

CHAPTER I

INTRODUCTION

1.1 Background

Indonesia is one of the world's megabiodiversity countries, possessing abundant starch-producing plants. Major sources of starch include tubers, cereals, and legumes (Hami et al., 2022). The abundance of these raw materials makes starch a renewable biomaterial with high economic value and significant potential for the development of various industrial products.

In the food industry, starch is one of the most widely used biopolymers due to its desirable functional properties, including gel-forming ability, viscosity enhancement, water-holding capacity, and texture stabilization. These characteristics make starch an essential ingredient in a wide range of food products, such as bread, sauces, soups, dairy products, infant foods, and other processed foods, where it improves texture, consistency, stability, and overall sensory quality. However, native starch has several limitations, including poor stability under high-temperature processing, mechanical shear, and acidic conditions. Consequently, numerous starch modification techniques have been developed to improve its functional properties, enabling it to meet the increasing demands of the modern food industry (Compart et al., 2023).

In addition to food applications, modified starch has been extensively utilized in various non-food industries. In the pharmaceutical industry, starch serves as a drug delivery carrier, a controlled drug release material, and a raw material for nanoparticle production. In the energy sector, starch is used as a feedstock for bioethanol production through the generation of fermentable sugars. Furthermore, starch is applied in the paper and packaging industries for the manufacture of bioplastics and adhesives, in the textile industry as a fiber sizing agent, in the detergent industry as an additive to improve starch-based stain removal performance, and in wastewater treatment processes to support the recycling of starch-containing industrial waste. These diverse applications demonstrate the considerable potential of modified starch as an environmentally friendly biomaterial for a wide range of industrial sectors (Compart et al., 2023).

1.2 Problem Formulation

Starch provides significant benefits in human life. However, starch requires proper treatment before processing or utilization due to its relatively complex composition. Therefore, it is important for a Chemical Engineering student to

understand how to modify starch composition so that it can be utilized optimally for human needs. In this experiment, the effect of hydrolysis temperature on the starch hydrolysis reaction and the reaction rate constant will be studied.

1.3 Experiment Goals

1. To study the effect of variables on the starch hydrolysis reaction.
2. To calculate the reaction rate constant and analyze the effect of variables on the reaction rate constant.
3. To compare the calculated reaction rate constant with values reported in the literature.

1.4 Experiment Benefits

1. Students can understand the effect of variables on the starch hydrolysis reaction.
2. Students can calculate the reaction rate constant and analyze the effect of variables on the reaction rate constant.
3. Students can compare the calculated reaction rate constant with literature values.

Process

Laboratory

CHAPTER II

LITERATURE REVIEW

2.1 Starch

Starch is a homopolymer of glucose composed of dehydrated glucose units linked together through glycosidic bonds. Each dehydrated glucose unit contains three hydroxyl groups located at positions C-2, C-3, and C-6. Among these, the primary hydroxyl group at carbon 6 exhibits the highest reactivity, followed by the secondary hydroxyl groups at carbons 2 and 3. Starch consists of two main fractions: amylose and amylopectin. The degree of polymerization of native starch ranges from approximately 160 to 6,000, with a relative molecular weight of about 25,000 to 1,000,000. Starch is insoluble in water and has limited intermolecular macromolecular interaction capability. In addition, starch has limitations in terms of processability, dimensional stability, and the mechanical properties of its final products. Therefore, native starch is generally not used directly without modification (Ozkan et al., 2019).

2.2 Amylose and Amylopectin

Starch belongs to the group of polysaccharides, which are glucose polymers composed of amylose and amylopectin. Amylose is a linear long-chain molecule with α -(1,4) glycosidic bonds and contributes to the amorphous matrix of starch. Amylopectin is a branched molecule with a double-helix structure and α -(1,6) branching points, which give starch its semi-crystalline structure. Amylopectin accounts for approximately 70–85% of total starch content and has a much larger molecular size (10^7 – 10^9 Da) compared to amylose (10^5 – 10^6 Da) (Compart et al., 2023).

