CORN HAIR EXTRACT AS CORROSION INHIBITOR FOR ST37 STEEL IN 3% HCL MEDIA

Nurhidayah*, **Rahmaniah, Sefrilita Risqi Adikaning Rani**, **Hernawati, Fira Yurdanianti**

Department of Physics, Science and Technology of Faculty, Universitas Islam Negeri Alauddin Makassar
Jl. H.M. Yasin Limpo 36 Gowa 92118, Indonesia

Received: 11st August 2022; Revised: 6th January 2023; Accepted: 6th April 2023

ABSTRACT

The research aims to analyze the impact of the concentration of the extracted corn hair inhibitor and the immersion time in reducing the formation of pitting corrosion with or without cracks of ST37 steel. The mass loss method and SEM analysis were applied used in this study to provide a reliable and accurate measurement of the inhibitor's effectiveness due to the corrosion formation. The results indicated that both concentrations of the inhibitor and the immersion time significantly impacted the morphological characteristics of the ST37 steel through the reduction of various types of corrosion. It indicated that the immersion time and the corrosion inhibitor concentration were related to the corrosion rate. The longer the sample was immersed, the greater the mass loss that occurred because the more Fe(OH)2 layers were formed. While the higher the concentration of inhibitor used, the lower the corrosion rate by hindering the diffusion of corrosion media to the surface of the sample. The results also indicated that the test of morphological characteristics of ST37 steel shows four types of corrosion formed such as stress, uniform, pitting, and pitting corrosions. Overall, this research demonstrates the potential use of corn hair extracted from waste material as an effective inhibitor for reducing the corrosion rate of ST37 steel. The findings of the research could have important implications in developing new sustainable corrosion inhibitors for the future manufacture of corn hair inhibitors in reducing the corrosion rate of ST37 steel.

Keywords: Corrosion; inhibitor; SEM; ST37 steel.

Introduction

Corrosion of ST37 steel can lead to a decrease in its mechanical strength, which can have serious implications in many industrial applications. To address this issue, researchers have investigated the potential use of corn silk extract as a corrosion inhibitor for ST37 steel. The extract contains antioxidants that can help to inhibit the chemical reactions that lead to corrosion.[1] The objectives of the study were to determine the effectiveness of the extract as a corrosion inhibitor, as well as the optimal concentration and immersion time required for maximum inhibition. The mass loss method was used to evaluate the corrosion rate of ST37 steel samples, both with and without the addition of corn silk extract. The results showed that the extract was effective in reducing the corrosion rate and that the optimal concentration and immersion time was 3% and 24 hours, respectively. In addition, the morphological characteristics of the steel samples were evaluated using SEM analysis, which showed that the addition of the extract helped to reduce the formation of various types of corrosion, including stress corrosion, uniform corrosion, pitting corrosion, and pitting corrosion with cracks. Overall, the findings of this study suggest that corn silk extract has potential as an effective and sustainable corrosion inhibitor for ST37 steel. This could have important implications for the development of new, eco-friendly corrosion inhibitors in various industrial applications.[2]

There are many types of inhibitors that can be used to slow down the corrosion rate of

*Corresponding author.
E-Mail: sefrilita.rani@uin-alauddin.ac.id

ST37 steel. One potential inhibitor is the extract of corn silk, which has been shown to contain antioxidants that can inhibit the chemical reactions that lead to corrosion. In addition to being effective, this inhibitor is also relatively inexpensive and easy to apply. Other types of inhibitors that have been studied for use with ST37 steel include organic and inorganic compounds, such as Carbon (C) at 0.12%, Silicon (Si) at 0.01%, Manganese (Mn) at 0.6%, Sulfur (S) at 0.0011%, and Phosphorus (P) at 0.050%.[3] These inhibitors work by forming a protective film on the surface of the steel, which helps to prevent the corrosive environment from coming into contact with the metal. In addition to inhibitors, there are other methods that can be used to slow down the corrosion rate of ST37 steel, such as, cathode protection and coatings. Cathode protection involves applying a current to the steel to create a protective film, while coatings involve applying a layer of material to the surface of the steel to protect it from the corrosive environment. Overall, while corrosion of ST37 steel cannot be avoided entirely, there are many methods available to slow down the corrosion rate and extend the lifespan of the material. The use of inhibitors, such as corn silk extract or organic and inorganic compounds, is an effective and cost-efficient method that can be applied in many industrial applications.[4]

