
Analysis of Corrosion Inhibitor Experiment Design from Tea Extract as Contextual Chemistry Learning

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Abstract. Experiments are an essential part of teaching chemistry in schools. Experiments in schools involving corrosion sub-materials currently only focus on determining the factors that affect corrosion. There has been no investigation into corrosion prevention using natural materials according to competence in the curriculum 2013. This study aims to identify the relationship between the design experiment of corrosion inhibitors from natural materials with the 2013 curriculum competency standards and analyze this design as an alternative to practicum in schools. A qualitative description was used in the research, with data collected through literature studies, laboratory experiments, and interviews. According to the study's findings, there was a link between the experimental stages of making iron corrosion inhibitors from tea extract and the corrosion sub-learning material's outcomes. Tea extract corrosion inhibitor can inhibit the best corrosion rate of 4.10^5 g/cm².day at 20% inhibitor concentration with 90% inhibition efficiency. Based on an analysis of the financial aspect, it was stated that the experimental design of iron corrosion inhibitors from tea extract required a relatively low cost. In contrast, from the human resource readiness aspect, it was stated that this experimental design could be used as an alternative to chemical experiments based contextually on the corrosion sub-material in schools.

Keywords: corrosion inhibitor, tea extract, contextual learning, design experiment

Introduction

The curriculum changes from KTSP to Curriculum 2013 affected the learning system and process. The curriculum change aims to improve the quality of the student's learning and the development of the times. The emphasis in this curriculum 2013 is increasing and balancing soft and hard skills, including affective, psychomotor, and cognitive (Agustin & Sugiyono, 2019). The 2013 curriculum is intended to improve learners' knowledge, skills, and attitudes. Learners must be active in the learning process, and the teachers must be creative in providing and introducing the material. According to Subamia et al. (2014), the 2013 curriculum based on practicum activities is effectively applied to this curriculum. Chemistry learning in the 2013 curriculum emphasizes students learning science concepts and principles and having direct experience in the practicum process (Fitri & Fikroh, 2021).

Learning chemistry tends to use rote methods in studying chemistry so that memorized concepts are temporary and impact the emergence of misconceptions (Marsita et al., 2010).

An effective strategy in chemistry learning is essential to improve student learning outcomes (Tenaw, 2015). The practicum method is one of the learning methods that can emphasize students' full participation in the learning process to increase student understanding (Yunita, 2017). Although the practicum method is considered essential for student learning, especially chemistry, it is rarely used. According to Hussien et al. (2022), a lack of resources (such as laboratory equipment), a lack of time to practice laboratory work, and a lack of engagement in laboratory activities were the significant factors affecting laboratory work implementation. A lack of teacher skills and insight, as well as only some schools have laboratories, so only a few chemical materials can be carried out in practical activities (Damayanti et al., 2019). Statistics from the Ministry of Education and Culture for the 2020/2021 Academic Year show that only 12% of high schools have laboratory facilities. Therefore, applying a contextual approach to learning chemistry is one of the efforts that can be made to overcome practicum constraints, minimal tools, and materials.

Contextual-based learning (CBL) is a concept that helps teachers relate the material being taught to real situations and encourages students to connect knowledge with the application of everyday life (Sagita et al., 2021). CBL aims to help students better understand the world of science, appreciate the importance of chemistry in the modern world, and see how it relates to daily life events (Bortnik et al., 2021). Based on the research of Silva et al. (2019), teaching natural sciences employing locally available material that contextualizes knowledge acquired in the classroom enhances learning. In addition, these studies agree that exploring material locally available to teach chemistry experiments solidifies learning as it links knowledge with our daily life (Queiroz et al., 2019). Local resources are used as an alternative to simple practicums at low cost. The corrosion sub-material is one of the chemical materials that require practicum activities. According to the findings of interviews with high school/MA chemistry teachers in Yogyakarta in February 2021, practicum activities in the corrosion sub-material were limited to determining the factors that cause corrosion. A lack of limited material tools in laboratory and a lack of teacher skills to finding new practicum design is one of the problems that needs to be resolved. Practicum activities in schools must follow the competencies in the 2013 revised 2018 curriculum, which requires students to design corrosion prevention ideas. This competency can be obtained through practicum activities based on corrosion prevention. According to Hayati et al. (2019), practicum activities involving simple materials can help students gain competency in carrying out practicums. Although much research has been conducted on natural materials used as iron corrosion inhibitors, the production of these inhibitors has yet to be supported by simple tools, materials, and working methods (Dewi et al., 2022). As a result, a simple experimental design utilizing local resources in the surrounding environment is required.

