Corrosion Resistance of Austenitic Stainless Steel in Cassava Fluid, Maize Pulp, and Seawater.

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ABSTRACT

One of the methods of protecting steel against corrosion is by alloying addition as found in stainless steel. Corrosion resistance of Austenitic Stainless Steel is investigated in cassava fluid, maize pulp, and seawater. The rate of corrosion of stainless steel was highest in seawater (0.00179 mm/y) than in maize pulp (0.001217 mm/y) and cassava fluid (0.001149 mm/y) after eighteen days of immersion. The salinity of seawater affected the performance of stainless steel in it as exposure of stainless steel surface to seawater under conditions in which there is no restriction on the availability of oxygen, gives evidence of pitting and crevice corrosion. The SEM pictures of stainless steel soaked in cassava fluid, maize pulp, and seawater for 288 hours showed white grain boundary which is an indication of the effect of corroding medium. Thus, Austenitic Stainless Steel is a good material for cassava and maize processing machinery.

(Keywords: Austenitic stainless steel, corrosion resistance, cassava fluid, maize pulp, salinity)

INTRODUCTION

It is widely known that steel would corrode when freely exposed to air at a rate between 0.05 mm per year to 0.125 mm per year (Adetunji, et al., 1992). This rate of corrosion can be higher in a more aggressive environment, like marine or industrial environment. Adequate protection of steel is therefore necessary considering its wide applications. Highly industrial nations often vote about five percent of annual budget to combat the menace of corrosion of facilities and infrastructures. Many methods are often applied to protect steel from corrosion (Abiola et al., 2007). Such methods include application of organic coatings (paintings) or alloying addition as found in stainless steel (chromium or nickel).

Corrosion is a chemical or electrochemical reaction between a metal and its environment which involves removal of the metal or its conversion to an oxide or other compound (Walker, 1980). Corrosion may also be defined as the passage of the metal atom from the metallic to the ionic state (Pascoe, 1972).

Rust is the common term for corroded steel or iron. It is a reddish-brown solid that weakens the iron or steel and can cause it to break. It forms when iron is exposed to oxygen and water, the oxygen being found in the air, and the water being found in a variety of different forms, for example, rain, condensation, water vapor in the surrounding air, etc. Many different objects can suffer from rusting. In some cases, if rusting is not prevented, then there can be a large risk of loss of life, for example with significant structural failures.

There are many ways of preventing rust, and most rust prevention methods involve coating the iron or steel in question with a protective layer that keeps both water and the oxygen in the air from reaching the iron or steel. The most frequently used method of preventing rust is painting. Care must be taken, however to paint over any chips in the paint work, as even the smallest gap in the paint could allow rusting to occur. Also, placing a film of oil or grease over the iron is also a preventive means but it must be frequently renewed and is normally used for moving machinery parts. Chromium, zinc, and tin plating can be used, and these methods involve using a protective coating for the iron. Zinc plating is also known as galvanizing. Stainless steel has been developed to contain 10-25 %chromium or nickel (Fontana and Greene, 1983).

Stainless Steels are iron alloys which depend upon a very thin transparent passive surface film of chromium oxide to resist corrosion (Loto and Ives, 1994). A supply of oxygen and a minimum level of 11% chromium dissolved in the matrix material are necessary to maintain the surface film, which is self-healing in air at room temperature. Molybdenum additions for good corrosion resistance, and relative freedom from crevice corrosion in low velocity seawater, depend on the level of chromium in the steel.

Austenitic steels with 20-22% chromium require 6% molybdenum and ferritic steels with 25-28% chromium require 3% molybdenum (Anees U.M.et al., 1993). Martensitic stainless steels have 11.5-13.5% chromium and they can be hardened by heat treatment. Duplex stainless steels usually have ferritic/austenitic microstructures. They combine the toughness and weldability of the austenitic steels with the strength, corrosion resistance and stress-corrosion cracking resistance of the ferritic steels. A standard duplex stainless steel would have the composition, 22Cr-5.4Ni-2.9Mo-0.02C-0.19N (Trethewey and Chamberlain, 1995).

Cassava is a tropical root crop that serves as a food security and income generation crop for many millions of people in the developing world (Scott et al., 2002). Cassava is grown widely in Nigeria and in many regions of the tropics, where it serves as one of the basic food source for about 200 – 300 million people (FAO, 2000, Onabolu et al.2002). During fermentation of fufu, lactic acid bacteria, yeast, and other bacteria contribute significantly to starch breakdown, acidification, detoxification, and flavor development (Oyewole, 1991; Oluwole and Olufemi, 2009.).

