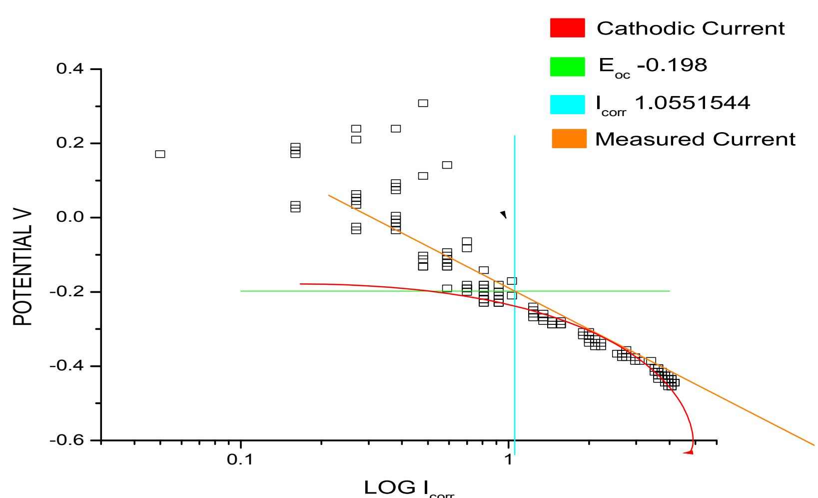
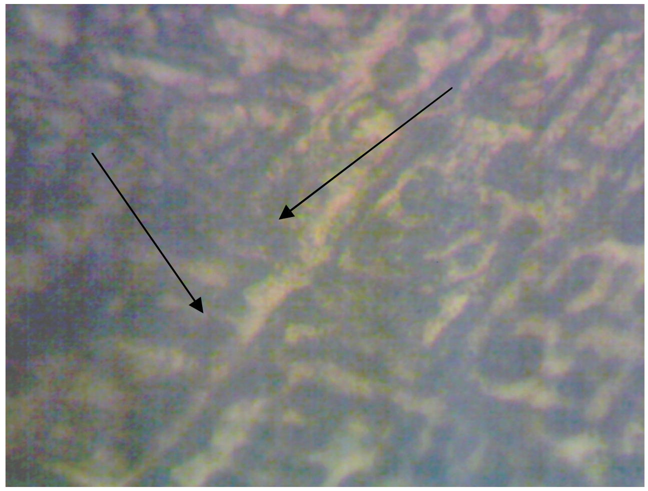


