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Effectiveness of Guava Leaf Extract (*Psidium guajava* L.) as Corrosion Inhibitor of Stainless Steel Orthodontic Wire

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ABSTRACT

Stainless steel orthodontic wire is one of the wires used in orthodontic treatment. This wire is subject to corrosion. One of the efforts to inhibit corrosion is the addition of corrosion inhibitors. Guava leaves can be used as corrosion inhibitors because they contain active tannin compounds that can inhibit corrosion. This study aimed to analyze the effectiveness of guava leaf extract as a corrosion inhibitor for stainless steel orthodontic wire. This research used 0.16x0.22" stainless steel orthodontic wire from Ormco brand which was cut 40 mm long. 20 pieces of stainless steel wire were divided into 4 groups, namely the group that was soaked in saliva without guava leaf extract (control), saliva, and guava leaf extract 200 ppm, 600 ppm, and 1000 ppm. All wires were weighed before and after immersion. The wire immersion was carried out in an incubator at a temperature of 370 C for 10 days. The corrosion rate of the wire is calculated by the weight loss method. Then proceed with calculating the value of the effectiveness of the inhibitor. The results of this study showed the average corrosion rate of the saliva-soaked group was 0.159 mpy, the saliva-soaked group and guava leaf extract 200 ppm 0.037 mpy, the saliva-soaked group and guava leaf extract 600 ppm 0.033 mpy, and the saliva-soaked and guava leaf extract group guava leaf extract 1000 ppm 0.023 mpy. The results of the Kruskal Wallis analysis showed that there was a difference in the corrosion rate between the groups soaked in saliva and guava leaf extract ($p<0.05$). The effectiveness value of guava leaf extract is effective in inhibiting the corrosion rate with the highest effectiveness of 85.53%

Keywords: Corrosion Inhibitor, Stainless Steel Orthodontic Wire, Guava Leaf Extract

INTRODUCTION

Stainless steel wire is one type of wire used by dentists in orthodontic treatment. Stainless steel wire is composed of 71% iron, 18% chromium, 8% nickel, and approximately 0.2% carbon. The advantages of this wire are that it has good elasticity, is strong, easy to shape, inexpensive, and resistant to corrosion. Although stainless steel orthodontic wires are resistant to corrosion, oral cavity conditions are an ideal environment for metal biodegradation to occur, causing corrosion of orthodontic wires.

Corrosion is defined as damage that occurs in orthodontic wires due to a chemical reaction between the metal and the oral environment such as saliva, normal flora, temperature, and pH of the oral cavity. Corrosion that occurs in orthodontic wire causes a decrease in the physical properties of the wire which will increase the potential for orthodontic treatment failure. In addition, corrosion also affects individual health such as allergic, mutagenic, and carcinogenic reactions.

The occurrence of corrosion in orthodontic wire can not be avoided but the corrosion rate can be reduced. Reducing the corrosion rate can be done by various methods, one of which is the addition of inhibitors. A corrosion inhibitor is a

substance added to a metal that will reduce the corrosion of the metal. This method is considered effective because it is cheap and easier to do. Corrosion inhibitors consist of inorganic and organic inhibitors. Arsenates, chromates and silicates are examples of inorganic inhibitors. Inorganic inhibitors are considered expensive, less safe and not environmentally friendly, so currently organic inhibitors are developed which are safer and more environmentally friendly. Secondary metabolite compounds contained in plants such as tannins, alkaloids, and saponins can be used as organic inhibitors.

According to Herawani et al. (2018), organic inhibitors derived from pandan extract can reduce the corrosion rate of stainless steel wire. In addition, Banjang et al. (2018) found that starfruit leaf extract can reduce the corrosion rate of stainless steel orthodontic wires. Both of these organic materials contain tannin compounds that can reduce corrosion.

