



Corrosion Behaviour of Nickel Plated Low Carbon Steel in Tomato Fluid

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Abstract

This research work investigated the corrosion resistance of nickel plated low carbon steel in tomato fluid. It simulated the effect of continuous use of the material in a tomato environment where corrosion products are left in place. Low carbon steel samples were nickel electroplated at 4V for 20, 25, 30 and 35 mins using Watts solution. The plated samples were then subjected to tomato fluid environment for for 30 days. The electrode potentials mV (SCE) were measured every day. Weight loss was determined at intervals of 5 days for the duration of the exposure period. The result showed corrosion attack on the nickel- plated steel, the severity decreasing with the increasing weight of nickel coating on substrate. The result showed that thinly plated low carbon steel generally did not have any advantage over unplated steel. The pH of the tomato solution which initially was acidic was observed to progress to neutrality after 4 days and then became alkaline at the end of the thirty days test (because of corrosion product contamination of the tomato) contributing to the reduced corrosion rates in the plated samples after 10 days. Un-plated steel was found to be unsuitable for the fabrication of tomato processing machinery without some form of surface treatment - thick nickel plating is suitable as a protective coating in this environment.

Keywords

Corrosion resistance; Nickel plating; Low carbon steel; Tomato fluid.

Introduction

Corrosion has been established in uncoated mild steel used in machinery for agro-processing [1,2]. Previous work on zinc plating on steel used for cocoa and cassava processing machinery showed that zinc coating did not offer much protection because of the presence of ethanoic acid and cyanide in the respective fluids during processing [3,4]. Tomatoes are the fruits of the plant *lycopersicon esculentum* and are one of the most widely grown of the tropical vegetables. The predominant acids are citric and malic glutanic acid. Methionine and S-methylmethionine are also present [5]. The presence of these acids is likely to cause some corrosion in low carbon steel machinery used in the processing of the tomato juice. The objective of the research is to investigate the corrosion behaviour of low carbon steel and its nickel plated counterpart in tomato fluid.

Materials and Method

Material

The starting material used in this investigation was low carbon steel rod. The chemical composition of the steel plate is presented in Table 1.

Table 1. Chemical Composition of Low Carbon Steel Used in the Experiment

Elements	Composition (wt %)	Elements	Composition (wt %)
Carbon	0.218	Tungsten	0.001
Silicon	0.192	Arsenic	0.004
Phosphorus	0.049	Tin	0.024
Manganese	0.584	Cobalt	0.009
Nickel	0.097	Aluminium	0.003
Chromium	0.011	Lead	0.002
Molybdenum	0.014	Calcium	0.001
Vanadium	0.001	Zinc	0.004
Copper	0.259	Iron	98.392



Method

Preparation of Specimens (Surface)

The samples were cut into pieces of 37mm length by 8.4mm diameter. The sample surface were subjected to grinding and polishing procedures [3,4] to get the surfaces ready for electroplating. They were rinsed in distilled water and then in acetone before drying. The prepared samples were then stored in desiccators until they were needed for the experiments.

Preparation of Tomato Fluid

Fresh tomatoes were procured and the blended. The juice was collected into a clean bowl and stored in a container and labeled. The fluid analysis was carried out at the Department of animal science and the Central science laboratory both of the Obafemi Awolowo University, Nigeria. The result is presented in Table 2.

Table 2. Tomato fluid properties (average)

Composition	Percent
pH	3.61
Ash	0.885
Protein	1.91
Lipid	0.77
Carbohydrate	4.58
Acidity	-
Fibre	1.14
Moisture	91.86

Samples Pre-Treatment before Electroplating Operations

The samples were removed from the desiccators in turn and pickled in 0.5M H₂SO₄ for 2 minutes, then rinsed in distilled water before degreasing in an 100 litre electrolytic degreasing tank containing 200g KOH and 100g NaOH in distilled water for 2 minutes, after which the samples were rinsed in distilled water. The samples were weighed using a digital weighing balance model Metler Toledo Pb153 of accuracy $\pm 0.001g$ and the weight was recorded as the initial weight.

Electroplating Operation

Three of the samples were electroplated at different plating times ranging from 20mins - 35mins, while the fourth sample was kept as the control sample. The surfaces of the samples were activated with acid solution. The samples were then dipped into the Nickel plating bath

using Watts solution [6] and the electroplating rectifier switched on. The electroplated samples were removed, dried and the weights recorded.

