Review of metal corrosion on food cans

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Abstract. Research has been carried out on Fe metal content from samples of tin cans of Lassegakote circulating in the community. This study aims to determine Fe metal content from canned beverage. Sample beverage solution are taken based on the difference in the length of time the sun is exposed. The concentration of Fe is determined by atomic absorption spectrophotometer. The results show that Fe metal content at various type of beverage with tinplate cans is increase if the sunlight exposure is longer.

1. Introduction
The three largest markets worldwide, according to their production extent, the number of consumers and their economic and social significance are the food, energy and water markets. Furthermore, their increasing scarcity and soaring prices lead to a global critical situation. The demand for increased food supply is related both, to population increase and personal and family income. Consequently, the food market is the largest one, including all the inhabitants of this planet, about seven billion, since everyone eats.

With the development of modern food packaging, Tinplate is widely used in canning industry through new packaging materials such as aluminum and chrome steel sheets. Besides, metals are also widely used in food cans [1]. Metals are considered to be important materials for the packaging of foods, combining properties of strength, toughness, ductility and impermeability. However, the structure of metals which gives them their valuable practical properties is also responsible for their main weakness or susceptibility to corrosion.

Corrosion is the chemical reaction between a metal and its environment; it is a universal process affecting all metals to a greater or lesser extent. Because the reaction takes place at the metal surface, the rate of attack can be reduced and controlled by modifying the conditions at the surface [3]. In fact, the industry still has problems with corrosion on packaging during the storage period. In general, this problem is observed several days (15-20 days) after packaging drinks. That still happens in the industry, and it's rarely observed by consumers [4].

This corrosion problem is an important aspect in food canning industry products that are often forgotten, which can cause various adverse consequences, including:
(a) Food products are contaminated by "corrosion products" so they are harmful to consumers.
(b) Corroded cans become leaky, so damage spreads everywhere, especially when transporting and storing. Leaky cans can also cause the entry of microbes from outside which result in decay of food in them.
Corrosion during the period of time the product is stored can change the taste, color and aroma of food, so as to eliminate consumer confidence in the products concerned. d. The damaged outer surface of the can can cancel the intention of the consumer to buy, even though the product inside is still intact. Given the various losses that can be caused, this corrosion problem is very important to be considered, both by consumers and producers. It can be added that food contamination by "corrosion products" can also come from other sources like the equipment in the industry.

Storage conditions, particularly temperature, also have some influence on the corrosion of tinplate by affecting the rate of dissolution of tin into canned food, which may give rise to a risk to human health [5]. Corrosion of food cans is influenced by various factors, there are content of certain compounds in corrosive food products such as sulfur compounds, chloride, nitrates, etc., which are derived from canned materials or from additive compounds; acidity or pH of food products [6]; the type and nature of canned materials, such as the chemical composition of metal base material, thick tin layer, thickness and type of organic protective layer, coating method and continuity of the coating; storage conditions such as temperature, pressure, room humidity and so on, and how to do canning. Thus, for handling this corrosion problem, there are many factors that must be taken into account.

Although tin is not toxic metal, but food security cannot be ignored if a large amount of tin dissolve into food during the corrosion process [2].

Sunlight exposure may lead to some effects on foods. The sunlight catalyzed reactions are considered to be complex in nature and the most-pronounced effects are observed with sunlight of the highest quantum energy. The light in the lower wavelengths of the visible spectrum and in the ultra violet (UV) spectrum. The deleterious effects may be summarized as the metal corrosion of food cans, the oxidation of fats and oils, the formation of unpleasant off-flavors, losses of vitamins A, B, C and the discoloration of pigments such as myoglobin in meats, and Some specific reactions may occur through photosensitization. The protective mechanisms already present in food systems such as B-carotene, tocopherols and synthetic antioxidants. Besides the above mentioned light-induced chemical changes in foods, the effects of display lighting and packaging materials must also be considered from the consumer's point of view. The display lighting may occur the corrosion of the cans and entering the food systems.

The tinplate surface consists of a large area of tin and tiny areas of exposed tin-iron alloy (FeSn$_2$) and steel as a result of scratches in the tin coating. Hot dipped tinplate had a considerable tin-iron alloy layer, electrolytic tinplate has a much thinner layer which is electropositive to the base and tin, thus acting as a chemically inert barrier to attack on the steel base. The effect of this barrier is to prevent a significant increase in the steel cathode area. Thus the density or degree of continuity of the alloy layer has a material effect on the rate of corrosion. In the case of tinplate exposed to an aerated aqueous environment, tin is noble to iron according to the electrochemical series. Therefore, all the anodic corrosion is concentrated on the minute areas of steel and the iron dissolves, i.e. rusts. In extreme cases perforation of the sheet may occur. This is the process which occurs on the external surface of tinplate containers. But, inside a tinplate can, the tin may be either anode or cathode depending on the nature of the food. In a dilute aerated acid medium the iron is the anode and it dissolves, liberating hydrogen. In
Deaerated acidic food, iron is the anode initially, but later reversal of polarity occurs and the tin becomes the anode, thus protecting the steel; tin has been described in this situation as a sacrificial anode. This reversal occurs because certain constituents of foods can combine chemically with Sn$^{2+}$ ions to form soluble tin complexes. As a consequence, the activity of Sn$^{2+}$ ions with which the tin is in equilibrium is greatly lowered, and the tin becomes less noble (i.e. more electropositive) than iron.