Guava leaves are one of the plants that are easily found in Indonesia. Guava leaves can be used to treat recurrent acute stomatitis, ulcers, sore throat, gingivitis, and diarrhea. Guava leaves can also kill the bacteria Streptococcus mutans and Lactobacillus acidophilus which are caries-causing bacteria. The content of secondary metabolites in guava leaves include tannins, flavonoids, alkaloids, polyphenols, saponins, and essential oils. The content of tannins in guava leaf extract can be used to inhibit the corrosion rate. Hartanto and Wicaksono (2018) and Wahyuni and Syamsudin (2014) research using guava leaf extract as a corrosion inhibitor stated that guava leaf extract was effective in reducing the corrosion rate. In his research, Hartanto and Wicaksono (2018) measured the corrosion rate of stainless steel and Wahyuni and Syamsudin (2014) measured the corrosion rate of iron. Therefore, in this study, researchers wanted to see the effectiveness of guava leaf extract as a corrosion inhibitor in inhibiting the corrosion rate of stainless steel orthodontic wires.

METHODS

This type of research is an experimental laboratory. The study was conducted from April to May 2021. The procedure for making guava leaf extract was carried out at the Pharmacy Biology Laboratory, Faculty of Pharmacy, University of North Sumatra. The sample immersion procedure and the calculation of the corrosion rate of the wire were carried out at the Integrated Laboratory of the Faculty of Medicine, Universitas Sumatera Utara. The research sample was Ormco brand stainless steel wire with a size of 0.016x0.022 inches.

The materials used in this study included fresh guava leaves, 70% alcohol, artificial saliva, pH 6.5. The tools used in this study included an analytical digital scale with an accuracy of 0.0001 gr (Vibra, Japan), blender (Panasonic, Japan), parchment paper, filter paper, (Whatman No. 42, England), 1000 volume flask ml, 250 ml volumetric flask, 1 roll of aluminum foil (Total Wrap, Indonesia), percolator, open, 10 ml dropper, drying cabinet, test tube (pyrex), vacuum rotary evaporator, pH meter Hanna (Milwaukee-Martini brand type pH56) calibrated, Inductively Coupled Plasma (ICP), and 370 C incubator.

The first stage is the stage of making guava leaf extract. Making guava leaf extract is done by maceration method. The manufacture of 100% guava leaf extract begins with cleaning the collected guava leaves. Guava leaves are washed and then dried in the open air without direct sunlight for 3 days. Half-dried guava leaves were put in a drying cabinet at 400C for 3 days (Figure 1). After that the guava leaves are removed from the drying cabinet. Then in a blender until it forms a powder. The guava leaf powder was weighed as much as 1000 grams and dissolved with 70% alcohol as much as 10 L then macerated for 2x24 hours. After that the solution was filtered with filter paper and the filtrate was accommodated in a different container (Figure 2). The filtrate was evaporated with a vacuum rotary evaporator at 700 C at 60

rpm for 2 hours to separate the solvent and guava leaf extract (Figure 3). The guava leaf extract was put in an oven to make it thicker (Figure 4). Then the guava leaf extract was put into a glass bottle.

Figure 1. Guava Leaf Extract in the Drying Cabinet (Personal Documentation)

Figure 2. Filtered Filtrate with Filter Paper (Personal Documentation)

Figure 3. Evaporated Filtrate with Rotary Evaporator (Personal Documentation)

Figure 4. Guava Leaf Extract Put in the Oven (Personal Documentation)

Figure 5. Leaf Extract Guava (Personal Documentation)

Making guava leaf extract 200 ppm was done by taking guava leaf extract in a glass bottle as much as 20 mg and put it in a measuring flask. Then 70% alcohol was put into the volumetric flask until the volume of the volumetric flask reached 100 ml. To make 600 ppm guava leaf extract, 60 mg of the extract was put into a volumetric flask. Then 70% alcohol was put into the volumetric flask until the volume of the volumetric flask reached 100 ml. To make 1000 ppm guava leaf extract, 100 mg of the extract was put into a volumetric flask then 70% alcohol was added until the volume of the volumetric flask reached 1000 ml (Figure 5).

The second stage is the stage of making saliva. Sodium chloride as much as 0.844 mg, Potassium chloride as much as 1.2 mg, Calcium chloride anhydrous as much as 0.146 mg, Magnesium chloride. 0.052 mg of 6H2O, 0.34 mg of Dibasic

Potassium phosphate, 60 mg of Sorbitol solution 70%, 3.5 mg of Hydroxyethyl cellulose were put into a volumetric flask. Then Aqua bidest was added to the volumetric flask up to the 1L limit. The pH of the solution was measured and a pH of 6.5 was obtained (Karnam et al., 2012).