Corrosion Monitoring in tomato fluids

The nickel electroplated samples were immersed in tomato fluid for duration of 30 days, including an un-plated sample as control. Electrode potential (mV) measurements between the sample surface and the corrosive environment were done at regular interval of 24 hours using a DT8300D digital multimeter with a zinc electrode used as a reference electrode. The reference electrode was not left in the cell for the duration of the experiment but used only at time of measurement of potential and removed afterwards. Values obtained were converted to Saturated Calomel Electrode (SCE) values [6]. Weight change determination was used due to its simplicity [1, 3, 4, 7]. The corrosion samples were removed from the corrosion environment (tomato fluid) with the aid of a tong after which the samples were properly cleaned in distilled water and then dried with a cotton wool. The dried samples were weighed with a digital chemical weighing balance and recorded and this continued at regular intervals of five days.

Results

Table 1 shows the nominal chemical composition of the steel samples used while Table 2 shows the average properties of tomato fluid. The coating thicknesses values, for the nickel plated steel sample at various times are shown in Table 3. It could be seen that the resulting nickel coating thickness varied effectively linearly with coating time. The coating thickness varied from about 0.2 μm to 0.7 μm . Figure 1 shows the weight-gained versus plating time for nickel-plated low carbon steel.

Table 3. Coating thickness of Nickel deposited on low carbon steel at 4Volt and Various Plating Times

Sample Numbers	Time (min)	Coating Thickness (μm)
1	20	0.2
2	25	0.4
3	30	0.7
4	35	0.5

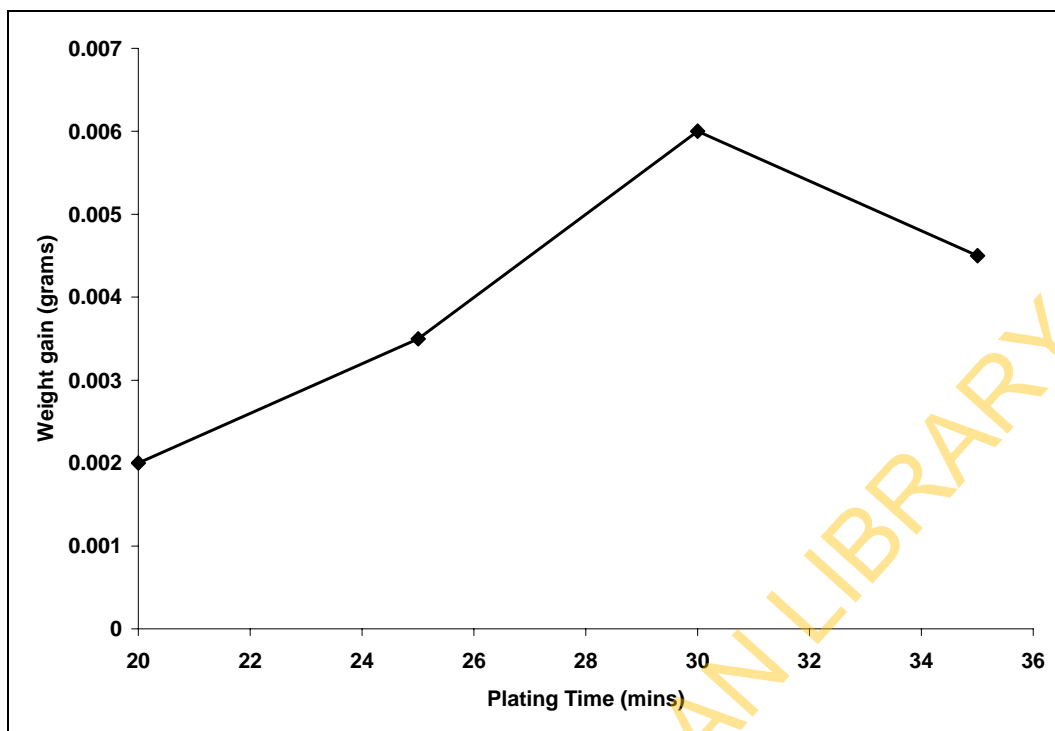


Figure 1. Plot of Weight-Gained Versus Plating Time for Nickel-Plated low carbon Steel

Figure 2 shows the changes in pH values for tomato fluid during the corrosion test period. It showed the pH of the corrosive fluid changing from acidic to neutrality and then to alkalinity at the end of the corrosion test.

Figure 3 shows the variation in the electrode potential in mV obtained for un-plated and nickel plated low carbon steel samples at various electroplating times. For the plated samples, the electrode potentials started at values consistent with that of steel and relatively rapidly moved to lower values on the 10th day consistent with that of passivated steel. Generally, the measurement of potential with time under these conditions resulted in data that appeared to be indistinguishable experimentally from each other for the different plated steels. The unplated steel vassilated between high potentials, values consistent with that of bare steel and passivation due to unremoved corrosion products.

