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Influence of Different Media on Some Cooking Utensils

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Abstract— *This work involves an attempted to study the corrosion behavior of some materials used as metallic cooking utensils in different media (5v% acetic acid, 5w/v% table salt, 5w/v% citric acid) at different temperatures (30,40,50,and 60 ^oC). The study was carried out using potentiostat at scan rate 3mV.sec-1. Tafel extrapolation method was used to measure corrosion parameters also corrosion resistance and corrosion rate was calculated. The calculated polarization resistance (Rp) results for comparison of the behavior of different materials at constant conditions showed that (Al) was the best in acetic acid and citric acid medium, while (Cu) showed the best value of polarization resistance in table salt.*

Keywords— *Corrosion current density, corrosion potential, polarization resistance.*

I. INTRODUCTION

The social and economic situation for a person or family plays on the way of life, type of nutrition, equipment and tools used in preparing food. Therefore, we notice a lot of people in different countries of the world use cooking utensils made of stainless steel, aluminum, copper, mixture of two or more materials etc., whether their surfaces are treated or not.

Food industry (FI) is a complicated network obeyed by essential, producers and the manufactures linked to them. The factories, involved in the operation of products and packaging should preserve the principal invested and reduce operation costs. The physicochemical features of processed foods allow them to achieve various corrosively grades relying on the type of content .Foods vary according to corrosion from non-corrosion to high corrosive substances [1, 2].

Maybe the most notable feature of corrosion is the enormous diversity of conditions in which happen and the wide number of constitute in which appears. Many handbooks of corrosion information have been collected that recorded the corrosion influence of particular material/environment collections; yet the data cover only a few portion of the possible cases and for specific values of the research involved [3].

Aluminium utensils are vastly used as local cooking vessel in the 3rd world countries. That utensil are undergo to many heating cycles during their service duty. In corrosive cooking environment, aluminium is susceptible to localized attack and gradual failure that happen because of pitting which limiting the service life extent of these utensils [4].

Rusting is an expressing for steel and iron corrosion, and when it occurs, the metals form their oxides. Virtually every environment is corrosive to some extent. Air, moisture, salted waters, steam, organic and inorganic acids, etc. cause corrosion, and high (temperature, pressure) involve additional acute corrosion conditions [5].

When choosing the type of saucepan or frying pan that we need, the thing that we have to consider is the material and the surface, which largely determine the characteristics of the saucepan or frying pan and then how appropriate it is for the purposes and dishes to be prepared.

The final choice of materials in addition to their resistance to corrosion, there must be consideration for technological and economic factors. The use of high-priced materials and the long-term availability of materials without hassle may be more economical than the use of inexpensive materials that may require frequent replacement.

We all know the role of computers and software and the revolution that they have made in providing databases for the properties and performance of many materials.

Michael Ashby has integrated databases into the smart system as tools for the designing process to get better selection of materials wanted for a specific environment [6].

Villacís et al. studied the best material to produce the cookware appropriate for induction cookers in terms of energy provision and performance. They found that the enameled cast iron and the stainless steel give higher efficiency [7].

Essam et al. studied the amount of aluminum intake hazardous to humans under for a specified period as it is believed to enhance diseases like the Alzheimer disease. As it was found that aluminum is very sensitive to variable range of pH as the corrosion rate increases in an alkaline environment. As noted that corrosion rates are decrease in drinking water compared to tap water [8].

Javier et al. studied various materials to see how these materials for cooking utensils would be influenced by inserting them into a salt spray chamber; it has been found that the enameled cast iron and the stainless steel give higher corrosion resistance [9-11].

II. EXPERIMENTAL PART

Materials

Different metallic materials were collected that used as cooking utensils to study their corrosion behavior in different media. These materials were inspected to investigate the chemical composition of them as listed in Table 1. The chemical composition was measured by "Portable metal scan analyzer" Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment. The device was manufacturing by ARUN technology, America, software

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2000. Specimens were cut to sheet with surface area equal to ($1cm^2$) to electrochemical test.

Three different corrosive media were used include: 5 V % acetic acid (CH_3COOH), 5 w/v% table salt ($NaCl$), 5 w/v% citric acid ($C_6H_8O_7$).

Electrochemical Test

The electrochemical standard cell utilized in this work was manufactured locally to conform to specification according to the ASTM standard G5-94 with provide for working electrode (cooking Utensils), auxiliary electrode was platinum type seated directly opposite to the working electrode, reference electrode was saturated calomel electrode (SCE); by using a Luggin capillary with salt-bridge connection to the reference electrode, the bridge probe tip was fixed about (1 mm) from the surface of the working electrode that was exposed to the solution to minimize the experimental error.

The samples were immersed in the electrolyte (media) and the potential was monitored as a function of time with respect to SCE, until the potential reached a stable value. WINKING M Lab potentiostat was used to carry out open circuit potential (OCP) test which was recorded during immersion working electrode in electrolyte for (600 sec.) versus saturated calomel electrode (SCE). Measurements were carried out by changing the electrode potential +200 mV around OCP [12, 13]. The linear Tafel segments of anodic and cathodic curves were extrapolated to corrosion potential to obtain corrosion parameters.