Organic corrosion inhibitors can be derived from natural sources such as plants and vegetables, making them an eco-friendly alternative to synthetic inhibitors. Some common organic inhibitors include extracts from plants such as aloe Vera, and olive oil, as well as fruit extracts like banana peel and pomegranate. These natural sources contain compounds that have been shown to effectively inhibit corrosion, such as alkaloids, flavonoids, and tannins. The use of organic corrosion inhibitors can offer several advantages over traditional methods. For example, they are often biodegradable, non-toxic, and readily available. They can also be easily applied to various types of metals and alloys and can be used in a wide range of industrial applications, including oil and gas production, water treatment, and automotive manufacturing. In addition, the use of organic corrosion inhibitors can help to reduce the environmental impact of industrial processes, as they are less harmful to the environment than traditional inhibitors. This can help to promote sustainable practices and reduce the overall carbon footprint of industrial operations. The use of organic corrosion inhibitors represents a promising approach to reducing the negative impacts of corrosion on metals and alloys while also promoting sustainable and environmentally friendly practices in the industry.[5]

Currently, research on corrosion inhibitors using organic materials has begun to develop, as evidenced by previous studies,[6] which showed that the outer skin of watermelon could be used as an inhibitor in slowing down corrosion, and research,[7] which resulted that jackfruit seed extract was effective in inhibiting the rate of corrosion. The corrosion rate can be calculated using the weight loss method. This method focuses on the mass changes in the specimen within a certain time after the specimen is exposed to a corrosive medium. This method can be used as a reference for the storage conditions of objects if it is run for a long time and can also be used as a reference for maintenance that must be placed on the object area.[8]

According to,[7] based on the weight loss method, the corrosion rate can be determined by the following equation:

$$CR = \frac{m \times K}{\rho \times A \times t} \quad (1)$$

Description:

CR = corrosion rate (MPY)
m = mass lost (grams)
k = corrosion rate constant (3.45×10^6 MPY)
ρ = density of metal (g/cm^3)
A = sample surface area (cm^2)
t = immersion time (hours)

Meanwhile, the inhibition efficiency can be determined by the following equation:

$$EI(\%) = \frac{C_R^0 - C_R}{C_R^0} \times 100\% \quad (2)$$

Description:

EI (%) = inhibition efficiency

C_R^0 = blank average corrosion rate (MPY)
C_R = average corrosion rate with the addition of inhibitor (MPY)

Based on research by Kusriani et al., The presence of tannins and flavonoids in sweet corn hair extract may explain its effectiveness as a corrosion inhibitor. Tannins and flavonoids are known to have antioxidant properties, which can help to protect metal surfaces from oxidation and corrosion.[9-10] These compounds can also form a protective layer on the metal surface through adsorption, which can prevent the diffusion of corrosive ions and reduce the corrosion reaction rate. Furthermore, the positive presence of Alkaloids and Saponins in sweet corn hair extract may also contribute to its effectiveness as a corrosion inhibitor. Alkaloids are known to have strong antioxidant and anti-corrosion properties, while Saponins have been shown to inhibit the growth of certain microbes that can contribute to corrosion. The phytochemical composition of sweet corn hair extract suggests that it has the potential to be an effective and eco-friendly corrosion inhibitor for use in various industrial applications. Further research is needed to fully understand the mechanisms underlying its corrosion-inhibiting properties and to optimize its use in practical applications.[11]

In this study, we investigated the effect of variations in concentration, immersion time, and the efficiency of corn silk extract inhibitor on ST 37 carbon steel, as well as the morphological characteristics of ST37 carbon steel before and after immersion in a corrosive medium, both with and without inhibitors.