2. Methods

The analyzed samples were obtained from various food stores in the Sampangan area to Gunungpati with a radius of 25 km. The selected food store is a food store with a minimum distance of 100 meters. A subsection. samples of canned drinks are then dried under direct sunlight for 1, 2 and 3 hours. The results obtained were analyzed for Fe content using atomic absorption spectrophotometer.

3. Result and Discussion

The tin container was originally made of tin plate consisting of base steel sheets coated with white lead (Sn) by immersion in molten tin hot dipping or electrolysis. Can coating by hot dipped is a long way in which steel sheets are dipped in liquid tin heat, so that the tin layer is too thick and unattractive. Electrolysis coating is a more modern way of coating by using galvanized electricity to produce more tin layers thin and flat[5]. The manufacture of tin plate cans is traditionally done by hitting iron until flattened and thin then soaked in fermented acidic solution, so the process is called pickling. In the manufacture of mechanical tin plate cans, acidification is carried out using sulfuric acid, while the melting process with use high pressure. This tin plate can be made into cans in the form of a hollow (hole), or flat can, a new canned tin then re-formed.

The result of this research is the iron concentration of food with various time of sun exposure. This result was obtained with the Table 1. Results of analysis of Fe heavy metals on all samples, as stated in Table 1, shows metal contamination weight of Fe at this low concentration does not exceed the SNI-013548-1994 threshold amounting to 10.0 mg / Kg. Whereas in large quantities of metal Iron can enter the body cause symptoms of nausea, vomiting, diarrhea, and bleeding in the system digestion and other reactions will lead to shock, coma, seizures, and death [6]. Damage to canned food products mainly due to interactions between base metal cans, that is Sn and Fe can cause unwanted changes like discoloration, off-flavor occurs, loss of nutritional value, and rust formation on cans [10]. Product chemical reaction with canned ingredients caused by several factors, including: high residual oxygen in food, the presence of accelerators such as nitrates and other sulfur compounds, food pH in cans, types of cans and layers corrosive barrier. Damage to canned food products mainly due to interactions between base metal cans, that is Sn and Fe can cause unwanted changes like discoloration, off-flavor occurs, loss of nutritional value, and rust formation on cans. Product chemical reaction with canned ingredients caused by several factors, including: high residual oxygen in food, the presence of accelerators such as nitrates and other sulfur compounds, food pH in cans, types of cans and layers corrosive barrier [9].
Table 1. The corrosion of iron from tinplate cans

| Code   | Abs (U1) C1 (ppm) | Abs (U2) C2 (ppm) | Abs (U3) C3 (ppm) | Average conc Fe (ppm) |
|--------|-------------------|-------------------|-------------------|----------------------|
| AS A 1 h 0,0277 | 2,3302           | 0,0286 | 2,4151           | 0,0291 | 2,4623 | 2,4025 |
| AS A 3 2h 0,029  | 2,4528           | 0,0295 | 2,5000           | 0,0311 | 2,6509 | 2,5346 |
| AS A 5 h 0,0311 | 2,6509           | 0,0299 | 2,5377           | 0,0312 | 2,6604 | 2,6164 |
| AS A 7 h 0,0451 | 3,9717           | 0,0285 | 2,4057           | 0,0267 | 2,2358 | 2,8711 |
| AS A 8 h 0,0502 | 4,4528           | 0,0281 | 2,3679           | 0,0294 | 2,4906 | 3,1038 |
| AS B 1 h 0,0272 | 2,2830           | 0,0267 | 2,2358           | 0,0292 | 2,4717 | 2,3302 |
| AS B 3 h 0,0315 | 2,6887           | 0,0292 | 2,4717           | 0,0245 | 2,0823 | 2,3962 |
| AS B 5 h 0,0443 | 3,8962           | 0,0257 | 2,1415           | 0,0264 | 2,2075 | 2,7484 |
| AS B 7 h 0,0331 | 2,8396           | 0,0267 | 2,2358           | 0,0299 | 2,5377 | 2,5377 |
| AS C 8 h 0,0312 | 2,6604           | 0,0315 | 2,6887           | 0,0342 | 2,9434 | 2,7642 |
| AS D 1 h 0,0241 | 1,9906           | 0,0251 | 2,0849           | 0,0283 | 2,3868 | 2,1541 |
| AS D 3 h 0,0232 | 1,9057           | 0,0258 | 2,1509           | 0,0294 | 2,4906 | 2,1824 |
| AS D 5 h 0,0238 | 1,9623           | 0,0277 | 2,3302           | 0,0304 | 2,5849 | 2,2925 |
| AS D 7 h 0,0233 | 1,9151           | 0,0255 | 2,1226           | 0,0413 | 3,6132 | 2,5503 |
| AS D 8 h 0,0329 | 2,8208           | 0,0363 | 3,1415           | 0,0215 | 1,7453 | 2,5692 |
| LS A 1 h 0,0385 | 3,3491           | 0,0352 | 3,0777           | 0,0321 | 2,7453 | 3,0440 |
| LS A 3 h 0,0385 | 3,3491           | 0,0343 | 2,9528           | 0,0397 | 3,4623 | 2,5247 |
| LS A 5 h 0,0344 | 2,9623           | 0,0339 | 2,9151           | 0,0392 | 3,4151 | 3,0975 |
| LS A 7 h 0,0338 | 2,3774           | 0,034  | 2,9245           | 0,0393 | 3,4245 | 3,2421 |
| LS A 8 h 0,032 | 2,7358           | 0,0316 | 2,6981           | 0,0374 | 3,2453 | 2,8931 |
| LS B 1 h 0,0285 | 2,4057           | 0,0274 | 2,3019           | 0,0394 | 3,4340 | 2,7138 |
| LS B 3 h 0,0302 | 2,5660           | 0,0308 | 2,6226           | 0,0398 | 3,4717 | 2,8868 |
| LS B 5 h 0,0315 | 2,6887           | 0,0322 | 2,7547           | 0,0397 | 3,4623 | 2,9686 |
| LS B 7 h 0,0283 | 2,3868           | 0,0314 | 2,6792           | 0,0387 | 3,3679 | 2,8113 |
| LS B 8 h 0,0306 | 2,6038           | 0,0261 | 2,1792           | 0,0379 | 3,2925 | 2,6918 |
| LS C 1 h 0,0314 | 2,6792           | 0,0274 | 2,3019           | 0,0382 | 3,3208 | 2,7673 |
| LS C 3 h 0,034  | 2,9245           | 0,0294 | 2,4906           | 0,0394 | 3,4340 | 2,9497 |
| LS C 5 h 0,0314 | 2,6792           | 0,0285 | 2,4057           | 0,0307 | 2,6132 | 2,5660 |
| LS C 7 h 0,0322 | 2,7547           | 0,033  | 2,8302           | 0,0319 | 2,7264 | 2,7704 |
| LS C 8 h 0,0278 | 2,3396           | 0,0252 | 2,0943           | 0,0307 | 2,6132 | 2,3491 |

