

## THE POTENTIAL OF PLANT STARCH AS A NATURAL INDICATOR IN PRACTICE OF IODOMETRIC TITRATION

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**Abstract.** Iodometric titration generally uses synthetic starch as an endpoint indicator. This indicator is non-biodegradable, environmentally unfriendly, and relatively expensive. An alternative that can be offered is the use of natural starch from local plants as a more sustainable indicator. This study aims to test the potential of starch from various plant sources as a natural indicator in iodometric titration. Analysis of copper levels using starch indicators from four local plants showed varying values, namely sticky rice 0.50 g, purple sweet potato 0.95 g, unhusked rice 0.67 g, potato 0.87 g, and, as a comparison, commercial synthetic starch indicators produced 0.58 g. Of the four starch sources, the glutinous rice starch indicator produced results closest to the synthetic indicator, with a difference of only 0.08 g. These findings indicate that glutinous rice starch has accuracy comparable to synthetic indicators, making it a potential alternative for effective iodometric titration indicators. Glutinous rice starch has the potential to be used as an effective, environmentally friendly, and more sustainable natural indicator compared to synthetic starch in iodometric titration.

**Keywords:** iodometric titration, local plants, starch indicator, sustainable chemistry

### INTRODUCTION

Chemistry learning includes complementary theoretical and practical activities to improve conceptual understanding. The practical activities serve as a vehicle for students to prove the theories they have learned while directly training their scientific process skills (Adiyanto et al., 2024; Qi et al., 2024). In accordance with this, inquiry-based and project-based approaches have been proven to increase student engagement and understanding, as shown in the research by Maulina et al., (2024) that through the application of inquiry worksheets in practical work on the use of bagasse waste as an Fe adsorbent. The iodometric titration practicum in analytical chemistry courses not only trains volumetric analysis skills and improves understanding of redox reaction concepts but can also be developed through project-based learning by involving students in designing projects to explore the potential of plants as natural indicators to replace synthetic starch.

Iodometric titration generally uses synthetic starch as an indicator. However, synthetic starch has several weaknesses, including being environmentally unfriendly, producing hazardous chemical waste, and being relatively expensive (Fitriana & Fitri, 2020; Shafqat et al., 2020). This situation has created a need for alternative indicators from natural materials that are more environmentally friendly. Natural starch is easier to obtain, environmentally friendly, and has the potential to replace synthetic starch.

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Starch is a complex polysaccharide found in food crops such as rice, corn, potatoes, and cassava, accounting for 75–80% of the dry weight of rice (Fitriana et al., 2020; Dewi et al., 2022). In the iodometric titration, starch is used as an indicator because it forms a blue complex with iodine at the endpoint of the redox reaction. This titration is usually applied at pH 5–8 with iodine as the oxidizer and sodium thiosulfate ( $\text{Na}_2\text{S}_2\text{O}_3$ ) as the secondary standard solution, which is standardized using potassium iodate ( $\text{KIO}_3$ ) to obtain an accurate concentration (Ariani & Muhsin, 2023; Jumi et al., 2023). In chemistry, the interaction of starch with iodine, which is usually present in the form of triiodide, produces a characteristic blue-black complex, mainly through amylose molecular bonds that form a helical structure and provide an intracellular channel for iodine/triiodide molecules (Pesek & Silaghi-Dumitrescu, 2024).

## METHOD

This research was experimental in the chemistry laboratory of FKIP ULM. The materials used were  $\text{KIO}_3$ , KI,  $\text{H}_2\text{SO}_4$  3M,  $\text{Na}_2\text{S}_2\text{O}_3$  0.1 N,  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ,  $\text{Na}_2\text{CO}_3$  0.1 N,  $\text{CH}_3\text{COOH}$  2N, sticky rice, purple sweet potato, Unus rice, and potatoes. The equipment used included a stand, clamp, burette, glass funnel, measuring cup, beaker, dropper, volumetric pipette, Erlenmeyer flask, and pipette pump.