Methods

The ST37 steel sample by 1×1×0.5 cm was utilized and smoothed by rubbing with the grade 120 sandpaper. The sample was subsequently washed and dried with a tissue, then weighed to establish the initial mass. Corn silk was extracted using the maceration technique, wherein dried corn silk was aerated for 5 days and then ground into a powder. The powder was added into a glass beaker with 150 grams of ethanol and soaked for 24 hours. The resulting solution was filtered and concentrated via rotary evaporation to obtain a concentrated liquid of corn silk extract. To produce an inhibitor solution with a concentration of 400 ppm, 0.4 grams of corn silk extract was diluted with 1 L of distilled water, while 0.6 grams of corn silk extract was diluted with 1 L of distilled water to produce an inhibitor solution with a concentration of 600 ppm.

The initial mass of the clean ST37 steel samples was recorded before immersing them in 30 mL of 3% HCl corrosive medium at room temperature for 10, 20, and 30 days. Samples with inhibitors were also immersed in the same corrosion medium with the addition of 400 ppm and 600 ppm of inhibitors. After immersion, the samples were cleaned using distilled water and dried with a tissue, followed by measuring the final mass. The difference in mass before and after immersion in the 3% HCl solution, both with and without the addition of inhibitors, was used to determine the mass loss of ST37 steel and subsequently calculate the corrosion rate and inhibition efficiency. SEM tests were conducted to analyze the type of corrosion and morphological characteristics formed on samples both with and without the addition of inhibitors extracted from corn silk.

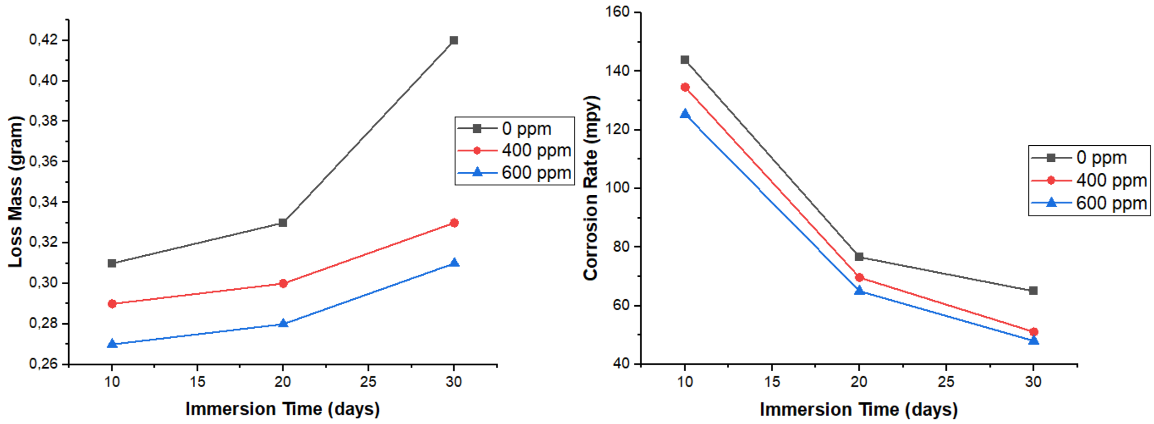
Result and Discussion

a. Corrosion Rate Research

The mass loss method was used to determine the corrosion rate through equation (1). For the 10-day immersion time, three steel samples were used with concentrations of 0 ppm (without inhibitor), 400 ppm, and 600 ppm in a 3% HCl corrosive solution. The 20-day immersion time also used three steel samples with the same varying concentrations. Similarly, the 30-day immersion time consisted of three steel samples with varying concentrations of 0 ppm (without inhibitor), 400 ppm, and 600 ppm in a 3% HCl corrosive solution.