Figure 5: Potential V vs Log I_{corr} for Electroplated Steel in Tomato Medium



Magnification X640
Fig. 6: A1uzinc in Tomato after 30 days

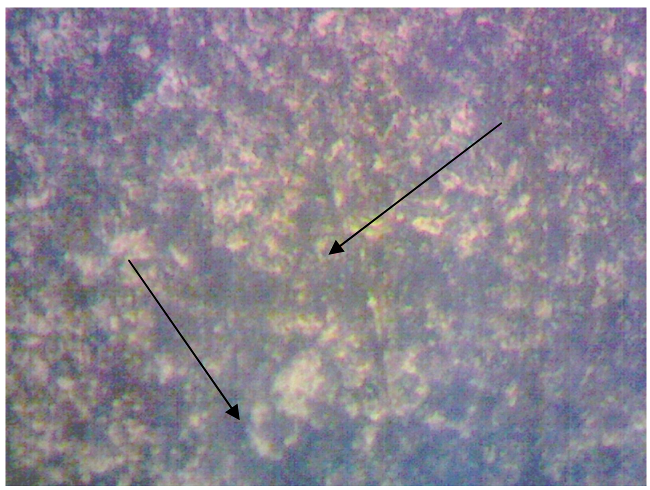


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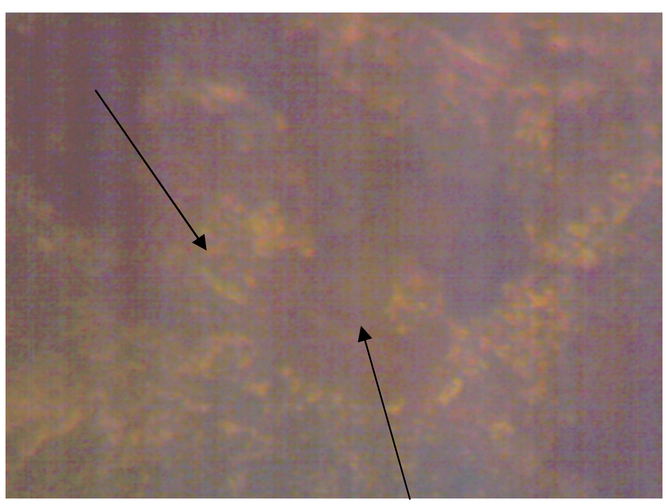
Fig. 7: Galvanized Steel in Tomato Juice after 30 days



Magnification X640
Figure 8: Electroplated Steel in Tomato Juice after 30 days

4.0 DISCUSSION

The corrosion rate of aluzinc in tomato juice varied from 0.091926 mm/yr for 5 days immersion time to 0.041231 mm/yr immersion time of 30 days. The corrosion rate dropped between 5 and 10 days and started increasing thereafter. The weight loss per surface area recorded a decrease from 7.555 g/m^2 for 5 days immersion time to 5.000 g/m^2 for 10 days. After 10 days immersion time, weight loss per surface area increased to 20.33 g/m^2 immersion time for 30 days. The pH value rose from 5.20 for 5 days to 7.39 for 10 days and dropped to 6.43 for 30 days. This result was in agreement with earlier results reported by in Olaniyi et al., 2010.

The corrosion rate of galvanized steel in tomato juice dropped from 0.262623 mm/yr for 5 days to 0.043964 mm/yr for 30 days. However, the weight loss per surface area decreased from 25.111 g/m^2 for 5 days to 8.333 g/m^2 for 15 days but later increased to 32.556 g/m^2 at 25 days of time immersion. The pH value of tomato juice was 5.18 at 5 days of time immersion. The value rose to 7.55 for 30 days of time immersion. The pH of tomato rose from acidity to neutral over a long duration of immersion. These findings were in agreement with earlier researchers like Adeyemi, O.O. and Olorunbomehin O.O 2010.

The corrosion rate of electroplated steel in tomato juice varied from 0.022079 mm/yr for 5 days immersion time to 0.179924 mm/yr for 30 days. The weight loss also varied from 2.111 g/m^2 for 5 days immersion time to 43.667 g/m^2 for 15 days immersion time. The pH of tomato in electroplated steel increased steadily from 4.96 for 5 days to 8.38 for 30 days. The pH rose from acidity to neutral over a long duration of immersion. These results agreed with the earlier researchers like Jekayinfa *et al.*, 2005.

5.0 CONCLUSION

From the experiment carried out and the result obtained in this study, the following could be concluded.

The corrosion rate of Aluzinc steel was the lowest in tomato juice followed by that of Galvanized steel and lastly Electroplated steel after 30 days of immersion in tomato juice.

The weight loss per surface area of Galvanized steel in Tomato juice showed initial decrease from 5 days to 15 days but later increased at 25 days of immersion time.

PPE showed that the corrosion rate of Electroplated steel was the highest in tomato juice followed by that of Galvanized steel and lastly Aluzinc. This actually corroborated the results obtained after 30 days immersion in the media using WLM.

The superiority of Aluzinc over and above galvanized and electroplated steel as processing and storage materials for tomato juice was confirmed by both methods employed.

The photomicrographs of Aluzinc, GS, and ES immersed in tomato juice for 30 days showed white grain boundaries due to corrosive effect.

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