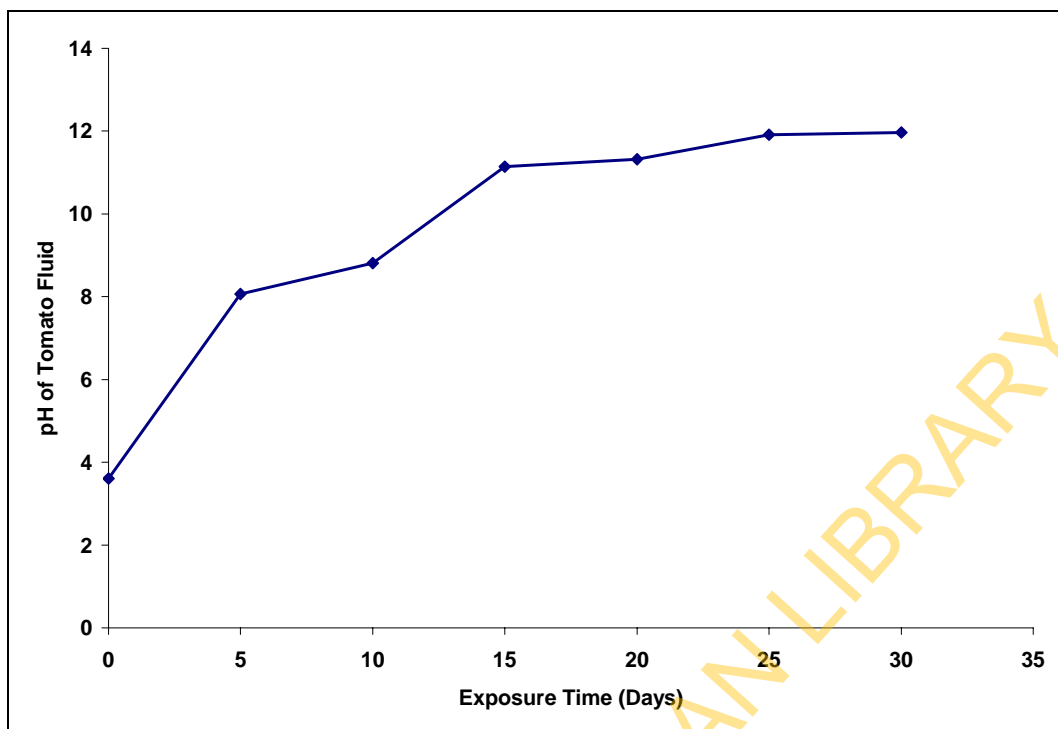


Figure 2. Changing pH Values of Tomato Fluid during Corrosion Test

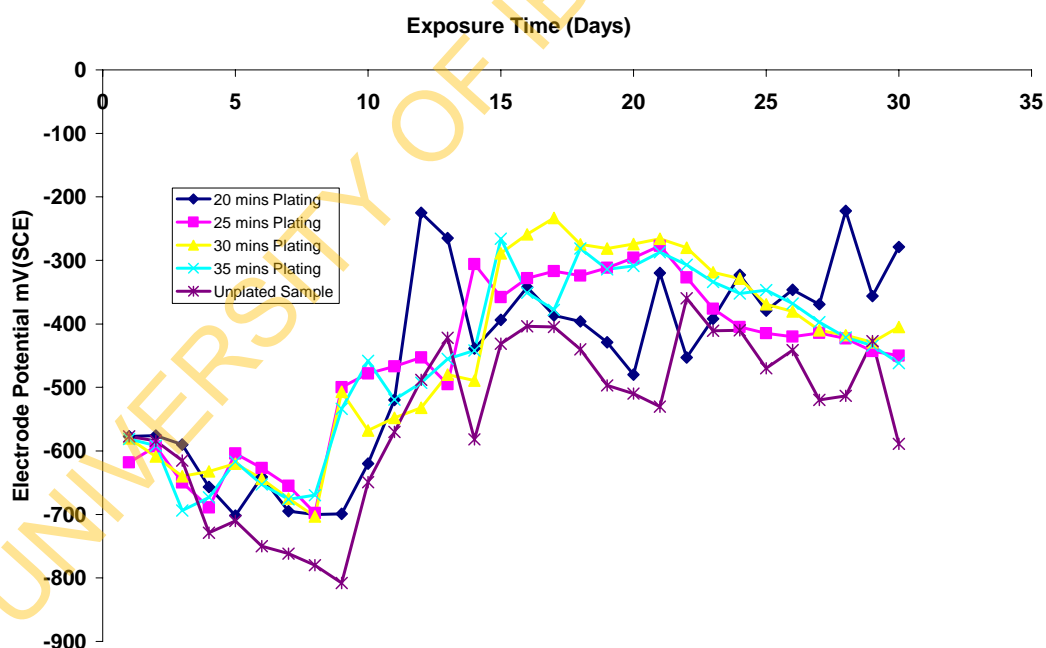


Figure 3. Plot of Electrode Potentials against Exposure Time for Nickel-Plated (4volts) low carbon Steel Samples at various Plating Time, Immersed in tomato fluid

Figure 4 shows the variation of corrosion rate in mm/yr for the various nickel plated low carbon steel samples as well as the corrosion rate of the un-plated sample immersed in tomato fluid. It showed a relatively high corrosion rate experienced by the nickel plated steel in the first 5 days of immersion. It is quite evident that thin coatings of nickel on steel are not beneficial. Thicker coating on steel was observed to offer protection to the steel.

