Summary and conclusion

The aim of this thesis is the study of the electrochemical behavior of tin in different buffer solutions which used to reserve the food stuff in tin cans. Although the compounds contained in the food stuff do not lead to high corrosion rate of tin, the presence of even very small tin compounds could spoil the food stuff. Therefore, some naturally occurrence safe substances are tested as corrosion inhibitor for tin in such media.

The thesis is divided into three parts:-

The first part includes the study of the cyclic voltammetry of tin electrode, in phosphate, citrate, and citro-phosphate buffers solutions.

The results indicated that $Sn(OH)_2$ and SnO are formed in the first passivation stages. Moreover, $Sn(OH)_4$ and SnO_2 are formed in the second stage by direct transformation from tin metal as well as the oxidation of tin(II) compounds. The results were explained on the basis of formation of soluble species containing phosphate or citrate. From these studies, it could be concluded that, the oxide film kinetics follow Muller's model in which the rate of the process is controlled by the resistance inside the pores.

A duplex structure of the film was suggested, which is formed from an under layer of $Sn(OH)_2$/ SnO and an outer layer of $Sn(OH)_4$/ SnO_2. These duplex layers prevent the dissolution of tin in the buffers solutions. Moreover, this passive layer is stable on a wide range of the potential.

In the second part of the thesis, the corrosion rate of tin was measured using potentiostatic technique, in phosphate, citrate, citro-phosphate buffer solutions with different pH values. It was found that the corrosivity of the buffer solutions increases as in the following order: phosphate < citro-phosphate < citrate, at all the tested pH values. On the other hand, the corrosion rate increases with respect to pH value in the order: 5 > 6 > 7 > 8.

Addition of natural honey, opuntia extract and vanillin changes the corrosion rate of tin in the different buffer solutions. In the cases of phosphate and citrate buffer solutions with pH 5, the inhibition efficiencies of the added compounds increase in the following order:-

Opuntia extract< natural honey< vanillin

On the other hand, the sequence is as following in case of citro-phosphate buffer solutions at pH 5.

Honey< opuntia extract< vanillin

In the three buffer solutions of pH 8, honey acts as an inhibitor, whereas, opuntia extract and vanillin act as inhibitors only in citrate buffer solution but as corrosive in the other two buffer solutions.

It was found that, the used compounds act as corrosion inhibitors for tin via adsorption on the metal surface. The adsorption of vanillin follows Langmuir-isotherm, whereas, opuntia extract and honey follow Temkin adsorption-isotherm.

In the third part, the susceptibility of tin to pitting corrosion, in the three buffer solutions, was studied in the presence of chloride ions. It was found that the resistance of tin to pitting corrosion increases in the following order:-

Phosphate< citro-phosphate< citrate

The data also show that, the resistance of tin toward pitting corrosion increases with pH of solution in the following order:-

pH 5 < pH 6 < pH 7 < pH 8

The same three additives used in general corrosion are used also to inhibit pitting corroion. The data show that only vanillin acts as pitting inhibitor in phosphate buffer solutions of pH 5 whereas, the opuntia extract and vanillin are inhibitors in citro-phosphate buffer solutions with the same pH value.

On the other hand, all the three compounds act as pitting inhibitors in citrate buffer solutions with pH 5 and the inhibition efficiency increases in the following order:-

Honey < vanillin < opuntia extract

The data also show that, all the three compounds enhance pitting corrosion in the three buffer solutions of pH 8.

In conclusion , the resistance of tin toward the general corrosion in the different tested solutions increases in the following order:-

Citrate (5) < phosphate (5) < citro-phosphate (5) < citrate (8) < citro-phosphate (8) < phosphate (8)

where, the numbers denote the pH values.

On the other hand, the resistance of tin toward pitting corrosion increases as following:-

Citrate(5) < Citrate(8) < Phosphate(5) < Citro-phosphate(5) < Citro-Phosphate(8) < Phosphate(8)

These sequences suggest that the most resistance of tin to both general and pitting corrosion is obtained in phosphate buffer solutions of pH 8.

However, more resistance to corrosion could be obtained by addition of the inhibitors. It was found that tin acquires the most resistance to general and pitting corrosion in the solution with the following composition:-

Citro-phosphate (pH 5) + 2000ppm (2g/L) vanillin.

This buffer solution is suggested to be used in tin cans which used in preserving food stuff. The added vanillin works also as fungicides and gives a pleasant odour for the food stuff without any hazard for human or environment.