It can be observed from Figure 1 (a) that the sample without the addition of inhibitor showed the highest mass loss after 30 days of immersion, which was 0.42 grams. On the other hand, the sample with the addition of

600 ppm inhibitor showed the lowest mass loss of 0.27 grams after 10 days of immersion. The mass loss was calculated by subtracting the final mass from the initial mass of the sample. Meanwhile, Figure 1 (b) shows that the highest corrosion rate of 143.94 MPY was obtained from samples without inhibitors that were immersed for 10 days, while the lowest corrosion rate of 47.98 MPY was obtained from samples with 600 ppm inhibitor added and immersed for 30 days.



(a) (b)

Figure 1. (a) Graph of the relationship between immersion time and inhibitor concentration with mass loss (b) graph of the relationship between immersion time and inhibitor concentration and corrosion rate

The results indicated that the largest mass loss occurred in the sample without inhibitor and a soaking time of 30 days, while the smallest mass loss was observed in the sample with the addition of 600 ppm inhibitor and a soaking time of 10 days. The corrosion rate was found to be highest in the sample without inhibitor and a soaking time of 10 days, while the lowest corrosion rate was observed in the sample with 600 ppm inhibitor and a soaking time of 30 days. The oxidation process caused by the reaction of the sample with 3% HCl corrosive solution resulted in mass loss or the corrosion process, where the sample released anode ions and received cathode ions that were released. It was also observed that immersion time and inhibitor concentration were correlated with mass loss, as longer immersion times resulted in increased mass loss due to the formation of Fe(OH)2 layers that blocked the diffusion of the corrosive medium to the sample surface, while higher inhibitor concentrations resulted in decreased mass loss.

The ST37 steel, which contains Fe, exhibits susceptibility to corrosion when exposed to the corrosive HCl solvent. The corrosion can occur either as a direct reaction between Fe and HCl or as a reaction with water and oxygen that are present in the solvent. This results in the formation of a corrosive product on the surface of the steel. The reaction between the steel and HCl can be represented by the following equation:

$$Fe + 2HCl \rightarrow FeCl_2 + H_2$$

In the conducted research, a corrosion medium was prepared by dissolving HCl in water. The presence of water molecules influences the reaction between Fe and HCl, and therefore the chemical reaction between the three can be expressed by the following equation:

$$Fe + 2HCl + 4H_2O \rightarrow FeCl_2 + 4H_2O + H_2$$

The above equation represents the corrosion reaction that occurs between Fe, HCl, and H_2O, leading to the formation of a corrosive product on the surface of the steel. The damage caused by the corrosion reaction can potentially compromise the quality of the steel.[12]

The mass loss observed in the samples without inhibitors was greater than that in the samples with added inhibitors. This can be attributed to the presence of tannins in the corn silk extract-based inhibitor. Tannins are complex compounds that play a crucial role in inhibiting the oxidation reaction of iron (metal).

b. Corn Hair Extract Inhibition Efficiency

The inhibition efficiency was calculated using equation 2 and expressed as the percentage decrease in the corrosion rate of steel in the absence of any inhibitor. As shown in Figure 2, the inhibition efficiency increases with increasing immersion time and inhibitor concentration. Samples that were not treated with any inhibitor (0 ppm concentration) exhibited no inhibition at all, while those treated with 400 ppm and 600 ppm of inhibitor showed increasing inhibition efficiency. The highest inhibition efficiency was observed in samples treated with 600 ppm of inhibitor. It can be concluded that there exists a direct proportional relationship between the concentration of the inhibitor and the efficiency of inhibition. Thus, higher inhibitor concentrations lead to greater inhibition efficiency.

As can be observed from Figure 2, the inhibition efficiency increases with increasing immersion time and inhibitor concentration. Samples that were not treated with any inhibitor or those treated with 0 ppm of inhibitor showed no inhibition. On the other hand, samples treated with 400 ppm and 600 ppm of inhibitor exhibited higher inhibition efficiencies. In fact, the highest inhibition efficiency was observed in samples treated with 600 ppm of inhibitor. Therefore, it can be concluded that there exists a directly proportional relationship between the concentration of the inhibitor and the efficiency of inhibition. In other words, the inhibition efficiency increases with increasing inhibitor concentration.