The third stage is the wire preparation stage. Stainless steel wire was prepared with a length of 40 mm so that 20 samples of wire with the same length were produced. Then all wires were weighed initially with an analytical digital balance with an accuracy of 0.001. All samples were weighed 3 times and the average was calculated and recorded. Then each wire was put into a test tube and the samples were divided into four groups. The first group was the wire group which was immersed in 5 ml of saliva. The second group was the wire group which was immersed in saliva and 5 ml of 200 ppm guava leaf extract. The third group was the wire soaked in saliva and 5 ml of 600 ppm guava leaf extract. The fourth group was the wire soaked in saliva and 5 ml of 1000 ppm guava leaf extract. Each group consists of 5 samples. The tube was then put in an incubator at 370C for 10 days. After 10 days the wire was removed from the incubator and then washed with running water, dried, and the final weight of the wire was weighed. Furthermore, the measurement of the corrosion rate is carried out using the formula:

$$C_R = \left(\frac{K(Wb - Wa)}{D.S.T} \right)$$

CR = Orthodontic Wire Corrosion Rate (mpy)
Wb = Initial Weight of Wire Before Immersion (g)
Wa = Final Weight of Wire After Immersion (g)
K = Constant = 3.45x106
D = Wire Density (g/cm3)
S = Wire Surface Area (cm2)
T = Soaking Time (Hours)

After obtaining the value of the corrosion rate of the wire based on the formula above, it is continued by calculating the value of the effectiveness of the inhibitor with the formula:

$$\eta(\%) = \left(\frac{(CRunhibited - CRinhibited)}{CRunhibited} \times 100\% \right)$$

η = Inhibitor efficiency (%)
$CR_{unhibited}$ = Corrosion rate without inhibitor (mpy)
$CR_{inhibited}$ = Corrosion rate with inhibitor (mpy)

RESULT AND DISCUSSION

Result

The data from the research that has been carried out is then calculated the average of each group and then tested by statistical testing and calculating the effectiveness of the inhibitor. The results of statistical testing are as follows:

Table 1. Stainless Steel Wire Corrosion Rate

No.	Group	N	Average Corrosion Rate (mpy)	p
1	Control	5	0.159	0.006*
2	200 ppm	5	0.037	
3	600 ppm	5	0.033	
4	1000 ppm	5	0.023	

*Significance Value (p<0.05) Using Kruskal Wallis Test

From Table 1 it can be seen that the higher the concentration of guava leaf extract used as a corrosion inhibitor, the lower the corrosion rate. The highest corrosion rate was seen in the control group (without the addition of inhibitor) which was 0.159 mpy while the lowest corrosion rate was shown in the 1000 ppm guava leaf extract group. The results of statistical analysis using the Kruskal Wallis test showed a significance level of 0.006. This means that there is a significant difference between the control group and the inhibitor addition group (p<0.05).

Table 2. Analysis Results with Mann Whitney Test

Treatment Group		p
Control	200 ppm	0.008*
	600 ppm	0.008*
	1000 ppm	0.008*
200 ppm	600 ppm	0.811
	1000 ppm	0.288
600 ppm	1000 ppm	0.339

To see the corrosion rate at which concentrations of guava leaf extract were statistically different, the Mann Whitney test was carried out. Based on Table 2, it can be seen that there was a statistically significant

difference ($p<0.05$) between the control group (without inhibitor) and all groups with guava leaf extract addition. Meanwhile, between groups of guava leaf extract 200 ppm and 600 ppm; 200 ppm by 1000 ppm; and 600 ppm with 1000 ppm are not significantly different.