Moseman et al. (2007) revealed in his study that maize crop is grown for food and livestock fodder. The world output of maize is put at 603 million metric tones ranking first ahead of rice and wheat. The United States is a leading corn growing nation. Three-fifths is used in livestock feed, one-fifth is exported, and the remaining one-fifth is used as foods and for the industrial production of alcohol, distilled spirit, sugar, corn starch, and dry process foods.

It was reported by Loto (1992) that exposure of stainless steel surface to seawater under conditions in which there is no restriction on the availability of oxygen, gives evidence of pitting and crevice corrosion. This work therefore evaluated the corrosion performance of Austenitic stainless steel (SS309) in cassava fluid, maize pulp, and seawater.

MATERIALS AND METHOD

Test Fluid Preparation

The cassava fluid was prepared by grinding peeled cassava tubers using the cassava grater designed and fabricated in this project and squeezing out the fluid using clean white cloth sieve. Maize pulp was sourced from a local producer. Seawater solution was taken from Bar Beach from the Atlantic Ocean in Lagos State, Nigeria.

The plastic containers were first washed with detergent, rinsed in distilled water, and were cleaned and allow to dry for hours.

Sample Preparation

The sourced samples were cut into sizes, 5 by 5 cm^2 using a shearing machine, engineer's rule, scriber, and engineer's try-square. The cut stainless steel samples of 0.6 mm thickness were weighed using a sensitive weighing balance and the weights of the samples were measured and recorded before soaking.

Each weighed sample was separately and fully immersed into a plastic container filled with cassava fluid (test medium) and then covered. The corroded samples were observed under Scanning Electron Microscope (SEM).

Table 1: Stainless Steel's Percentage Composition.

Element	C	Ni	Cr	Fe
%	0.2	12	22	64.8

RESULTS

Corrosion Performance of Stainless Steel in Cassava Fluid

The experimental results are presented in Tables 2 to 4. Stainless steel showed high corrosion resistance in cassava fluid. The corrosion rate rose from 0.000608 mm/y obtained at soaking time of 144 hours to the highest rate of 0.001622 mm/y obtained at soaking time of 216 hours. Weight loss per surface area rose from 0.0800 g/sq.m (144 hrs) to 0.4533 g/sq.m (432 hrs). The pH values fluctuate from 3.93 to 4.33, thus indicating acidic medium.

Table 2: Corrosion Performance of Stainless Steel in Cassava Fluid (Mean).

Weight (g)	Time (hr)	Corrosion rate (mm/y)	pH	W/SA (gm²)
0.00027	72	0.00162±0.00035	4.01±0.081	0.10667±0.0231
0.00217	144	0.00060833±0	3.93±0.006	0.0800±0.00
0.00080	216	0.001622±0	4.04±0.058	0.3200±0.00
0.000833	288	0.00126736±0.00009	4.14±0.0	0.3333±0.0231
0.00090	360	0.0010950±0.00	4.33±0.025	0.360±0.00
0.00113	432	0.001149±0.00	4.25±0.00	0.4533±0.0231

Corrosion Performance of Stainless Steel in Maize Pulp

The experimental results are presented in Tables 2 to 4. The corrosion rates of stainless steel in maize pulp rose from 0.001217 mm/y (432 hrs) to 0.003650 mm/y (72 hrs). The weight loss per surface area rose from 0.24 g/sq.m (72 hrs) to 0.48 g/ sq.m (432 hrs). The pH values ranged between 4.48 and 4.61 indicating acidic medium.

Table 3: Corrosion Performance of Stainless Steel in Maize Pulp (Mean).

Weight (g)	Time (hr)	Corrosion rate (mm/y)	pH	W/SA (gm-²)
0.00060	72	0.003650±0.00	4.48±0.00	0.240±0.00
0.001100	144	0.00335±0.00	4.52±0.029	0.440±0.00
0.0008	216	0.001622±0.00	4.60±0.00	0.320±0.00
0.00090	288	0.001368±0.00	4.60±0.006	0.360±0.00
0.001	360	0.001217±0.00	4.55±0.00	0.400±0.00
0.00120	432	0.001217±0.00	4.61±0.012	0.480±0.00

Corrosion Performance of Stainless Steel Samples in Seawater

The experimental results are presented in tables 2 to 4. The corrosion rates are slightly higher than that of cassava and maize pulp. Values of 0.00179 mm/y (432 hrs) to 0.01318 mm/y (72 hrs) are obtained. The weight loss per surface area rose from 0.707 g/m^2 to 3.28 g/m^2. The pH values of 6.54 to 6.61 indicating weak acid.