### Starch isolation

We weighed 500 g of sample and washed it with water until clean to remove impurities and contaminants. Homogenized the rice with 300 mL of distilled water. Then, the rice was ground using a blender to release the starch granules into the solution, then covered and left to stand for 24 hours. After 24 hours, decanted using distilled water and 95% ethanol. Decanting was repeated to ensure complete separation, producing a white starch precipitate, which was filtered using a Buchner apparatus. The precipitate was dried in a desiccator for several days (Robiah, 2020).

### Preparation of 1% starch indicator

A total of 1 gram of starch was weighed and dissolved in 100 mL of hot water. After it was completely dissolved, the solution was cooled before use.

### Preparation of sodium thiosulfate solution

Preparation of sodium thiosulfate solution: Weigh 1.2404 grams of  $\text{Na}_2\text{S}_2\text{O}_3$  and place it in a 500 mL measuring flask, then dilute to the mark with distilled water.

### Standardization of sodium thiosulfate with 0.01 N potassium iodate

Taking 10 mL of 0.01 N  $\text{KIO}_3$ , it is placed in an Erlenmeyer flask, then 10 mL of 10% KI and 4–5 mL of 2 N  $\text{H}_2\text{SO}_4$  are added. After that, it was titrated with  $\text{Na}_2\text{S}_2\text{O}_3$  until the solution turned light yellow, then 1 mL of 1% starch indicator was added, and titration was continued until the blue color disappeared completely (titration was replicated 3 times). The volume of titrant obtained was used to calculate the normality of  $\text{Na}_2\text{S}_2\text{O}_3$  (Muna, 2022).

$$(N_1 \cdot V_1) \text{KIO}_3 = (N_2 \cdot V_2) \text{Na}_2\text{S}_2\text{O}_3$$

### Determination of copper salt levels

We weighed 3.1 g of  $\text{CuSO}_4$  and dissolved it in a 250 mL dilution flask. Pipetted 20 mL of the solution into an Erlenmeyer flask, added 3 drops of 0.1N  $\text{Na}_2\text{CO}_3$ , 3 mL of 2N  $\text{CH}_3\text{COOH}$ , and 0.1 g of KI, then shaken. Titrate with a standard sodium thiosulfate solution until a straw yellow color is obtained. Add 1 mL of the isolated amylose indicator solution, then titrate again until the blue color disappears. Repeat the titration three times. As a standard, also perform the analysis of copper salts using a standard (synthetic) starch indicator with the same steps (Muna, 2022).

Figure 1 shows the research procedure flow:

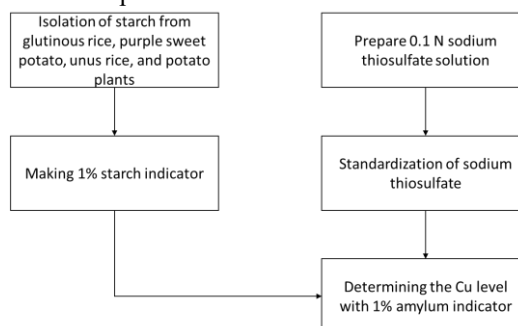


Figure 1. Research procedure flowchart

## RESULTS AND DISCUSSION

### Starch Isolation

Samples of glutinous rice, purple sweet potato, Unus rice, potato, corn, and taro potato from which the starch was isolated produced starch. The following are the percentages of starch obtained:

Table 1. Starch yield percentage

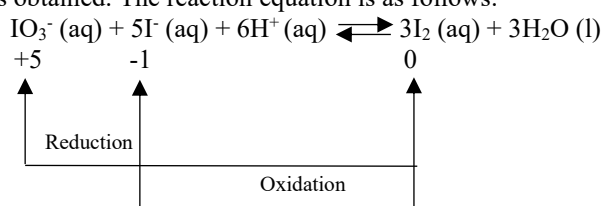
| No. | Starch Source       | Sample weight (g) | Starch weight (g) | Percentage (%) |
|-----|---------------------|-------------------|-------------------|----------------|
| 1.  | glutinous rice      | 300               | 12.4              | 4.1            |
| 2.  | purple sweet potato | 300               | 2.7               | 0.9            |
| 3.  | unus rice           | 300               | 11.2              | 3.7            |
| 4.  | potato              | 300               | 7.8               | 2.6            |