Although corrosion cannot be prevented, inhibitors can reduce the corrosion rate (Fazdri et al., 2020). The use of inhibitors is an alternative to reduce the corrosion rate because of their low cost and simple operation (Akrom, 2021). Currently, the use of many inhibitors comes from inorganic inhibitors even though these inhibitors have weaknesses, namely being toxic and not environmentally friendly (Fazdri et al., 2020). As a result, efforts to find non-toxic inhibitors have been made, including using organic inhibitors

derived from natural resources (Jyothi et al., 2019). Inhibitors from natural resources are considered to be biodegradable, renewable, non-toxic, and pollutant, easy to produce, inexpensive, and have high anti-corrosion efficiency (Popoola, 2019). Natural resources containing tannin have been studied as potential corrosion inhibitors (Nardeli et al., 2019). Tannins are natural polyphenolic compounds that are abundant in various plants in Indonesia with quite complex structures (Rochmat et al., 2019). The structure of tannins contains hydroxy groups (-OH), so the basic tannins have the potential as corrosion inhibitors on metals. The maceration method can produce tannin compounds from natural materials (Fraga-Corral et al., 2020). The choice of solvent is essential for the success of the maceration process. Solvents usually used in the maceration process include methanol, ethanol, acetone, sodium hydroxide, and liquid ions (Das et al., 2020). Ethanol solvents are more effective in producing higher total tannins than methanol and acetone solvents (Kusuma et al., 2022).

Tea is a natural ingredient with a reasonably high tannin content. According to Sukmawanta et al. (2022), tea is the best corrosion inhibitor compared to coffee and cocoa. The results of Yetri et al. (2016) showed that the inhibition efficiency of tea extract in inhibiting corrosion reached 86.3% in the HCl medium and 92.0% in the NaCl medium. Another study related to controlling the corrosion rate of steel in sodium chloride medium using tea extract inhibitors showed that the highest inhibition efficiency values were obtained by adding 10% inhibitor concentration for four days of immersion with an efficiency value of 92% (Sari et al., 2013). Many studies have been carried out on using tea extract as a corrosion inhibitor from natural materials. However, they are only limited to the effectiveness of inhibiting the corrosion rate. This study focuses on Identify the relationship between the design experiment of corrosion inhibitors from natural materials with the 2013 curriculum competency standards and analyze this design as an alternative to practicum in schools.

Methods

The research method used in this study is descriptive qualitative research.

Qualitative research is a study used to describe and analyze data based on phenomena, attitudes, social activities, and perceptions of people and groups (Bachri, 2010). Data collection techniques through data triangulation, which means data collection is carried out using several collection techniques, namely literature studies, interviews or interviews, observation, and experiments. According to Miles & Huberman (2007), the process of analyzing qualitative data includes data collection, data reduction, data presentation, and drawing conclusions. The stages of this research included identifying the curriculum and performance indicators for competence in the corrosion sub-material and analyzing the potential of the experimental design for manufacturing iron corrosion inhibitors from tea extract as an alternative experiment in senior high schools.

Identification of curriculum and competency indicators for corrosion sub materials.

The method used in curriculum identification and learning outcomes for the corrosion sub-material is through a literature study on the 2013 revised 2018 curriculum

text. The aim is to analyze the content of the 2013 revised 2018 curriculum for learning in schools. The essential things in the manuscript were analyzed by studying corrosion sub-material chemistry.