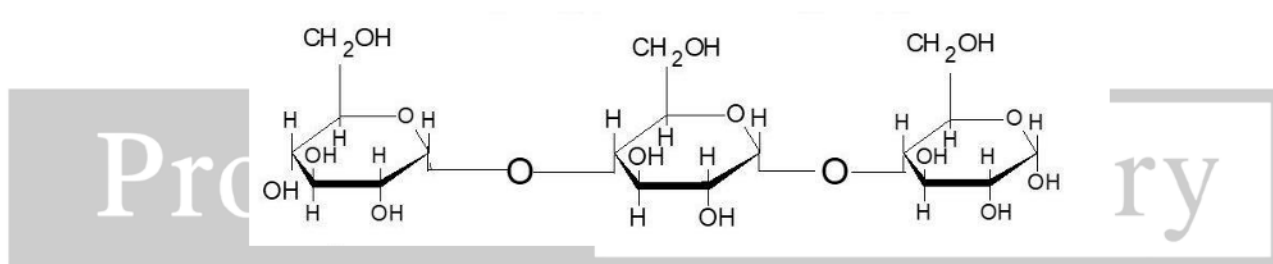


Figure 2.1 Structure of Amylose

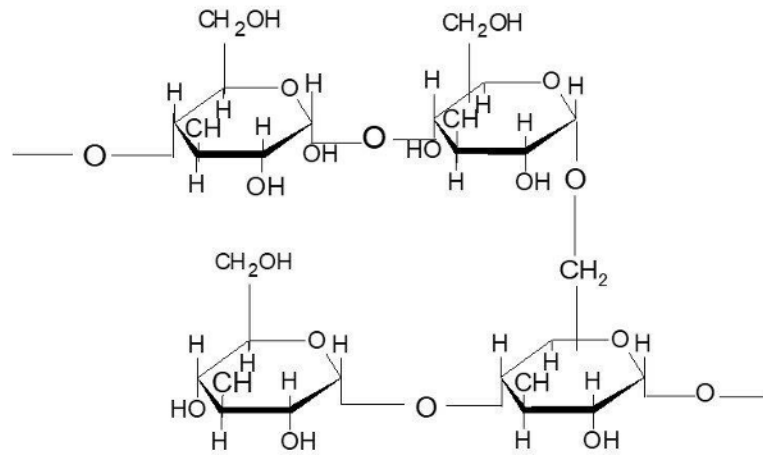


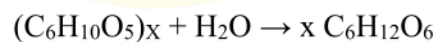
Figure 2.2 Structure of Amylopectin

2.3 Starch Hydrolysis

2.3.1 Kinetics of Starch Hydrolysis Reaction

Hydrolysis is a reaction involving the attachment of a hydroxyl group ($-\text{OH}$) to a compound. The $-\text{OH}$ group is generally derived from water molecules. Hydrolysis can be classified into pure hydrolysis, acid-catalyzed hydrolysis, base-catalyzed hydrolysis, combined alkali-water hydrolysis, and enzymatic hydrolysis. Based on the reaction phase, hydrolysis is categorized into liquid-phase hydrolysis and vapor-phase hydrolysis.

Starch hydrolysis is the process of breaking down starch molecules into simpler components such as dextrin, isomaltose, maltose, and glucose. This reaction occurs between starch as the reactant and water as the co-reactant. The reaction follows pseudo-first-order kinetics because water is present in large excess, allowing its concentration to be assumed constant during the reaction. The overall reaction is:



Based on reaction rate theory:

$$-r_A = k \cdot C_{\text{starch}} \cdot C_{\text{water}} \quad (2.1)$$

Since the water is sufficiently large, the water concentration during the reaction can be considered constant and incorporated into a new constant k' :

$$k' = k \cdot C_{\text{water}} \quad (2.2)$$

Thus, Equation (2.1) can be rewritten as $-r_A = k \cdot C_{\text{starch}}$. From this rate equation, starch hydrolysis is classified as a first-order reaction. If $-r_A = -\frac{dC_A}{dt}$ then Equation (2.2) becomes:

$$\frac{-dC_A}{dt} = k' C_A \quad (2.3)$$

$$\frac{-dC_A}{C_A} = k' dt \quad (2.4)$$

If $C_A = C_{A0}(1 - X_A)$ and the equation is solved by integration with the boundary conditions $t_1: C_{A0}$ dan $t_2: C_A$, the following equation is obtained:

$$-\int_{C_{A0}}^{C_A} \frac{dC_A}{C_A} = k' \int_{t_2}^{t_1} dt \quad (2.5)$$

$$\ln \frac{C_{A0}}{C_A} = k'(t_2 - t_1) \quad (2.6)$$

$$\ln \frac{1}{(1-X_A)} = k'(t_2 - t_1) \quad (2.7)$$

Where X_A is the reaction conversion after one second.

