

Original Research

Corrosion Inhibition Effect of Starfruit Leaf Extract (*Averrhoa bilimbi L.*) On Stainless Steel Orthodontic Wire

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ABSTRACT

Background: The use of stainless steel orthodontic wire can corrode in oral cavity. Corrosion can affect human body and feature of orthodontic wire and this corrosion will release chromium ions. There is an inhibitor can be used to reduce corrosion. Natural ingredient extract inhibitor is usually preferred because it's not harmful to environment. Starfruit leaf is one of examples of natural inhibitor. This study was aimed to determine the corrosion inhibition effect of starfruit leaf extract on stainless steel orthodontic wire. **Material & Methods:** This study used 8 samples, each consisting of 2 orthodontic wires with a length of 40 mm and a diameter of 0.4. Eight samples were divided into 2 groups where one group was immersed in artificial saliva solution and the other group was immersed in starfruit leaf extract in 1,3,7 and 14 days. The results was measured by using AAS. **Results:** The Independent samples t-test showed that a significant differences between groups ($p < 0.05$). **Conclusion:** Starfruit leaves extract has corrosion inhibition on stainless steel orthodontic wire.

Keys words: corrosion, inhibition, star fruit leaf extract, stainless steel.

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INTRODUCTION

Orthodontic treatment is one of the treatments that plays an important role in improving the alignment of teeth, correcting dento cranio facial malrelations and malformations, so that it can restore the function of chewing, speaking and facial appearance.^{1,2} One of the components used in orthodontic treatment is orthodontic wire.^{3,4} Currently, various types of fixed orthodontic wires have been circulating in the market, including stainless steel wire, cobalt chromium, beta-titanium and nickel-titanium (NiTi). Orthodontic wire that is often used is orthodontic stainless steel wire which has advantages such as good elasticity, adequate strength, malleability, economy, and resistance to corrosion, however the corrosion-resistant properties of orthodontic stainless steel wire can be affected by conditions in the oral cavity.

Stainless steel wire is also known as corrosion-resistant steel which contains iron (Fe), carbon (C),

chromium (Cr), and nickel (Ni). Prices are more economical, but different manufacturing processes can affect the corrosion resistance level of stainless steel wire.^{3,4} The oral cavity is an ideal environment for metal biodegradation because the temperature and quality and pH of the saliva can affect the stability of metal ions. Organic acids from the decomposition of food waste containing sulphur can also encourage the release of Cr and Ni ions from orthodontic stainless steel wires that have been immersed in the oral cavity for so long. Saliva contains inorganic ions (N⁺, K⁺, Cl⁻ and HCO₃⁻). The inorganic components in the saliva act as an electrolyte medium that can trigger electrochemical reactions. As a result of this electrochemical reaction, the release of Cr and Ni ions from the stainless steel orthodontic wire is a sign of corrosion.⁵

Corrosion cannot be prevented but the rate can be reduced. Various ways have been done to reduce the rate of corrosion, one of which is the use of

inhibitors.^{5,6} The addition of this corrosion inhibitor has been used in industrial fields such as oil and gas. Corrosion inhibitor itself is defined as a substance which when added in small amounts to the environment will reduce the environmental corrosion attack on the metal.⁷ Corrosion inhibitors consist of inorganic and organic inhibitors (green inhibitors). Inorganic inhibitors include arsenate, chromate, silicate, and phosphate, which are expensive, dangerous, and environmentally unfriendly chemicals that will give bad effects when interacting directly with the human body. Therefore, currently being developed the use of organic materials that are more natural to be used as corrosion inhibitors which are safer and more biocompatible with the body. One of the natural ingredients that contain many antioxidants and have the potential to be used as a corrosion inhibitor is the leaf of starfruit (*Averrhoa bilimbi L.*) Starfruit leaves contain secondary metabolite compounds including tannin, sulphur, formic acid and flavonoid compounds. The results of several studies show that tannin is a corrosion inhibitor.^{8,9} In addition to tannin, corrosion inhibition on metal surfaces can also occur by administering flavonoids. The starfruit plant is one of the most

popular medicinal plants in Indonesian society so it is easy to find.