Tea Extract Potency as a Corrosion Inhibitor Experimental Design

A. Extracting tea as an inhibitor

The tea obtained in this extraction is in the form of packaged tea sold in the market. The tea was dissolved in 70% ethanol, ranging from 0 to 5, 10, 15, and 20%. The extraction process lasted 24 hours, after which it was filtered to obtain the tea extract filtrate. The tannin was tested using FeCl_3 before it was used as an inhibitor.

B. Preparation of iron

The iron has a thickness of 0.1 cm, a length of 2 cm, and a width of 1 cm. The iron is sanded, washed, and dried for one day.

C. Iron inhibition

The prepared iron was soaked in a tea extract solution for 24 hours. After that, the iron is dried with a tissue.

D. Preparation of corrosive medium

Three grams of sodium chloride powder were dissolved in 100 mL of water to make 3% sodium chloride powder.

E. Corrosion test

After the inhibition process, the iron is immersed in a corrosive medium of sodium chloride solution. The soaking period lasted five days. The experimental data were analyzed for the corrosion reaction rate that occurred through Equation 1.

$$r = \frac{W_o - W_f}{A \times t} \quad \text{.....1)} \quad (\text{Asdim, 2007})$$

Where $W_o - W_f$ is weight loss, A is area and t are time.

The result of the corrosion rate analysis used as inhibition efficiency (IE) data were processed using Equation 2.

$$IE = \frac{V_{ko} - V_{ki}}{V_{ko}} \times 100\% \quad \text{.....2)} \quad (\text{Asdim, 2007})$$

Where V_{ko} is corrosion reaction rate without inhibitor and V_{ki} is corrosion reaction rate with inhibitor

Analysis of experimental design of corrosion inhibitors from tea extract as a high school alternative experiment

The practicum results are used as a reference to assess the potential of tea extract as an inhibitor for contextual chemistry learning in several ways, including financial and human resource aspects. The financial aspect includes the overall costs used to carry out this experiment. In contrast, the human resource aspect is carried out by interviewing teachers and students regarding the readiness to implement simple experiments to manufacture corrosion inhibitors.

Results and Discussion

Identification of Curriculum and Competency Indicators for Corrosion Sub Materials

The curriculum applied in Indonesia currently refers to the 2013 revised 2018 curriculum. Identifying the senior high school's chemistry curriculum is conducted to determine competency and indicators of competency achievement in schools, especially in the corrosion sub-material. The identification of learning competency achievements is obtained from the syllabus of MAN 3 Bantul, which is analyzed based on competency standards, essential competencies, indicators, and learning objectives that have been formulated. Based on the identification of the 2013 revised 2018 curriculum, the correlation between the experimental results of corrosion inhibitors from tea extract with indicators of competency achievement in the corrosion sub-material is shown in Table 1.

Table 1. The relationship between the experiment and the corrosion sub-learning material's achievement

No	Practical steps	Learning materials
1.	Preparation of corrosion inhibitor from tea extract	Determine natural materials that can inhibit the occurrence of corrosion
2.	Iron plate coating process with various concentrations of tea extract inhibitors	Analyze the corrosion prevention process.
3.	Changes in the color of the iron plate after being tested by reducing it with sodium chloride solution.	Explain the effect of the use of inhibitors on the color change of the iron plate
4.	Determination of corrosion rate and inhibition efficiency	Analyzed experimental data by calculating the determination of corrosion rate and inhibition efficiency.

Identifying the curriculum and indicators of competency achievement in chemical material was carried out in line with Fitri & Fikroh (2021), which identified curriculum and competency indicators for practicum designs. It is intended that the practicum design offered achieves basic competence in chemical material. Based on Table 1, the learning material in the first stage is to determine natural materials that can inhibit corrosion. Natural materials that can be used as natural inhibitors are plant parts that contain tannin compounds (Sari et al., 2013). The learning material in the second experimental stage analyzes the process of preventing corrosion. One of the effective ways to prevent corrosion at a low cost and in a simple process is to use natural inhibitors. Natural ingredient inhibitors containing tannins work by turning oxidized steel into a tightly closed steel surface (Mark et al., 2019).