Equation (2.7) can be solved using a linear regression approach $y = mx + c$,

where $y = \ln \frac{1}{(1-X_A)}$ and $x = t_2$.

2.3.2 Starch Hydrolysis Methods

The process of starch decomposition is known as starch hydrolysis. Starch hydrolysis is divided into two methods: acid hydrolysis and enzymatic hydrolysis.

1. Acid Hydrolysis

Acid hydrolysis is a process that uses acids to convert polysaccharides (such as starch and cellulose) into sugars. This hydrolysis is carried out using H^+ catalysts derived from acids such as HCl, H_2SO_4 , and HNO_3 (Wang & Copeland, 2015). The acid hydrolysis method is relatively simpler because it does not require multiple stages, as in enzymatic hydrolysis. In addition, acid hydrolysis requires a relatively shorter processing time, simpler technology, easier process condition control, and lower costs (Devitria & Sepriyani, 2018).

2. Enzymatic Hydrolysis

Enzymatic hydrolysis is the process of converting cellulose and hemicellulose into reducing sugars using enzymes. The enzyme used to convert hemicellulose into glucose is xylanase, while the enzyme used to convert cellulose into glucose is cellulase. Enzymatic hydrolysis can specifically cleave glycosidic bonds without leaving harmful residues (Salsabilla & Fahrurroji, 2021).

2.4 Starch Modification

The application of native starch is often limited due to its low solubility, low water absorption capacity, and the turbidity of the gel produced. Amylose tends to undergo retrogradation, forming rigid gels, while amylopectin forms softer gels, resulting in low thermal resistance and increased thermal

decomposition rates. In addition, native starch has limited functional stability against variations in pH and temperature during processing. Some starch granules are inert, insoluble in water at room temperature, and highly resistant to enzymatic degradation, preventing them from performing their functional applications optimally (Mauro et al., 2023).

Various limitations of native starch can be overcome through starch modification using conventional methods such as thermal, chemical, and enzymatic treatments, as well as modern non-thermal methods including high-pressure treatment, ultrasonic waves, plasma treatment, and electric field application. Starch is generally modified to improve its physical and chemical properties in order to obtain the desired functional characteristics. The physicochemical properties of starch that may be affected after modification include solubility, light transmittance value, rheological properties, thermal properties, and the crystalline structure of starch granules (Hutabarat & Stevensen, 2023).

2.5 Fehling's Reagent in the Analysis of Sugars from Hydrolysis

2.5.1 Composition and Function of Fehling's Reagent

Fehling's reagent is a chemical solution used to detect the presence of reducing sugars such as glucose in a solution. This reagent consists of two components, namely Fehling A and Fehling B, which are mixed immediately before use to maintain solution stability. Fehling A is a copper(II) sulfate (CuSO_4) solution, blue in color, and serves as the source of Cu^{2+} ions. Fehling B is a mixture of sodium potassium tartrate (Rochelle salt) ($\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$) and sodium hydroxide (NaOH), which functions as an alkaline medium and stabilizes Cu^{2+} ions to keep them soluble under alkaline conditions (Aljamali et al., 2025).

2.5.2 Reaction Mechanism

The Fehling method is based on an oxidation-reduction (redox) reaction between reducing sugars and copper(II) ions (Cu^{2+}) under alkaline conditions. Fehling's reagent consists of two separate solutions: Fehling A, which contains copper(II) sulfate (CuSO_4), and Fehling B, which contains sodium potassium tartrate (Rochelle salt) and sodium hydroxide (NaOH). These two solutions are stored separately to prevent the premature precipitation of copper ions before use.