MATERIALS AND METHODS

The study was a laboratory experimental by using the sample of stainless steel wire. The stainless steel wire used is 0.40 mm in diameter, which is then prepared with a length of 40 mm so that 8 wire samples of the same length are produced. The samples were then grouped into 8 groups, each consisting of 2 pieces. The stainless steel wire were soaked in the artificial saliva solution pH 6.75 ± 0.15 and 5 ml of starfruit leaves extract in a borosilicate glass tube then tightly closed, and storing at 37⁰ C for 1, 3, 7, and 14 days. The release of Cr and Ni ions at each immersion was measured by using AAS (Atomic Absorption Spectrophotometric).

RESULT

The eight samples tested consisted of four samples of stainless steel wire soaked in starfruit leaf extract and four samples of stainless steel wire soaked in artificial saliva. The immersion results are shown in tables 1 and 2.

Table 1. The results of the release of Cr and Ni ions on wire soaked in starfruit leaf extract

No	Sample code	Form	Unit	Results Mean of Cr Ion	Results Mean of Ni Ion
1	1 days	Liquid	ppm	1.49100	0.00443
2	3 days	Liquid	ppm	1.66100	0.00452
3	7 days	Liquid	ppm	1.97000	0.00468
4	14 days	liquid	ppm	2.14000	0.00476

Table 2. The results of the release of Cr and Ni ions on wires immersed in artificial saliva

No	Sample code	Form	Unit	Results Mean of Cr Ion	Results Mean of Ni Ion
1	1 days	Liquid	ppm	2.67200	0.00480
2	3 days	Liquid	ppm	2.73200	0.00484
3	7 days	Liquid	ppm	2.82100	0.00502
4	14 days	liquid	ppm	2.88000	0.00514

The result of this study indicate that the results of immersion on the first, third, seventh and fourteenth days of increased Cr ion deposition in each of the research sample solutions, namely artificial saliva and starfruit leaf extract. The independent sample t-test was conducted after it was found that the data were normally distributed. The results obtained showed that each group had a significance level of 0.00 ($p < 0.05$), which means that there was a significant difference in the release of Cr ions from the stainless steel wire between those soaked in star fruit extract and artificial saliva of 1, 3, 7 and 14 days.

DISCUSSION

The measurement results showed that there was a release of Cr metal ions with varying amounts of

release in the control group, namely stainless steel orthodontic wire immersed in artificial saliva. According to Einer (2004), Cr ion can form a protective surface oxide due to oxygen activity on the metal surface. Apart from the Cr ion which reacts with oxygen from the electrolyte media, it will be deposited on the metal surface as chromium oxide (Cr₂O₃) which is a further protection for the metal underneath from the corrosion process.¹⁰ Meanwhile, Wan Nik (2011) stated that the decrease in the corrosion rate in the group with the addition of an inhibitor is due to the presence of active compounds in the extract of starfruit leaves such as tannins, saponins, alkaloids, and flavonoids which contain functional groups - C = O, OH, and C = C which functions as an antioxidant so that it can become a