The learning material in the third stage is the effect of the use of inhibitors on the color change of the iron plate. A brownish-red color change indicates the presence of corrosion on the iron surface, so this experiment aims to observe the color change on the iron plate using variations in inhibitor concentrations and without inhibitors (Yufita et al., 2018). The learning material in the fourth practicum stage analyzes the experimental data by calculating the corrosion rate and inhibition efficiency. The data that has been obtained is then analyzed using the corrosion rate calculation using the weight loss method and analyzed using inhibitor efficiency calculations (Setiawan & Nasrulloh, 2020).

Tea Extract Potency as a Corrosion Inhibitor Experimental Design

The experimental design of iron corrosion inhibitors utilizes natural materials in the manufacturing process. The natural ingredients used are parts of plants that contain tannin compounds. The selection of natural materials with tannin content has been studied to have a role in forming a protective film on the iron surface to prevent corrosion (Ramila, 2020). One of the natural ingredients reported to have a reasonably high tannin content is the tea plant, with a tannin content of up to 18% (Habibie et al., 2014). Production of corrosion inhibitors from tea plants is carried out through the maceration method. This method is considered relatively easy to do and does not damage the tannin content in the tea because it does not go through a heating process (Nurhasnawati et al., 2017). This research is in line with Kusuma et al. (2022), which state that the maceration method is the most effective method for extracting the tannin content in natural products.

The maceration process was carried out using 70% ethanol solvent. The choice of ethanol as a solvent is because tannin compounds dissolve more effectively in ethanol than in water solvents (Monisa et al., 2016). In the natural product maceration process, the ethanol solvent produces a higher total tannin than methanol or acetone solvents (Kusuma et al., 2022). In addition to the type of solvent, the process's duration also determines the extract's yield to be obtained. The length of maceration used in this study refers to the research by Fitri & Fikroh (2021) which states that the most effective length of maceration is around 24 hours. The maceration results in tea extract were tested for tannin content before the corrosion test. The tannin test used a FeCl_3 solution and showed positive results marked by forming a black-green color in the tea extract (Ariani, 2018). The results of the tannin test are shown in Figure 1.

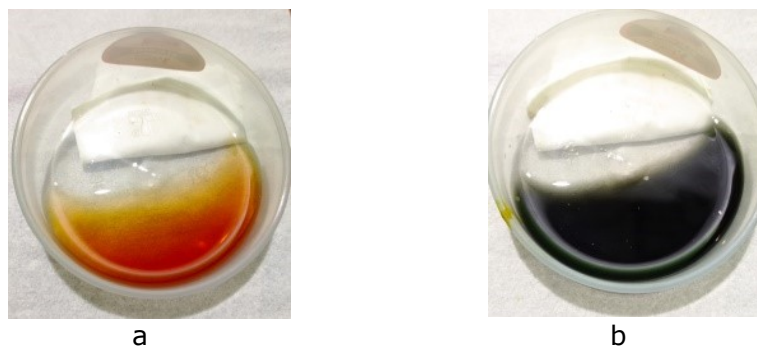


Figure 1. a. before addition FeCl_3 ; b. after addition FeCl_3

The results of the tannin test on the tea extract showed that the type of tannin was hydrolyzed. Sari et al. (2015) explained that the tannin test with black results was a type of hydrolyzed tannin. The hydrolyzed tannin structure is shown in Figure 2.