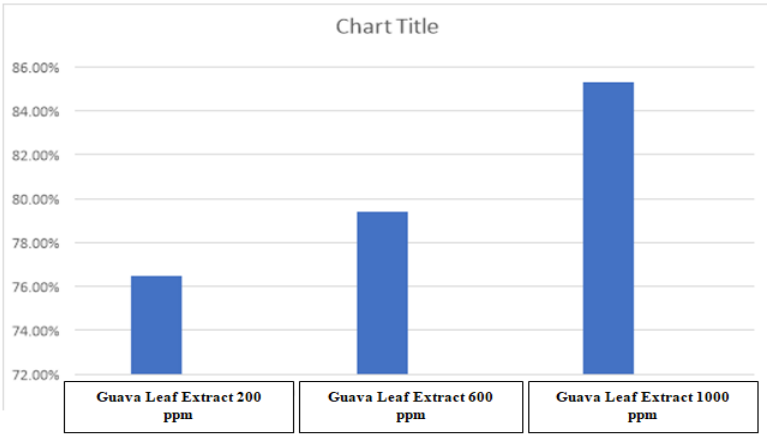


Figure 6. Effectiveness Value of Leaf Extract Guava 200, 600, and 1000 ppm

In Figure 6 it can be seen that the higher the concentration, the higher the effectiveness of the inhibitor. The highest effectiveness value was found at a concentration of 1000 ppm guava leaf extract. The lowest effectiveness was found in the 200 ppm group with an effectiveness value of 76.47%, while in the 600 ppm group the effectiveness of the inhibitor reached 79.41%.

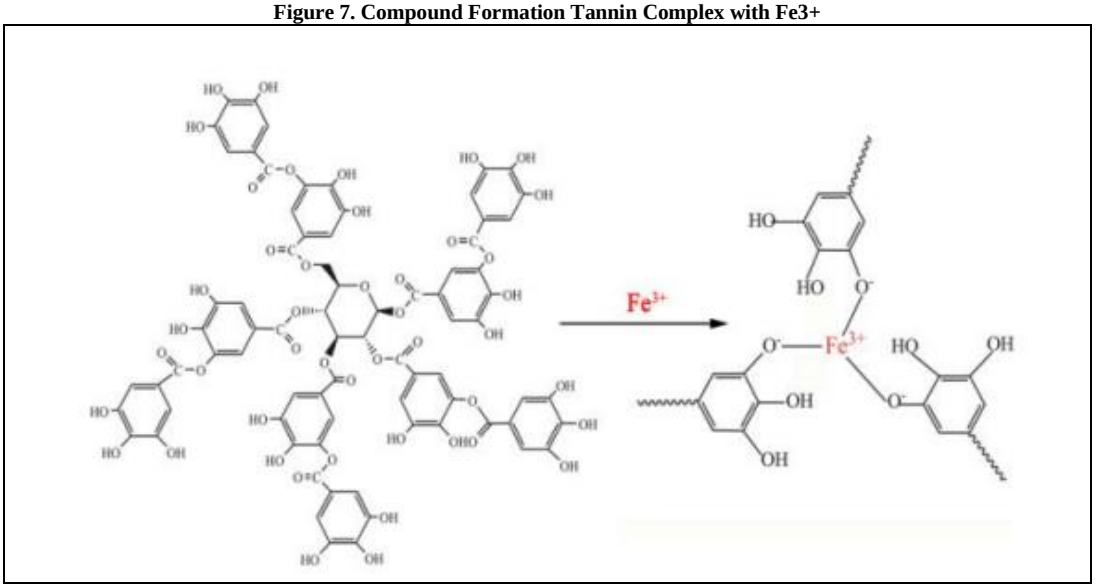
DISCUSSION

The results showed that the highest average corrosion rate was in the stainless steel wire immersed in saliva, while the lowest average corrosion rate was found in the saliva-soaked stainless steel wire group and 1000 ppm guava leaf extract. The high corrosion rate on wires immersed in saliva is caused by the content of salivary inorganic compounds (Na+, K+, Ca2+, Mg2+, Cl-, SO42-, H+, HCO3-PO43-, and HPO42-) which act as electrolyte mediators that can react with metal components in orthodontic wires. Research by Rasyid et al. (2014) and Darmayanti and Erstyawati (2021) the inorganic content of saliva (bicarbonate, phosphate, sodium, potassium, potassium, chloride and magnesium) acts as an electrolyte medium that can trigger electrochemical reactions. Electrochemical reactions are reactions that occur at the anode (experiencing oxidation) and cathode (experiencing reduction), where metal ions are used as anodes and H+ ions from the electrolyte media as cathodes (Rasyid et al., 2014; Darmayanti and Erstyawati, 2021; Roeswahjuni et al. , 2019).