Table 4: Corrosion Performance of Stainless Steel in Seawater (Mean).

Weight (g)	Time (hr)	Corrosion rate (mm/y)	pH	W/SA (g/m²)
0.00217	72	0.013181±0.00176	6.54±0.006	0.8667±0.1155
0.0030	144	0.009125±0.00	6.58±0.00	1.20±0.00
0.004200	216	0.0085167±0.00	6.64±0.011	1.68±0.00
0.008200	288	0.0124708±0.00	6.59±0.0	3.28±0.00
0.00220	360	0.002677±0.00	6.60±0.006	0.880±0.00
0.00177	432	0.00179120±0.000585	6.61±0.012	0.707±0.023

Scanning Electron Microscope Pictures

The pictures obtained from Scanning Electron Microscope (SEM) were contained in Figures 2 to 4. The white grain boundaries resulted from corrosion process while pitting and crevice corrosion were also shown.

DISCUSSION

The salinity of seawater affected the performance of stainless steel in it as exposure of stainless steel surface to seawater under conditions in which there is no restriction on the availability of oxygen, gives evidence of pitting and crevice corrosion. This is in line with previous researcher (Loto, 1992) that corrosion performance of stainless steel in sea water is affected by salinity causing pitting corrosion as shown in Figures 2 to 4. The low corrosion rates of stainless steels samples in cassava fluid and maize pulp are caused by presence of very thin transparent passive surface film of chromium oxide.

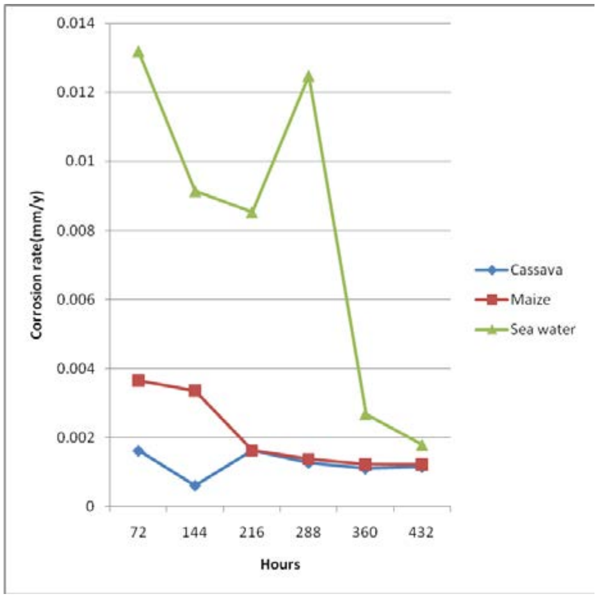

Figure 1: Corrosion Rates of Stainless Steel in Selected Media.

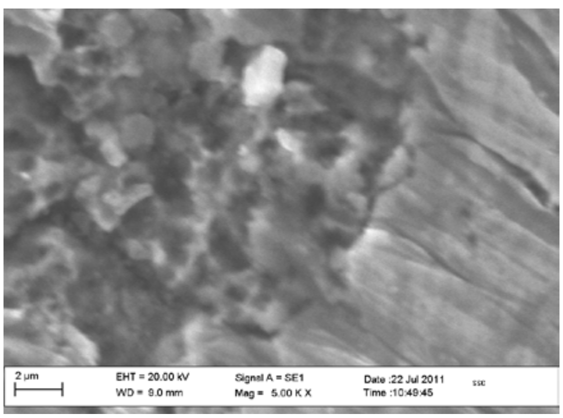

Figure 2: Stainless Steel in Cassava for 12 Days.

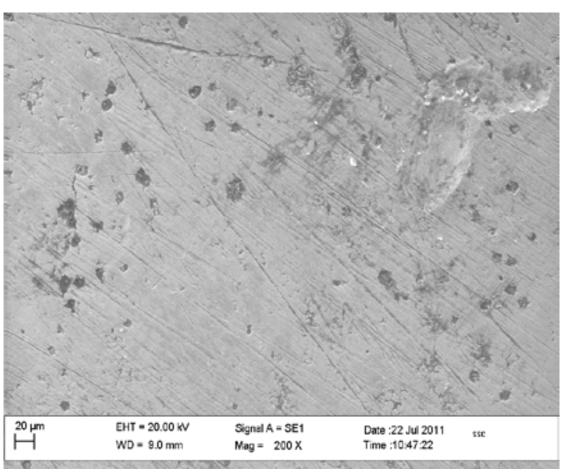

Figure 3: Stainless Steel in Maize Pulp for 12 Days.