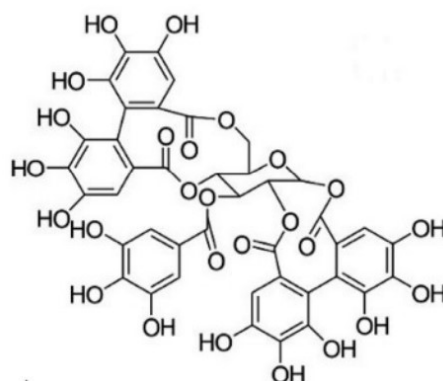


Figure 2. Structure of hydrolyzed tannins ($C_{76}H_{52}O_{46}$) (Sari et al. 2015)

The iron plate to be used is first cleaned, dried, and dried in the sun for one day to remove the water content on the iron plate (Mukoningah et al., 2022). The iron plate is then weighed to determine the initial mass of the iron plate (w_0). The inhibition process of the iron plate was carried out by soaking the plate in the extract for 24 hours. Soaking for 24 hours is the optimum time to extract tannin compounds, where tannin levels will decrease after optimum conditions are reached (Rahayu et al., 2020). The longer the immersion of the iron plate in the inhibitor solution, the slower the corrosion rate and the higher the efficiency (Jalaluddin et al., 2015). In the inhibition process, a coating occurs on the surface of the iron plate from the adsorbed inhibitor precipitate. The functional groups in tannin compounds play a role in interactions between molecules and the iron surface, then form a protective film (Ramila, 2020). According to research by (Setiawan & Nasrulloh, 2020) the thicker the layer formed on the metal due to immersion in the inhibitor solution media, the corrosion rate tends to decrease.

The corrosion rate test was carried out by immersing an iron plate inhibited with various concentrations of inhibitor into a 3% NaCl corrosive solution. The use of NaCl solution as a corrosive medium aims to present Cl^- ions which act as catalysts in electrochemical processes. According to Febriyanti et al. (2017) the presence of Cl^- ions speeds up the anodic reaction thus accelerating the formation of corrosion on the metal surface. Soaking in 3% NaCl solution was carried out for 5 days. This is based on research conducted by Mukoningah et al. (2022) who stated that the longer the immersion process for iron plates that had been inhibited by extracts of natural ingredients in NaCl solution, the lower the corrosion rate of iron plates inhibited by inhibitors, while for iron plates without inhibitors, the corrosion rate would increase. The following is a picture of an iron plate after the immersion process with 3% NaCl solution shown in Figure 3.

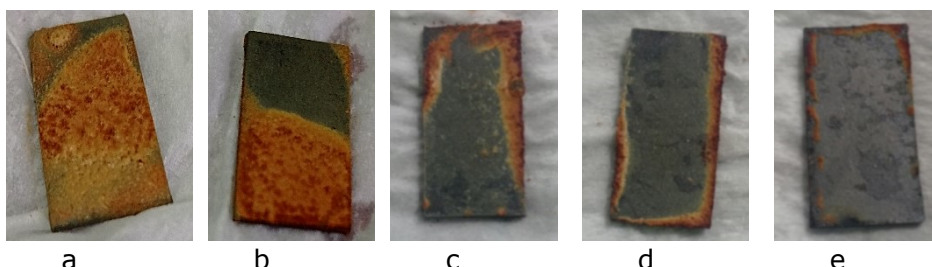


Figure 3. Iron plate after immersing with NaCl, a. 0%; b. 5%; c.10%; d.15% dan e.20%

Figure 3 shows that the iron plate produces yellow rust to brownish red on the iron surface. This is in line with Handoko (2017), which stated that there were four results of iron corrosion, namely yellow-green indicating the type of $Fe(OH)_2$ rust, brownish red

indicating the type of rust $\text{Fe}(\text{OH})_3$ and FeOOH , blackish brown indicating the type of rust Fe_3O_4 (magnetite) and yellow indicates the type of Fe^{3+} cation rust. Inhibitor with a concentration of 20% showed that the Fe-tannin complex compound completely covered the iron plate's entire surface so that the iron plate's rust looked very little compared to other plates. This shows that the more tannin compounds adsorbed on, the larger the plate, and the greater the inhibition power so that the corrosion rate decreases (Priyotomo et al., 2021).

The iron plate from immersion is removed and dried to remove the water content. The iron plate is weighed to determine the final sample mass (W_f). The data was then processed to produce values for corrosion rate and inhibition efficiency using equations 1 and 2. The equation for calculating the corrosion rate and inhibition efficiency used in this study was in line with research conducted by Nasution et al. (2012) The following data on the results of the corrosion test are shown in Table 2.