The inhibition efficiency values for inhibitor concentrations of 400 ppm and 600 ppm continued to increase until the 30th day of immersion. It can be expected that the inhibition efficiency will continue to increase as the concentration of the inhibitor solution increases. However, with increasing time, the efficiency of the inhibition may decrease if the functional groups of the inhibitor molecules reach their maximum adsorption capacity on the steel surface and can no longer form a protective layer.

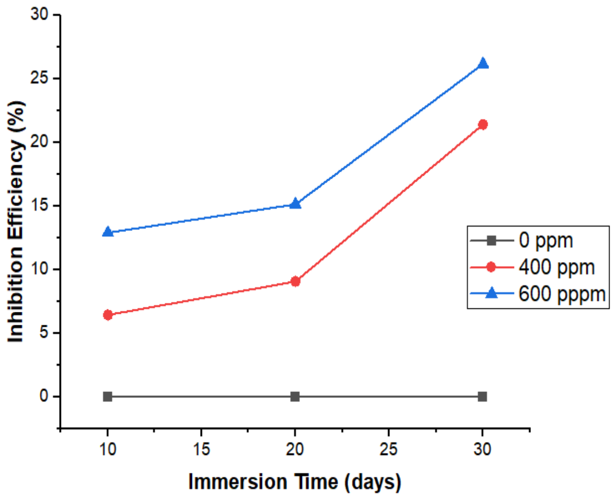


Figure 2. Graph of the relationship between immersion time and inhibition efficiency using various inhibitor concentrations

c. ST37-Steel Morphological Characteristics

The morphological characteristics of ST37 steel samples that were soaked in 3% HCl with variations in concentration and immersion time were examined using SEM. The results are presented in the following figure. Figure 3(a) displays the morphological characteristics of untreated ST37 steel. The SEM results indicate that the sample is corroded with stress corrosion cracking, as concluded in the research conducted by

Nurbanasari et al.[13] This type of corrosion occurs due to the simultaneous formation and propagation of cracks in the metal, induced by both the tensile stress acting on the material and the corrosive environment.