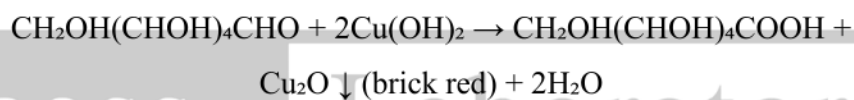
When Fehling A is mixed with Fehling B, the Cu^{2+} ions from CuSO_4 initially react with hydroxide ions (OH^-) supplied by NaOH to form a light-

blue precipitate of copper(II) hydroxide ($\text{Cu}(\text{OH})_2$). This precipitate subsequently dissolves because tartrate ions coordinate with Cu^{2+} ions to form a stable copper(II)-tartrate complex under alkaline conditions. The formation of this complex is essential because it maintains copper ions in solution, allowing them to react efficiently with reducing sugars during heating.

When the freshly prepared Fehling's reagent is added to a sample containing reducing sugars and heated, the aldehyde group ($-\text{CHO}$) of the reducing sugar is oxidized to a carboxylate group ($-\text{COO}^-$). Simultaneously, the copper(II) ions (Cu^{2+}) in the copper-tartrate complex are reduced to copper(I) ions (Cu^+). Since Cu^+ ions are unstable in alkaline solution, they readily combine to form a brick-red precipitate of copper(I) oxide (Cu_2O). Therefore, the greater the concentration of reducing sugars present in the sample, the greater the amount of Cu^{2+} ions reduced, resulting in the formation of a larger quantity of Cu_2O precipitate.

The color change of the solution from blue to brick red serves as an indicator that the reduction of Cu^{2+} ions has occurred. The blue color indicates that copper(II) ions are still predominant in the solution, whereas the formation of a brick-red precipitate indicates that a substantial portion of the Cu^{2+} ions has been reduced to Cu_2O through the oxidation of reducing sugars. Consequently, the amount of Cu_2O formed is directly proportional to the concentration of reducing sugars in the sample, making this reaction suitable for the quantitative determination of reducing sugars using the Fehling method (Zhang & Chen, 2020).

The reactions involved in the Fehling method are as follows:



Process

2.6 Influential Variables

The variables that influence the starch hydrolysis reaction include:

1. Catalyst

Hydrolysis is a relatively slow reaction, therefore, a catalyst is required to accelerate the reaction. The catalyst used can be either an acid or an enzyme due to their faster performance. Various acids can be used, ranging from HCl and H_2SO_4 to HNO_3 (Nasution et al., 2023). The reaction

rate is influenced by the concentration of H^+ ions rather than the type of acid used. However, in industrial applications, hydrochloric acid is commonly used (Zuhair Ds., 2022). This selection is based on the fact that the salt formed during neutralization does not cause significant problems, except for a salty taste if present in high concentration. Therefore, the acid concentration in the hydrolysis medium is kept as low as possible. Generally, acid solutions with higher concentrations than those used in syrup production are applied. Hydrolysis at atmospheric pressure (1 atm) requires a much more concentrated acid.

2. Temperature

The effect of temperature on the reaction rate follows the Arrhenius equation, where a higher temperature results in a faster reaction rate. The optimum temperature in the hydrolysis reaction leads to lower activation energy, allowing for higher hydrolysis conversion (Milek & Lamkiewicz, 2022). To achieve a certain conversion, approximately 48 minutes are required to hydrolyze cassava starch at $100^{\circ}C$ (Ardiansyah et al., 2018). Meanwhile, the hydrolysis of wheat and corn starch using an H_2SO_4 catalyst requires a temperature of $160^{\circ}C$.

3. Mixing (Agitation)

Mixing is required to enhance contact between reactants and accelerate the hydrolysis rate. At the initial stage, agitation helps reduce mass transfer resistance, especially in systems with high solid concentrations. An appropriate stirring speed can improve reaction efficiency, whereas excessive agitation may reduce efficiency due to excessive shear forces. Increasing the agitation speed from 0 to 150 rpm can enhance glucose yield; however, increasing it further to 200 rpm may reduce hydrolysis efficiency (Guo et al., 2015).

4. Reactant Ratio

If one of the reactants is present in excess, the equilibrium can shift favorably toward the products. Therefore, starch suspensions with lower concentrations provide better results compared to higher concentrations.

When the starch suspension concentration is reduced from 40% to 20% or 1%, the conversion increases from 80% to 87% or 99%, respectively (Groggins, 1958). At high suspension concentrations, reactant molecules have limited mobility due to crowding effects. To produce glucose, a starch suspension of approximately 20% is generally used.