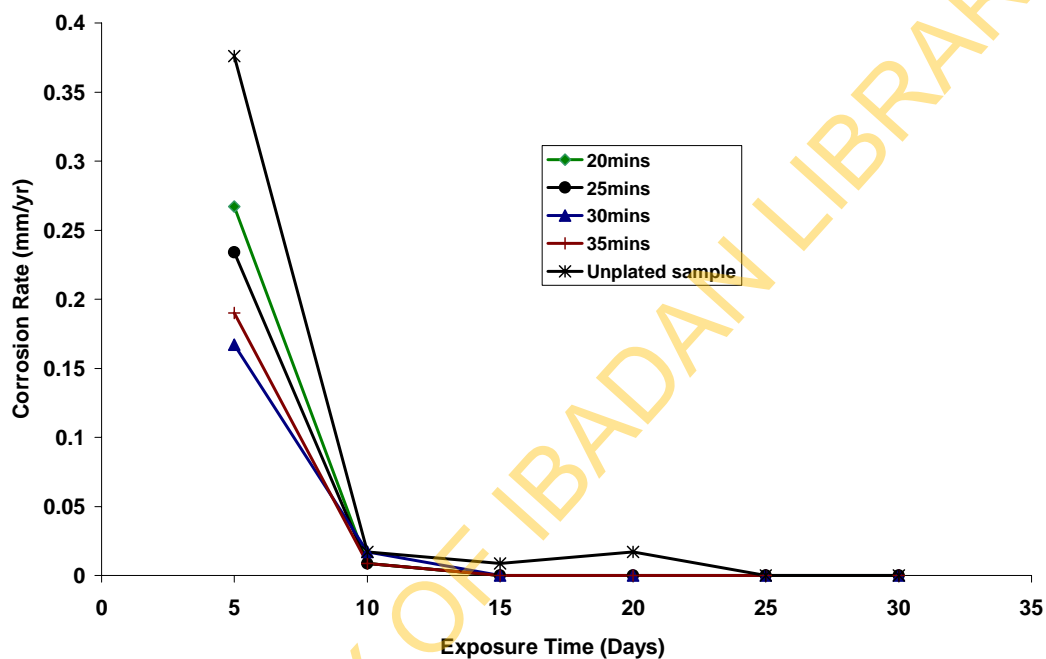


Figure 4. Plot of corrosion rate against exposure time in tomato fluid for unplated and nickel-plated low carbon steel

Discussion

Effect of Exposure Time on Potential

All the plated samples showed potential characteristic of steel on the first day but moved rapidly into higher potential by the fifth day indicating corrosion activity occurring. The samples from the eighth day moved into a passivity region which coincided with a pH of 9. This passivity continued till the 30th day when the pH was 12. Note that the pH was changing rapidly during the immersion, bringing about significant changes in the electrode potential values. An increase in coating weight generally decreased the negative potential

with time showing slower corrosion rate with increasing plating thickness.

Effect of Exposure Time on Corrosion Rate

The extent of susceptibility to corrosion in natural fluids depends on the aggressiveness of chemical reactivities, transport properties of environment, concentration of corrosion species in the medium (pH), the metallurgy of the alloy sample and temperature of the corrosion medium [8]. In the tomato fluid, the corrosion rates of all the samples decreased with time tending to relatively low rate after 10 days of exposure, Figure 3. This can be attributed to the formation of a layer of corrosion product on all the sample surfaces [9-11] from the corrosion products and the changing of the pH of the corrosive environment to basicity.

Suitability of Nickel coatings in a Tomato Environment

It is evident that uncoated steel is unsuitable for a material of construction for tomato processing equipment and this work tested the use of nickel coatings as a potential protective coating. Thick nickel coating appears to offer protection in this environment. Low coating thicknesses certainly have marginal protection.

Conclusions

Uncoated steel has been found to be unsuitable for use in tomato food processing due to its relatively high corrosion rate.

Electroplated nickel was tried as a possible corrosion protective coating for steel in tomato fluids.

Nickel corrosion was observed to be much less than that of steel. Thick nickel coating was observed to offer protection in tomato fluid environment.



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