Based on Table 1, it was found that the dry weight of starch isolation was highest in glutinous rice, at 4.1%. These results are in accordance with Asfar et al., (2022), who found that sticky rice contains very high levels of amylopectin, approximately 92% to 98%, thus potentially producing greater starch isolation results compared to other types of plants. Although it was the highest among the other samples, this percentage was still relatively low compared to the findings of Huang et al., (2024) that rice generally has an amylopectin content of 70% of total starch, so that sticky rice will produce different texture and indicator properties compared to other starch sources. According to Dorantes-Fuertes et al., (2024) in their literature review, they explained that tubers and roots can produce up to 12.5% starch if the washing and sedimentation processes are carried out correctly.

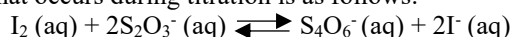
The results of starch isolation are greatly affected by the extraction method, pretreatment conditions, and purification techniques used. Variations in isolation methods can lead to significant differences in the amount of starch obtained, and suboptimal conditions (e.g., pH or solvent) can drastically reduce yields (Kumar et al., 2023; Zhang et al., 2024). The low extraction results in this study were caused by the lack of control over the moisture content and storage conditions of the initial material, resulting in a decrease in starch content due to enzymatic degradation. In addition, the lack of isolation replication also limited the reliability of the results. Another contributing factor was purification efficiency, as very fine starch granules had the potential to be discarded along with the supernatant during the washing and sedimentation process.

### Standardization of Sodium Thiosulfate ( $\text{Na}_2\text{S}_2\text{O}_3$ )

The  $\text{Na}_2\text{S}_2\text{O}_3$  standard solution is a secondary standard solution that is unstable to light and oxidation, so it needs to be standardized with potassium iodate ( $\text{KIO}_3$ ) to determine the accuracy of the  $\text{Na}_2\text{S}_2\text{O}_3$  concentration when preparing the solution and before use in iodometric titration.  $\text{KIO}_3$  functions as a strong oxidizing agent that will release iodine ( $\text{I}_2$ ) and iodide ( $\text{I}^-$ ). After  $\text{KIO}_3$  dissolves, KI and  $\text{H}_2\text{SO}_4$  are added. KI serves to increase the solubility of  $\text{I}_2$  and acts as a reducing agent in the standardization process. The purpose of adding  $\text{H}_2\text{SO}_4$  is to create an acidic environment for the reaction and to act as a catalyst or environment because the  $\text{KIO}_3$  and KI solution can proceed in a strongly acidic state, whereas in a neutral or low acidity state, it cannot be titrated because the reaction is slow. A brownish-black mixed solution is obtained. The reaction equation is as follows:



This reaction produces  $\text{I}_2$ , which reacts with the titrant compound. The solution is then titrated with standardized  $\text{Na}_2\text{S}_2\text{O}_3$  until the solution turns straw yellow. The reaction that occurs during titration is as follows:



Natural starch, which is isolated from several local food plants, is compared to commercial synthetic starch. Visually, both types of starch show clear color changes, although the blue intensity of natural starch tends to be more faded. This is consistent with the findings of Zhang et al. (2024), who stated that the starch source and amylose-amylopectin composition affect the stability of the starch-iodine complex. The positive effects of using the amylose fraction as an indicator were also observed by Heidary et al. (2022), who found that the use of pure amylose solution as an indicator in iodometric titration was more stable and produced a sharp color change. The titration volume results are presented in Table 2.

**Table 2. Titration volume results in sodium thiosulfate standardization**

| Titration         | Volume (mL) |
|-------------------|-------------|
| 1                 | 27.53       |
| 2                 | 28.31       |
| 3                 | 27.19       |
| Average of volume | 27.68       |

The concentration of  $\text{Na}_2\text{S}_2\text{O}_3$  solution can be calculated using the following formula:

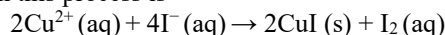
$$\text{The normality of } \text{Na}_2\text{S}_2\text{O}_3 = \frac{n\text{Na}_2\text{S}_2\text{O}_3}{V\text{Na}_2\text{S}_2\text{O}_3} = \frac{0.002016 \text{ mol}}{0.02768 \text{ L}} = 0.0728 \frac{\text{mol}}{\text{L}} \times 2 = 0.14 \text{ N}$$

The titration data shown in Table 2 resulted in an average volume of 27.68 mL and a normality value of 0.14 N. These results indicate that the standardization process was running well and that the  $2\text{S}_2\text{O}_3^{2-}$  solution used had an adequate concentration accuracy. The reaction that occurs is a redox reaction between  $\text{I}_2$  and  $\text{S}_2\text{O}_3^{2-}$  producing  $\text{S}_4\text{O}_6^{2-}$  and  $\text{I}^-$ .