partner for free electrons on the metal surface. The active content in the extract of starfruit leaves used are indeed diverse and almost all of them contain elements of oxygen, sulphur, and nitrogen so it is difficult to determine which component plays the best role in inhibiting the corrosion rate or it may be that all the ingredients can inhibit the corrosion rate.¹¹ On the other hand, Siagian (2010) stated that the presence of inhibitors on the surface of stainless steel is due to adsorption. The adsorption that occurs in the starfruit leaf extract inhibitor occurs between the ions on the surface of the stainless steel wire and the active groups present in the active compounds in the starfruit leaf extract. Adsorption occurs due to the adhesion force between the inhibitor and the stainless steel surface.¹² The adsorption of inhibitor molecules on the stainless steel surface will produce a kind of thin layer (film) on the stainless steel which can inhibit the corrosion rate. However, starfruit leaf extract does not react with or eliminate aggressive ions. The molecules of the active compounds in the leaf starfruit extract maybe adsorb the molecules, that will later accumulate on the metal surface and form a thin layer, namely the bond between the CR ion and the -OH group which is more stable and can block metal interactions with the environment. The results of this study indicated that there were differences in the release of Cr ions immersed in artificial saliva and starfruit leaf extract. The release of Cr ions immersed in artificial saliva was greater than that immersed in starfruit leaf extract. This shows that the addition of an inhibitor has been proven to slow down the corrosion rate. The decrease in the corrosion rate of metals due to the presence of these organic compounds is in accordance with the research conducted by Hermawan et al. (2012) who showed that tannins from cocoa pod husk extract played a role in decreasing the corrosion rate of steel.¹³ The research result of Favre (1993) showed that the tannin compounds in the extract can form a complex with Fe (III) on the steel surface so that the corrosion reaction rate will decrease. This complex will block the attack of corrosive ions on the steel surface, so that the corrosion reaction rate will decrease.¹⁴ According to Billy (2012), tannins have shown to inhibit the rate of corrosion that occurs in metals by providing a kind of protective layer on the metal surface so that it does not corrode.¹⁵ The same thing was stated by Nasution (2012) regarding the role of tannins from mangosteen peel extract in reducing the corrosion rate of steel and in Al-Qudah's research (2011) which showed a decrease in the rate of corrosion due to the presence of organic compounds, namely flavonoids from a plant that can play a role in the inhibition process of metals corrosion.¹⁶ According to Habiebie (2014), organic inhibitors in the form of tea leaf extracts and guava leaves containing tannins showed an effect on slowing down the corrosion rate on 304.45 stainless steel plate. According to Diah (2016), the decrease in

the corrosion rate of API 5L carbon steel has decreased by using organic inhibitors in the form of bay leaves containing tannins (21.7%), flavonoids (0.4%).^{17,18}

The results of this study showed that the longer the wire was immersed, the greater the release of Cr ions in both variables. It can be seen in the results of research that the release of Cr ions immersed in artificial saliva and starfruit leaf extract for 1, 3, 7, and 14 days has increased. The results of this study are in line with the research conducted by Habiebie (2014), which shows that the higher the temperature and the longer the time to soak the sample, the higher the corrosion rate will be.¹⁷ According to Eliades (2002), excessive release of Cr ions or corrosion that occurs over a long period of time will have a negative impact on both the stainless steel orthodontic wire itself and on one's health. If there is corrosion or release of too much Cr ions, it can change the dimensions of the wire shape and affect the strength of the stainless steel orthodontic wire which results in the brittleness of the wire.¹⁹ Sfondrini's study (2009) exhibited that the release of Cr from orthodontic stainless steel wire can also have a negative impact on health if it exceeds the body's normal intake. Cr is a heavy metal group that can be allergic, cytotoxic and even carcinogenic to the human body.²⁰ According to Kristianingsih (2014), the inorganic components in artificial saliva become an electrolyte medium that can trigger electrochemical reactions. Electrochemical reactions are reactions that occur at the anode (undergoing oxidation) and cathode (experiencing reduction), metal ions as anode and H⁺ ions from the electrolyte medium as the cathode. This electrochemical reaction causes a corrosion process which is characterized by the release of Cr ions from the stainless steel orthodontic wire.²¹

CONCLUSION

There is a difference in the release of Cr ions from the stainless steel wire soaked in artificial saliva and in the extract of starfruit leaves for 1, 3, 7, and 14 days. The release of Cr ions from the wire soaked in starfruit leaf extract is less than that soaked in artificial saliva. Hence, Starfruit leaf extract is proven to have corrosion inhibition power against orthodontic stainless steel wire.

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