III. Results and Discussion

1-Corrosion Behavior in Acetic Acid

Aluminum:

Aluminum and its alloys mostly uses in utensils and will be contacted with food components. Al corrodes in acetic acid to release Al^{3+} as follow:

$Al \rightarrow Al^{3+} + 3e$

While the hydrogen evolution at cathode according to reaction:

$2H^{+} + 2e \rightarrow H_2$

Figure 1 shows the polarization curves of Al in acetic acid. These curves indicate the variation in corrosion potentials because the difference in anodic and cathodic sites on Al surface. Corrosion current density increases with increasing temperature from 303 K to 333 K due to increasing the mobility of ions and electrons from and to electrodes as listed in Table 2.

Brass

Brass is copper alloy (≈65%Cu-35%Zn) which undergoes from dezincification. Zinc dissolves in corrosive medium and leave copper within brass structure at anodic sites. Figure 2 shows the polarization curves of brass in acetic acid at different temperatures and the data are listed in Table 3. The data indicate that increasing the temperature led to get more positive potential and lower current density, i.e., the brass is more stable with increasing temperature.

2- Corrosion Behavior in Citric Acid

Aluminum:

The behavior of Al in citric acid is shown in Figure 3 indicating the cathodic and anodic regions, and the data are shown in Table 4 illustrating the shifting of corrosion potential to more positive value with increasing temperature and increases the corrosion current density values [14-20].

Brass

The corrosion behavior of brass in citric acid is shown in Figure 3 and the data are listed in Table 3 indicating the variation in corrosion potential values and increasing corrosion current values with increasing temperature from 303 to 333 K [21-24].

The calculated Rp values for different material in citric acid at different temperatures indicate that the aluminum it is the best for cooking in presence of citric acid in food as shown in Figure 4 and Table 5.

TABLE 1. Chemical composition of collected metallic materials.

Ele. (Wt%) / *Sample*	Fe	Cu	Zn	Al	C	Cr	Ni	Sn	Mn	Ti	Si
Al	-	-	-	>94	-	-	-	-	-	-	-
Brass	-	84.15	15.44	-	-	-	-	0.41	-	-	-
Cu											
Steel	79.3	<0.050	-	0.0697	<1.0	8.58	6.15	<0.040	0.185	0.0461	4.38

TABLE 2. Corrosion parameters of Al in acetic acid.

Temp. (K)	**-E_{corr} (mV)**	**i_{corr} ($\mu A.cm^{-2}$)**	**-b_c**	**+b_a**	**C_R (mpy)**
			$mV.dec^{-1}$		
303	653	247.85	962.2	844.7	107.3191
313	748	280.34	918.1	910.2	121.3872
323	526	303.24	972.4	969.6	131.3029
333	780	340.08	993.4	908.7	147.2546

TABLE 3. Corrosion parameters of brass in acetic acid.

Temp. (K)	**-E_{corr} (mV)**	**i_{corr} ($\mu A.cm^{-2}$)**	**-b_c**	**+b_a**	**C_R (mpy)**
			$mV.dec^{-1}$		
303	760	338.26	352.9	683.1	273.1816
313	524	269.55	404.2	483.2	217.6908
323	519	254.20	471.4	422.8	205.2940
333	509	202.33	360.9	390.3	163.4034

TABLE 4. Corrosion parameters of steel in acetic acid.

Temp. (K)	**-E_{corr} (mV)**	**i_{corr} ($\mu A.cm^{-2}$)**	**-b_c**	**+b_a**	**C_R (mpy)**
			$mV.dec^{-1}$		
303	385	289.95	573.1	453.1	132.2784
313	372	333.61	638.8	487.3	152.1966
323	359	356.73	647.1	509.5	162.7442
333	280	388.57	649.0	519.0	177.2699

TABLE 5. Corrosion parameters of Al in citric acid.

Temp. (K)	**E_{corr} (mV)**	**i_{corr} ($\mu A.cm^{-2}$)**	**-b_c**	**+b_a**	**C_R (mpy)**
			$mV.dec^{-1}$		
303	112	236.9	1437.1	1340.2	102.5777
313	659	247.14	2475.7	1821.4	107.0116
323	863	256.73	2273.9	2655.3	111.1641
333	952	268.93	2488.2	2803.7	116.4467