Table 2. Corrosion test result data

Iron Plate	Inhibitor (%)	W_o (g)	W_f (g)	ΔW (g)	Corrosion rate ($\text{g}/\text{cm}^2.\text{day}$)	Inhibition efficiency (%)
1	0	1,578	1,568	0,010	0,00043	0
2	5	1,651	1,646	0,005	0,00022	50
3	10	1,748	1,745	0,003	0,00013	70
4	15	1,644	1,642	0,002	0,00009	80
5	20	1,585	1,584	0,001	0,00004	90

Based on the data from the calculation of the corrosion rate, it was found that the lowest corrosion rate was found at a 20% inhibitor concentration with a value of 0.00004 $\text{g}/\text{cm}^2.\text{day}$, and the highest corrosion rate was at a 0% inhibitor concentration or without an inhibitor with a corrosion rate of 0.00043 $\text{g}/\text{cm}^2.\text{day}$. These data show that the higher the concentration of tea extract, the lower the corrosion rate, and the percentage of inhibition efficiency increases. This is in line with research conducted by Anbarasi & Vasudha (2014), who reported that the inhibition efficiency increased with increasing oil palm leaf extract concentrations while the corrosion rate decreased. The decrease in the corrosion rate occurs due to the adsorption of inhibitors on the surface of the iron plate resulting in a barrier layer that minimizes the iron plate experiencing an anodic reaction (Salleh & Abdullah, 2019). The relationship between corrosion rate and inhibitor concentration is shown in Figure 4, and the relationship between inhibition efficiency and inhibitor concentration is shown in Figure 5.

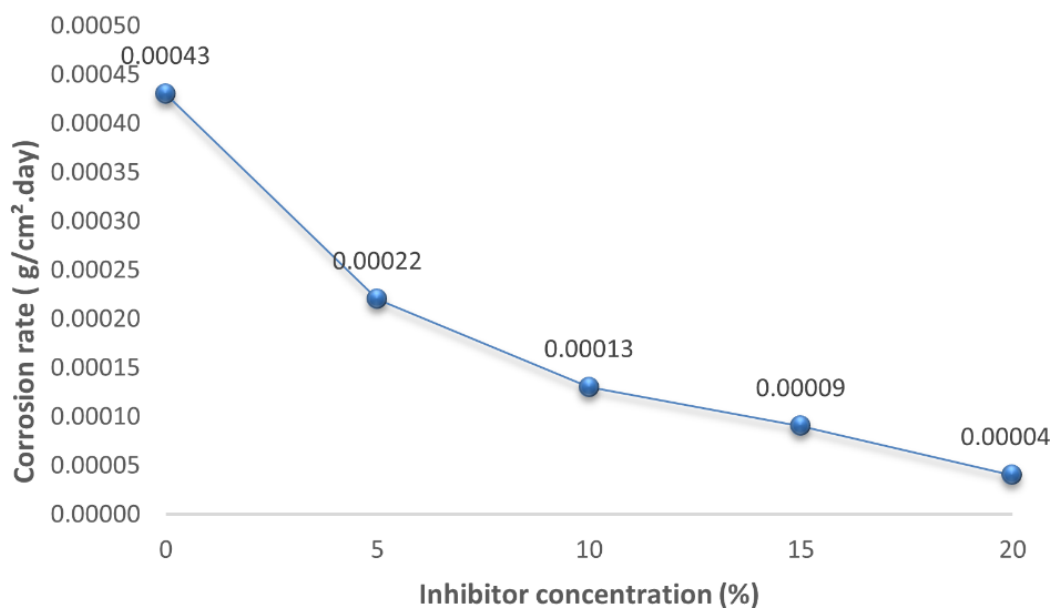


Figure 4. Graph showing the relationship between corrosion rate and inhibitor concentration