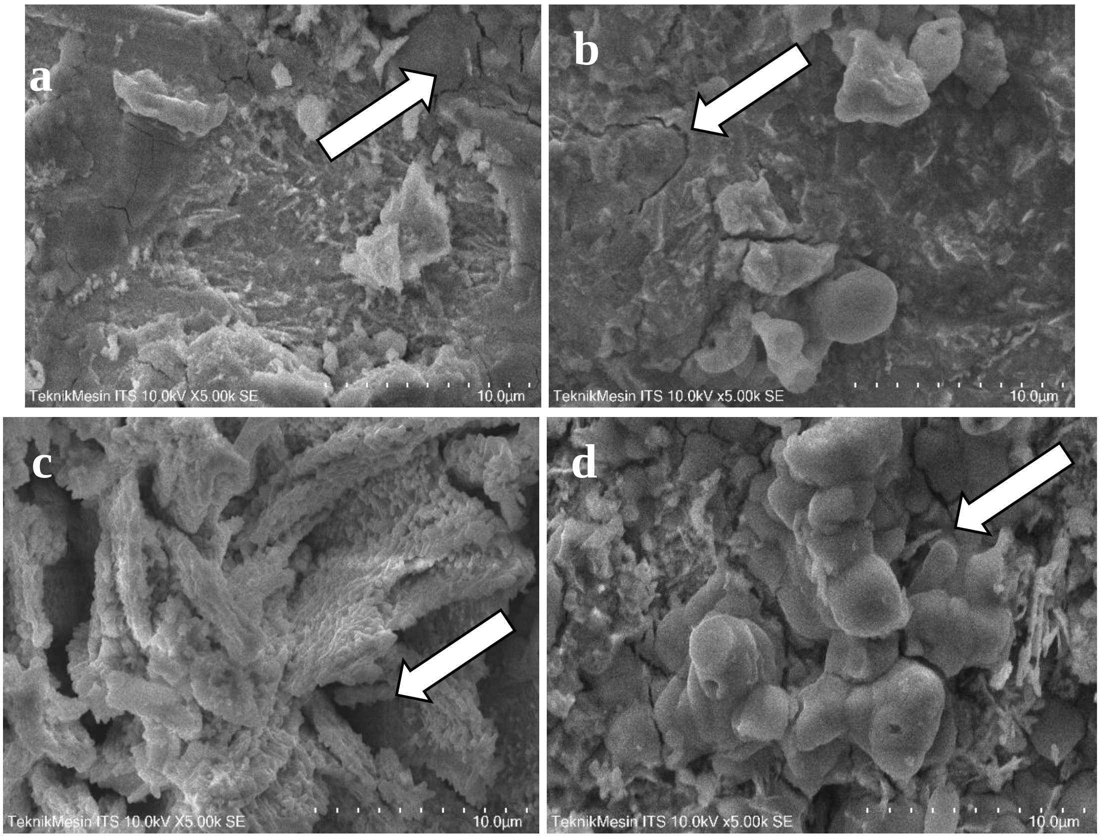


Figure 3. SEM test results (a) without treatment; (b) immersion time of 10 days without inhibitor; (c) immersion time of 20 days and inhibitor 400 ppm; (d) immersion time 30 days and inhibitor 600 ppm

Figure 3(b) illustrates the morphological characteristics of the sample without the addition of inhibitor, which was immersed in HCl solution for 10 days. The SEM results indicate that the sample has similarities with the results of research conducted by Nurbanasari et al.,[13] in which cracks are formed on the surface of the sample, indicating that the sample is exposed to stress corrosion cracking. The presence of cracks on the metal surface is a hallmark of stress corrosion cracking, which is usually caused by the condition of the solution, temperature, stress, and shape of the metal.

Figure 3 (c) shows the morphology of the samples immersed for 20 days in HCl medium with 400 ppm inhibitor added. The steel surface appears to be covered with a thin layer, which can be assumed to be the protective layer formed by the inhibitor on the surface of the steel. This layer helps to inhibit the corrosion process, as shown by the decrease in the size and number of pits and the absence of cracks compared to the samples without inhibitors. Based on Anjani et al.'s research, the type of corrosion that occurs in the sample is well corrosion.[12,14]

Uniform corrosion occurs when the corrosion rate is relatively constant across the entire metal surface, leading to a general loss of material. This type of corrosion is often caused by exposure to a corrosive environment such as an acid or salt solution. The SEM image in Figure 3(d) shows that the sample soaked for 30 days with 600 ppm inhibitor added has a relatively smooth surface, indicating that uniform corrosion is the dominant type of corrosion. Inhibitors can help prevent uniform corrosion by slowing down the electrochemical reaction on the metal surface, thus reducing the rate of corrosion.[15]

Conclusion

The research findings indicate that the inhibitor concentration has an inverse effect on the corrosion rate of ST37 steel, meaning that the higher the inhibitor concentration, the lower the corrosion rate that occurs. Conversely, the lower the inhibitor concentration, the higher the corrosion rate. The immersion time significantly affects the inhibition efficiency of corn silk extract on ST37 steel. The longer the immersion time, the higher the inhibition efficiency. The highest efficiency value of 26.18% was obtained from the sample with an immersion time of 30 days. The morphology analysis of ST37 steel using SEM showed that the type of corrosion that occurred in the untreated sample and the sample without inhibitor with 10 days of immersion was stress corrosion cracking. The sample with an immersion time of 20 days and 400 ppm inhibitor experienced galvanic corrosion, while the sample with an immersion time of 30 days and the addition of 600 ppm inhibitor experienced uniform corrosion. As a suggestion, further research should use two or more methods to determine the corrosion rate, so that the influence of the method used on the obtained corrosion rate results can be observed.