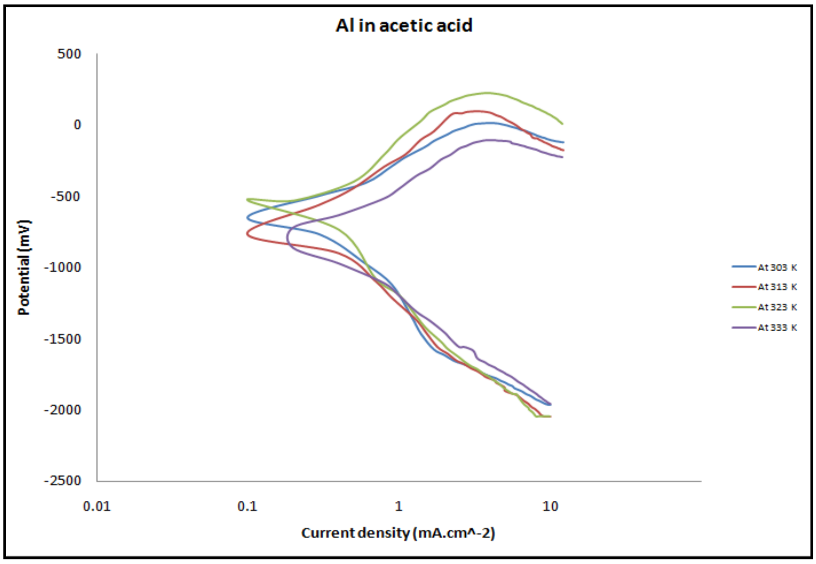

Figure 1. Tafel plot of Al in acetic acid.

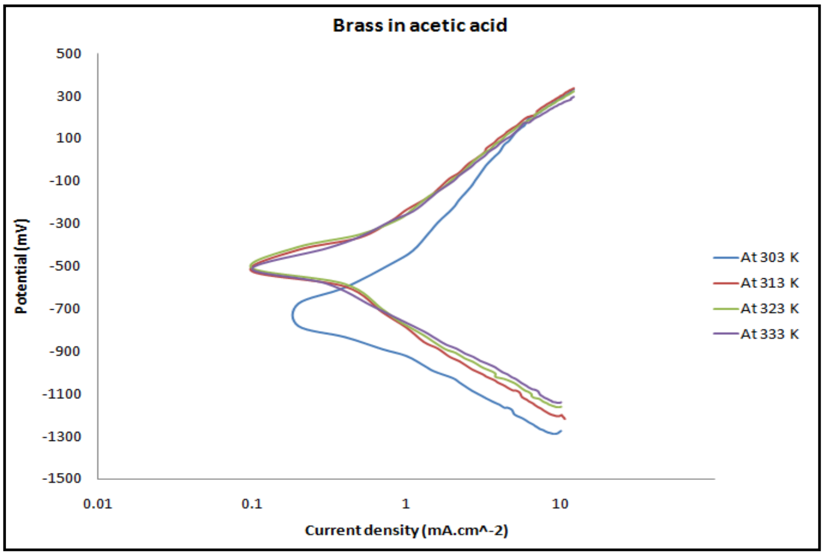

Figure 2. Tafel plot of brass in acetic acid.

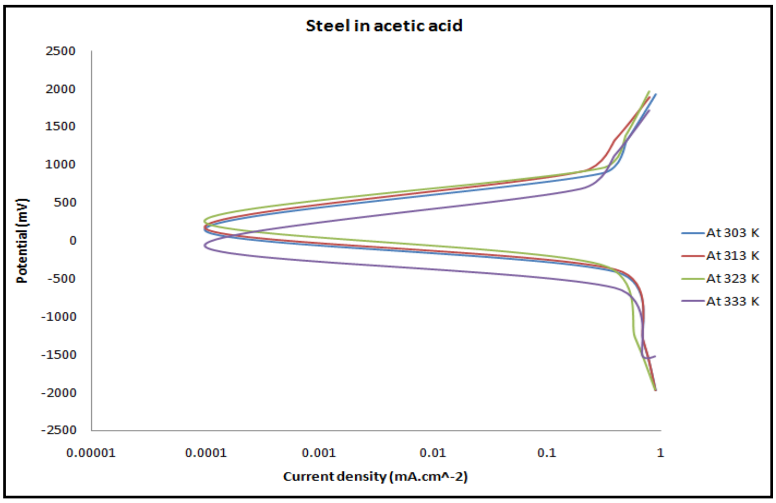

Figure 3. Tafel plot of Steel in acetic acid.

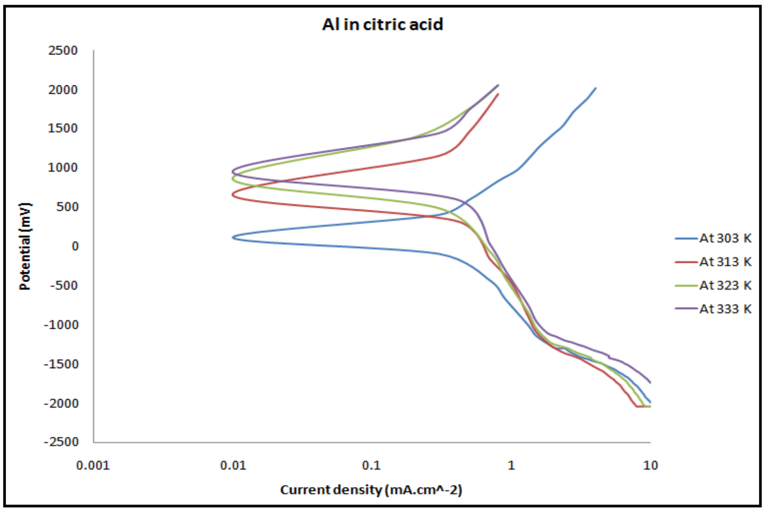

Figure 4. Tafel plot of Al in citric acid.

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