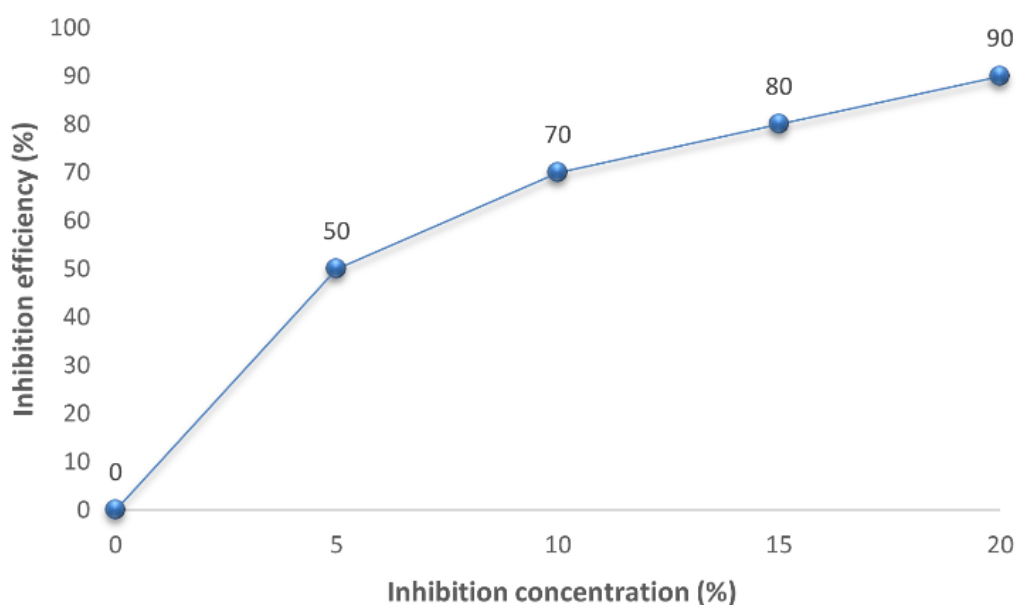


Figure 5. Graph showing the relationship between inhibition efficiency and inhibitor concentration

Analysis of experimental design of corrosion inhibitors from tea extract as a high school alternative experiment

The financial and human resource aspects of the potential of tea extract corrosion inhibitors as an alternative to contextual chemistry learning are analyzed. According to the financial aspect, the production of inhibitors and iron corrosion tests, which cost Rp. 45,300 each, are included in the costs incurred in carrying out the corrosion inhibitor practicum with tea extract. Because tools and materials like iron plates, hairdryers, measuring cups, and beakers can be used repeatedly, the costs are low. The costs incurred can be reduced if the goods used do not require a new purchase or if privately owned used items are used.

Based on human resources, the readiness of teachers and students to implement this practicum was obtained through interviews with two teachers and five students at a high school in Yogyakarta in October 2021. According to the interviews' findings, tea extract's experimental design as a corrosion inhibitor can be used as an alternative practicum on the corrosion sub-material. This experiment design is supported by the use of readily available tools and materials and a simple and easy-to-understand format that can be carried out at or outside of school. This research results align with the results of (Dewi et al., 2022) who claim that the practicum design of corrosion inhibitors using natural materials can be used as an alternative practicum in the corrosion sub-material. This experimental design can accommodate all three aspects: pedagogical, financial, and human resources. This research is in line with Fitri & Fikroh, (2021) that simple experimental designs exploiting the potential of the surrounding natural materials tend to meet financial and human resources better.

Conclusion

The experimental results show that Tea extract corrosion inhibitor can inhibit the best corrosion rate of 4.10^{-5} g/cm².day at 20% inhibitor concentration with 90% inhibition efficiency. based on identification curriculum there is a relationship between the experimental design of corrosion inhibitors from tea extracts and competency achievement in the corrosion sub-material. Modification of tools, materials, and work methods in this practicum design is adapted to high school learning characteristics. From a financial and human resource aspects, this experimental design has the potential to be used as an alternative to a simple experimental design in high schools.

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