References

1. Wirasutisna KR, Fidrianny I, Rahmayani A. Telaah kandungan kimia rambut jagung (Zea mays L.). Acta Pharm Indones. 2012;35(1):5.
2. Siregar T, Sitorus E, Priastomo Y, Bachtiar E, Siagian P, Mohamad E, et al. Korosi dan Pencegahannya. Yayasan Kita Menulis; 2021. 192 p.
3. Aminuddin RR, Santosa AWB, Yudo H. Analisa Kekuatan Tarik, Kekerasan dan Kekuatan Puntir Baja ST 37 sebagai Bahan Poros Baling-baling Kapal (Propeller Shaft) setelah Proses Tempering. J Tek Perkapalan. 2020;8(3):368–74.
4. Ginting E, Riyanto A. Efektivitas Ekstrak Daun Pepaya (Carica papaya L.) Sebagai Inhibitor pada Baja ST37 dalam Medium Korosif NaCl 3% dengan Variasi Waktu Perendaman. J Teori Dan Apl Fis. 2018;6(2):167–74.
5. Mardiah M, Lapua EP, Wahyudiantara IP, Iqbal M, Lestari I, Rodiyatunnisa R, et al. Studi Laju Korosi Logam Aluminium dengan Penambahan Inhibitor dari Ekstrak Daun Karamunting (Rhodomyrtus tomentosa) dalam Larutan NaCl. J Chemurgy. 2018;1(2):39–42.
6. Ratnasari F. Pemanfaatan Ekstrak Kulit Dalam Semangka Sebagai Inhibitor Korosi Tinplate Dalam Media 2% NaCL [PhD Thesis]. Institut Teknologi Sepuluh Nopember; 2016.
7. Aprianti N. Pengaruh Inhibitor dari Biji Nangka terhadap Laju Korosi Baja Karbon Medium [PhD Thesis]. Universitas Islam Negeri Makassar; 2021.
8. Rohmadianto D, Suhartatik N, Widanti YA. Aktivitas Antioksidan Teh Rambut Jagung (Zea Mays L. Sacharata) Dengan Penambahan Rosela (Hibiscus Sabdariffa L) Dan Variasi Lama Pengeringan. JITIPARI J Ilm Teknol Dan Ind Pangan UNISRI. 2018;3(2).
9. Kusriani H, Marliani L, Apriliani E. Aktivitas antioksidan dan tabir surya dari tongkol dan rambut jagung (Zea mays L.). Indones J Pharm Sci Technol. 2017;4(1):10–7.
10. Setyantoro ME, Haslina H, Wahjuningsih SB. Pengaruh Waktu Ekstraksi Dengan Metode Ultrasonik Terhadap Kandungan Vitamin C, Protein, dan Fitokimia Ekstrak Rambut Jagung (Zea mays L.). J Teknol Pangan Dan Has Pertan. 2019;14(2):53–67.
11. Mulyati B. Tanin dapat dimanfaatkan sebagai inhibitor korosi. J Ind Elektro Dan Penerbangan. 2019;8(1).
12. Bukhori MS, Ranto R, Widiastuti I. The Effect Of Inhibitor Level Of Rambutan Rind Extract And Hcl Solvent Concentration On The Corrosion Rate Of St 37 Steel. J Mech Eng Vocat Educ JoMEVE. 3(2):67–70.
13. Nurbanasari M. Crack of a first stage blade in a steam turbine. Case Stud Eng Fail Anal. 2014;2(2):54–60.
14. Anjani ADS. Pengaruh Inhibitor Alami dari Biji Nangka terhadap Laju Korosi Baja Karbon Tinggi [PhD Thesis]. Universitas Islam Negeri Alauddin Makassar; 2022.
15. Fahriani F. Pengaruh Inhibitor Alami terhadap Laju Korosi Rendah Baja Karbon Rendah [PhD Thesis]. Universitas Islam Negeri Makassar; 2021.