In this study, the average corrosion rate was lower in the stainless steel wire group soaked in saliva and guava leaf extract concentrations of 200 ppm, 600 ppm, and 1000 ppm, and the higher the concentration of guava leaf extract, the lower the corrosion rate. This result is in line with the research which revealed that the corrosion rate of wire soaked with organic matter was lower than the control group immersed in saliva or saline solution (Herawani et al., 2018; Tambun et al., 2015; Roeswahjuni et al., 2019). The decrease in corrosion rate is due to the presence of active compounds in guava leaf extract such as tannins which contain -C=O and O-H groups which function as antioxidants so that they can become partners for free electrons on metal surfaces. The OH- group on tannins in the ortho position on the aromatic ring will form a complex compound with iron ions to become Fe-tanate as can be seen in Figure 7. This Fe-tanate complex compound will become a corrosive ion barrier from the external environment for direct contact with ferrous

metal (Rochmat et al., 2019). In addition to tannins, other antioxidant substances in guava leaf extract such as polyphenols, alkaloids, saponins and essential oils have many elements of N, O, P, S which can form complex compounds that are difficult to dissolve with metal ions so as to inhibit the corrosion rate (Wahyuni and Syamsudin, 2014).

Figure 7. Compound Formation Tannin Complex with Fe3+



The decrease in the corrosion rate of wire due to an increase in the concentration of guava leaf extract occurred due to an increase in concentration which caused an increase in the effectiveness of an extract in inhibiting the corrosion rate. According to Farmasyantiet al.(2018), the higher the concentration of corrosion inhibitors, the more inhibitor molecules will bind to the surface of the wire to form a stronger complex. This layer will protect the wire surface from the corrosive environment. The results of this study are also in line with research conducted that the corrosion rate of wire soaked in cocoa husk extract 600, 800, and 1000 ppm was lower than the corrosion rate immersed in artificial saliva. The higher the concentration of cocoa rind extract, the lower the corrosion rate of stainless steel wire (Darmayanti and Erstyawati, 2021).

The results of this study indicate that the maximum corrosion rate was obtained at a concentration of 1000 ppm guava leaf extract. This study is different that the maximum corrosion rate was obtained at a concentration of 800 ppm guava leaf extract while at a concentration of 1200 ppm there was a decrease in the corrosion rate. Hartanto and Wicaksono (2018), guava leaves concluded that the greatest corrosion protection was obtained by immersing stainless steel in 1000 ppm guava leaf extract, while at concentrations of 1500 ppm and 2000 ppm there was an increase in the corrosion rate. return of inhibitor molecules from the metal surface to the solution environment (Victoria et al., 2015; Hartanto and Wicaksono, 2018; Farmasyanti et al., 2018).

Giving inhibitors can reduce the rate of corrosion and can increase the value of inhibition. Its ability to inhibit is measured by the value of its effectiveness. The effectiveness value depends on the concentration of the inhibitor used. In the study, it was seen that the highest effectiveness value was obtained at a concentration of 1000 ppm guava leaf extract when compared to concentrations of 200 and 600 ppm. The greater the inhibitor concentration used, the greater the efficiency obtained. This is because the metal part covered by the active compound of guava leaves is increasing and will be

more effective in forming a passive layer on the metal surface so that the effectiveness value is higher. The passive layer functions as a corrosion rate controller by being a separator between the metal and the environment, without reacting or removing aggressive ions in the environment.

CONCLUSION

Based on the results of the study, it can be concluded that guava leaf extract can be used as a corrosion inhibitor because the tannin content in guava leaf extract can reduce the corrosion rate of stainless steel orthodontic wires. In this study, the greatest inhibition effectiveness value was 85.35% at a concentration of 1000 ppm guava leaf extract.

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Conflict of Interest: None

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