CHAPTER III

EXPERIMENTAL METHOD

3.1 Experimental Design

3.1.1 Experimental Setup

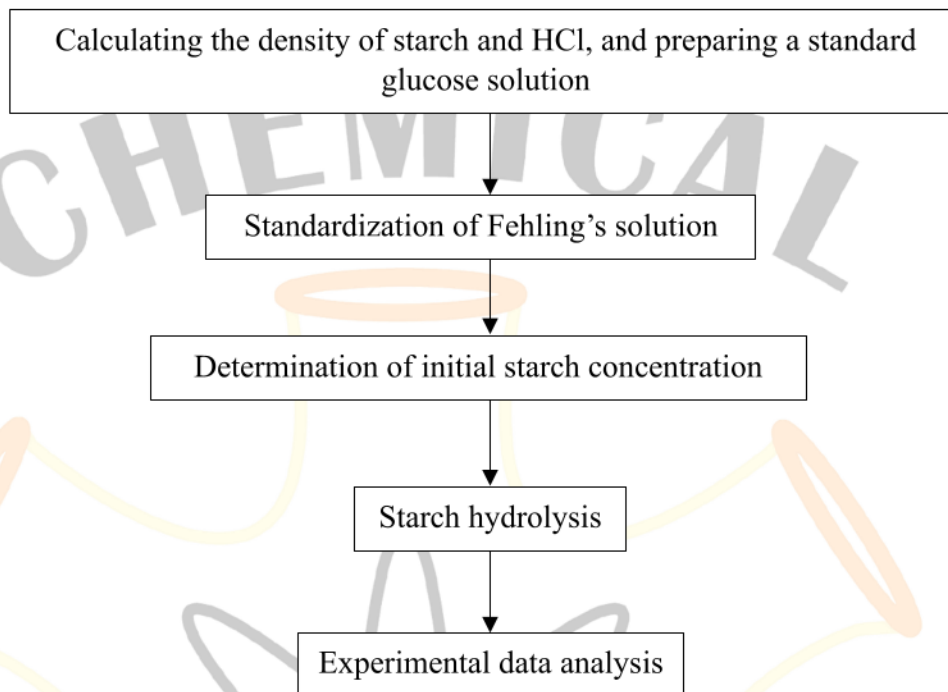


Figure 3.1 Experimental Setup Scheme

3.1.2 Determination of Variables

- a. Controlled Variables :
- b. Independent Variables :

3.2 Materials and Equipment

3.2.1 Materials

1. Anhydrous glucose
2. Starch powder
3. NaOH
4. HCl
5. Methylene blue (MB) indicator
6. Fehling A solution
7. Fehling B solution
8. Aquadest

3.2.2 Equipment

1. Graduated cylinder
2. Thermometer
3. Erlenmeyer flask

4. Retort stand and clamp
5. Burette
6. Three-neck round-bottom flask
7. Volumetric flask

3.3 Apparatus Diagram

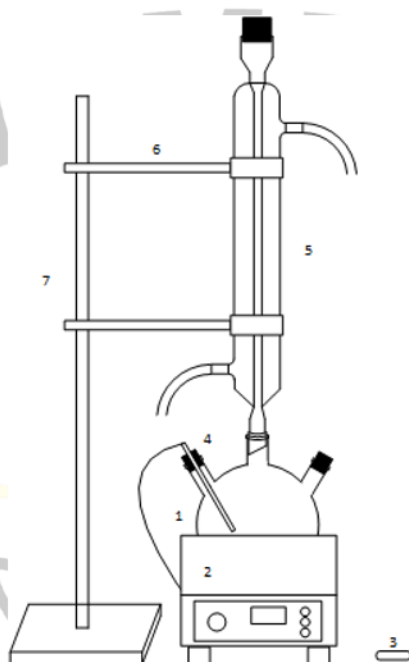


Figure 3.2 Hydrolysis Apparatus Setup

Description:

1. Three-neck round-bottom flask
2. Heating Mantle
3. Stirrer
4. Thermocouple
5. Reflux condenser
6. Clamp
7. Retort stand

3.4 Experimental Procedure

1. Initial Preparation

a. Determination of Starch Density

Add 1 gram of starch into a graduated cylinder containing 5 mL of distilled water. Record the change in volume.

$$\rho_{\text{starch}} = \frac{m_{\text{starch}}}{\Delta V} \quad (3.1)$$

b. Determination of HCl Density

Weigh the empty pycnometer (m_1). Fill the pycnometer (with known volume, V) with HCl solution and weigh it again (m_2). Calculate the density of HCl as follows:

$$\rho_{\text{HCl}} = \frac{m_2 - m_1}{\Delta V} \quad (3.2)$$

c. Preparation of Standard Glucose Solution

Dissolve 2 grams of anhydrous glucose in 1000 mL of distilled water.