Many factors affecting rate of corrosion on food cans. First, polarization of the electrodes. When current flows, there is a change in the potential of an electrode; this is known as polarization. As the current begins to flow, the potential of the cathode becomes increasingly negative and the anode increasingly positive [8]. Consequently the potential difference between the anode and the cathode decreases until a steady state is reached when corrosion proceeds at a constant rate. Thus, the corrosion current and therefore the corrosion rate will be affected by anything which affects the polarization of the electrodes. Second, supply of oxygen. The rate at which oxygen is supplied largely governs the rate of corrosion, since corrosion by oxygen reduction requires the presence of oxygen for the cathodic reaction 3 to proceed. The rate of supply is proportional to the rate at which oxygen diffuses to the metal surface, and this depends on the concentration of dissolved oxygen in solution. This is the justification for the practice of attempting to remove all the oxygen from canned foods prior to seaming on the can end. Third, temperature. The rate of corrosion generally increases with increase in temperature as more...
reactant molecules or ions are activated and are able to cross over the energy barrier. As well, increasing the temperature has a tendency to increase the rate of diffusion of molecules or ions in a solution, although the solubility of oxygen in water decreases with increasing temperature. Four, passivation. Passivation refers to a material becoming "passive," that is, being less affected by environmental factors such as air and water [11]. Passivation involves a shielding outer-layer of corrosion, which can be applied as a microcoating, or which occurs spontaneously in nature. As a technique, passivation is the use of a light coat of a protective material, such as metal oxide, to create a shell against corrosion. If the metal can be oxidized to an oxide that is stable in the electrolyte, then the metal is called passivated. Passivation usually requires strong oxidizing conditions. Thus corrosion resistant metals and alloys can withstand an aggressive environment because of the presence of thin films of adherent oxides on their surfaces. The oxide layer will completely stop the anodic reaction which is the direct cause of corrosion, and if the film is insoluble in the electrolyte solution, it will form an insulation barrier which will reduce the rate of the cathodic reaction [7].

4. Conclusion
Results of analysis of Fe heavy metals on all samples, shows metal contamination weight of Fe at this low concentration does not exceed the SNI-013548-1994 threshold amounting to 10.0 mg / Kg. Damage to canned food products mainly due to interactions between base metal cans, that is Sn and Fe can cause unwanted changes like discoloration, off-flavor occurs, loss of nutritional value, and rust formation on cans. The chemical reaction of products with canned ingredients is caused by several factors, one of which is the type of can and a corrosive barrier layer. Temperature is one of the factors causing corrosion. The rate of corrosion generally increases with increase in temperature as more reactant molecules or ions are activated and are able to cross over the energy barrier. As well, increasing the temperature has a tendency to increase the rate of diffusion of molecules or ions in a solution, although the solubility of oxygen in water decreases with increasing temperature. The concentration of Fe is determined by atomic absorption spectrophotometer and the results show that Fe metal content at various type of beverage with tinplate cans is increase if the sunlight exposure is longer.

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