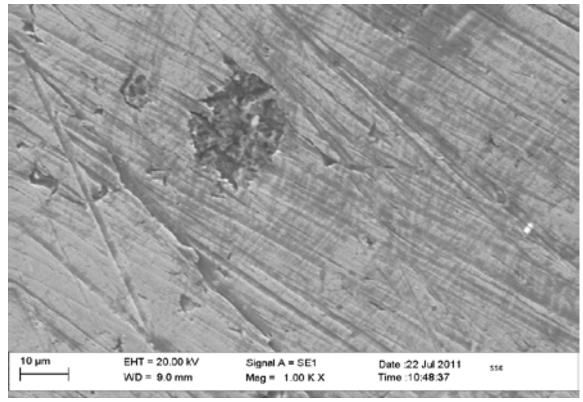

Figure 4: Stainless Steel in Seawater for 12 days.

CONCLUSION

The rate of corrosion of stainless steel was highest in seawater (0.00179 mm/y) than in maize pulp (0.001217 mm/y) and cassava fluid (0.001149 mm/y) after eighteen days of immersion.

The SEM pictures of stainless steel soaked in cassava fluid, maize pulp and seawater for 288 hours showed white grain boundary which is an indication of the effect of corroding medium.

The pH of test fluid showed acidity for both cassava fluid and maize pulp and weak acid for seawater.

REFERENCES

1. Abiola, O.K. A.O. James, and N.C. Oforkar. 2007. “Inhibition of Acid Corrosion of Mild Steel by Pyridoxal and Pyridoxol Hydrochloride”. *Int. Journal of Electrochem. Science*. (2); 278-284.

2. Adetunji, O.R., J.A. Ali, and G.O. Egundebi. 1992. “Evaluation of Process Variables on the Corrosion Performance of Hot Dip Galvanized Steel Sheets”. *Nigerian Corrosion Association Conference Proceedings*. 83- 89.

3. Anees, U.M., A.S. Nadeem, and N.A. Ismael. 1993. “Crevise Corrosion Performance of Some Commercial Stainless Steels in Arabian Gulf Seawater”. Technical Report No SWCC (RDC).28.

4. Fontana, M.G. and N.D. Greene. 1983 *Corrosion Engineering*. McGraw Hill International: London, UK. 216.

5. Food and Agricultural Organization (FAO). 2000. "Cassava an Essential Part of Diet, Championing the Cause of Cassava". http://www.fao.org/NEWS/2000/000405-e.htm.

6. Loto, C.A. 1992. "Pitting and Crevice Corrosion Susceptibility of Super Austenitic Stainless Steels in Sea Water". *Conference Proceedings of Corrosion Nigeria*. 65-77.

7. Loto, C.A and M.B. Ives. 1994. "Corrosion Resistance of Super Austenitic Stainless Steels in Seawater". *Nigerian Society of Engineers Technical Trans*. 29(1):1-9.

8. Moseman, A.H. 2007 "Corn". *Microsoft Encarta DVD*. Microsoft: Redmond, WA.

9. Oluwole, O.O. and O. Olorunfemi. 2009. "Corrosion Behavior of Nickel Plated Medium Carbon Steel in Cocoa Liquor". *Pacific Journal of Science and Technology*. 10(2):172-177.

10. Onabolu, A.O., O.S.A. Oluwole, H. Rosling, and M. Bokanga. 2002. "Processing Factors affecting the Level of Residual Cyanohydrins in Gari". *J. Sci. Food Agric.* 82:966–969.

11. Oyewole, O.B. 1991. "Fermentation of Cassava for Lafun Production". *Food Laboratory News*. 17(2):29-31.

12. Pascoe, K.J. 1972. *An Introduction to the Properties of Engineering Materials*. Van Nostrand Reinhold Company: Berkshire, UK. 315-319.

13. Threthewey, K.R. and J. Chamberlain.1995. *Corrosion for Science and Engineering*. Longman: London, UK. 336-373.

14. Walker, R. 1980. "A Corrosion Inhibitor for Metals". *Journal of Chemical Education*. 57(11): 789-791.

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