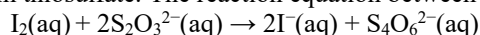
The starch indicator is used to clarify the endpoint of titration by forming a dark blue complex with free iodine. This blue color will suddenly disappear when  $I_2$  has reacted with  $S_2O_3^{2-}$ , making it easier to determine the equivalence point. According to Alsberg (1926), starch should be added close to the end of the titration. If added too early, it causes the formation of a starch-iodine complex that is too stable, trapping the iodine and slowing down the reaction with thiosulfate, which results in a shift in the endpoint. Exposure to light and increased temperature are also environmental factors that can reduce the stability of iodine in solution (Deres et al., 2023).

### Determination of copper salt levels

The determination of copper salt levels is using the iodometric titration method, which utilizes the redox properties of  $Cu^{2+}$  ions. Iodometric titration is ideal for analyzing copper, because  $Cu^{2+}$  ions under certain conditions can oxidize  $I^-$  ions into  $I_2$ , which can then be titrated using a  $Na_2S_2O_3$  solution. The first step in this procedure is to measure out 3.1 g of copper crystals, which are then dissolved in a dilution flask, producing a characteristic blue solution containing  $Cu^{2+}$  ions. Ten milliliters of this solution is pipetted into an Erlenmeyer flask as a sample for titration. To this solution, 3 drops of 0.1 N  $Na_2CO_3$ , 3 mL of 2 N  $CH_3COOH$ , and 0.1 g of KI are added. The addition of  $Na_2CO_3$  and  $CH_3COOH$  aimed to create conditions that support the reaction between  $Cu^{2+}$  and  $I^-$  ions.  $Na_2CO_3$  acts to maintain the stability of the solution, while  $CH_3COOH$  lowers the pH to create the acidic conditions necessary for the reaction to occur. The addition of KI causes a brownish-yellow color to form in the solution, indicating that  $Cu^{2+}$  ions oxidize  $I^-$  ions to form iodine  $I_2$ . The redox reaction that occurs in this process is



In this reaction, the initially dissolved  $Cu^{2+}$  ions are reduced to CuI (copper(I) iodide), which then precipitates as a white solid, while  $I_2$  forms in the solution as an oxidizing agent that can be titrated. The  $I_2$  that forms gives the solution a brownish-yellow color, indicating the presence of free  $I_2$  that is ready to be titrated with  $Na_2S_2O_3$ . The titration is then continued using  $Na_2S_2O_3$  until the solution turns straw yellow. This color change indicates that the iodine in the solution has been reduced due to the reaction with sodium thiosulfate. The reaction equation between  $I_2$  and  $Na_2S_2O_3$  is:



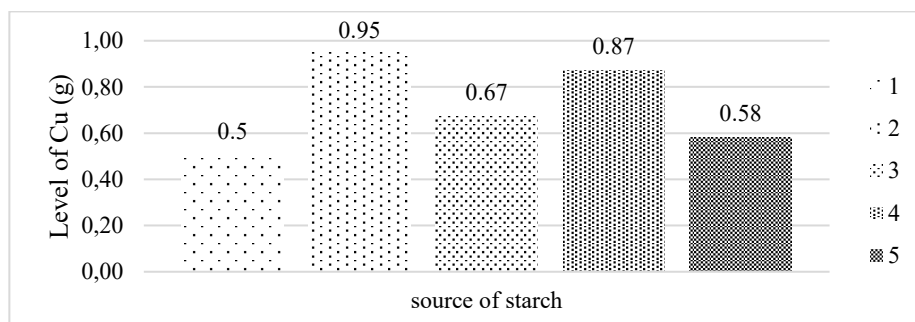
In this reaction, each  $I_2$  molecule interacts with two  $Na_2S_2O_3$  molecules, producing  $I^-$  ions and  $S_4O_6^{2-}$  ions. When a straw yellow color formed, 1 mL of kanji indicator was added, which produced a moss green color due to the formation of a complex between  $I_2$  and kanji, which then turned dark blue. In the final stage of titration, the process is continued until the blue color in the solution disappears, indicating that the iodine has been completely reduced by  $Na_2S_2O_3$ . This iodometric titration is useful for determining the copper content in a solution, which can be calculated using the formula:

$$\text{Level of Cu (g)} = \frac{V_1}{V_2} \times \text{mass } Cu^{2+}$$

Description:

$V_1$  = Volume of  $CuSO_4 \cdot 5H_2O$  dilution

$V_2$  = Volume of  $CuSO_4 \cdot 5H_2O$  titrated



**Figure 2. Cu level from iodometric titration results with plant starch indicator**

Description: 1) Glutinous rice; 2) Purple sweet potato; 3) Unus rice; 4) Potato; 5) Synthetic starch (standard)

Figure 2 shows that starch sources from glutinous rice, purple sweet potatoes, Unus rice, and potatoes can be used as amyllum indicators in iodometric titration. The natural indicator from purple sweet potatoes showed the highest Cu content of 0.95 g, followed by the indicator from potatoes at 0.87 g. These two natural indicators show higher performance than synthetic indicators, which is 0.58 g. This indicates that indicators from purple sweet potatoes and potatoes are more sensitive in detecting the endpoint of iodometric titration, which is marked by the disappearance of dark blue color due to the reaction between iodine and sodium thiosulfate.

The difference in Cu levels obtained may be caused by the sharpness of the color change displayed by each type of starch. Starch from purple sweet potatoes and potatoes may form a more stable complex with iodine and produce a sharper color contrast, making it easier to determine the endpoint of titration visually. In addition, the content of other compounds such as anthocyanins in purple sweet potatoes can also strengthen the color of the complex (Meganingtyas & Alauhdin, 2021; Asmorowati et al., 2024). However, this needs to be further studied to ensure that there are no visual disturbances or side reactions.

Meanwhile, indicators from Unus rice (0.67 g) and glutinous rice (0.50 g) showed relatively equivalent or lower performance compared to synthetic indicators. This indicates that not all natural starch sources have the same ability to detect iodine effectively. This difference may be influenced by the structure and concentration of amylose-amylopectin in each type of starch, which plays a role in the formation of iodine-starch complexes. Quantitatively, natural indicators have the potential to be alternatives to synthetic indicators.

In contrast, indicators from Unus rice (0.67 g) and glutinous rice (0.50 g) produced relatively similar or even lower Cu levels compared to synthetic indicators. This confirms that not all local food sources have the same effectiveness in forming iodine complexes, as they are influenced by the amylose-amylopectin ratio and the molecular structure of the granules (Pesek & Silaghi-Dumitrescu, 2024). Sources with higher amylose content tend to produce a more contrasting blue color intensity, making it easier to observe the titration endpoint (Heidary et al., 2022).

These results also showed the potential of natural indicators in supporting iodometric analysis based on green chemistry principles. However, the difference in Cu content results with synthetic indicators also needs to be considered, as it may indicate bias due to variations in the visual sharpness of the endpoint. Therefore, further analysis of color stability, temperature effects, and titration repetition is needed to ensure the reliability of natural indicators in metal analysis, such as copper (Zhang et al., 2024).

## CONCLUSION

This research shows that starch from local foods like glutinous rice, purple sweet potatoes, unhusked rice, and potatoes can be used as natural indicators in iodometric titration. The results of copper level analysis using glutinous rice (0.50 g) were close to synthetic starch (0.58 g), while purple sweet potatoes and potatoes provided better color sensitivity. Therefore, this natural indicator has the potential to be an environmentally friendly alternative for analytical chemistry practicums. Further research is needed to evaluate the stability of the indicator against storage, pH, and laboratory operating conditions.

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