2. Determination of Starch Content

a. Standardization of Fehling's Solution

Mix 10 mL of Fehling A, 10 mL of Fehling B, and 15 mL of standard glucose solution. Heat the mixture until boiling. After boiling, add 3 drops of methylene blue (MB) indicator. Titrate with the standard glucose solution until the color changes to brick red. Record the volume of titrant required (F). The titration was performed at a constant temperature of 60°C.

b. Determination of Initial Starch Content

Weigh ... grams of starch and add ... mL of HCl/H₂SO₄ catalyst and ... mL of distilled water into a three-neck round-bottom flask. Heat the mixture to ... °C for 1 hour. After cooling, dilute the solution with distilled water to 500 mL. Take 20 mL of the solution and neutralize with NaOH until pH = 7. Take 5 mL of the neutralized solution and dilute to 100 mL. Then take 10 mL of this diluted solution. Into an Erlenmeyer flask, add 10 mL sample solution, 10 mL Fehling A, 10 mL Fehling B, and 15 mL standard glucose. Heat to 60 °C and add 3 drops of MB indicator. Titrate with standard glucose solution until the color changes to brick red. Record the required titrant volume (M). It is important to ensure that the titration is performed while maintaining the temperature at 60°C. Repeat the same procedure for other variables.

c. Starch Hydrolysis

Weigh ... grams of starch and add ... mL of HCl/H₂SO₄ catalyst and ... mL of distilled water into a three-neck round-bottom flask. Heat the mixture to ... °C. After 5 minutes, withdraw a 20 mL sample. Neutralize the sample with NaOH until pH = 7. Take 5 mL of the neutralized solution and dilute to 100 mL. Then take 10 mL of the diluted solution. Into an Erlenmeyer flask, add 10 mL sample solution, 10 mL Fehling A, 10 mL Fehling B, and 15 mL standard glucose. Heat to 60 °C and add 3 drops of MB indicator. Titrate with standard glucose

solution until the color changes to brick red. Record the titrant volume required (M). It is important to ensure that the titration is performed while maintaining the temperature at 60°C. Sampling is conducted every 5 minutes for a total of 25 minutes ($t_1 = 5$ min, $t_2 = 10$ min, $t_3 = 15$ min, $t_4 = 20$ min, $t_5 = 25$ min). Repeat the same procedure for the second variable.

Determination of initial starch content:

$$X_{P0} = \frac{(F-M) \times N \text{ glucose} \times \frac{500}{\text{basis}} \times \frac{100}{5} \times 0,9}{W} \quad (3.3)$$

Where,

N = 0,002 gr/mL

W = weight of starch

Reagent requirement calculations:

a) Calculation of HCl requirement

$$V_{HCl} = \frac{N \text{ HCl} \times MW \text{ HCl} \times V \text{ Solution}}{\rho \text{ HCl} \times \text{HCl content} \times 1000 \times \text{greq}} \quad (3.4)$$

b) Calculation of starch requirement

$$\% \text{suspension} = \frac{X_p \times W \text{ starch}}{W \text{ starch} + W \text{ HCl} + W \text{ aq}} \quad (3.5)$$

Where,

$$W_{\text{starch}} = \rho_{\text{starch}} \times V_{\text{starch}} \quad (3.6)$$

$$W_{\text{HCl}} = \rho_{\text{HCl}} \times V_{\text{HCl}} \quad (3.7)$$

$$W_{\text{aq}} = \rho_{\text{aq}} \times (V_{\text{solution}} - V_{\text{starch}} - V_{\text{HCl}}) \quad (3.8)$$

$$X_{P0} = \frac{(F-M) \times N \text{ glucose} \times \frac{500}{\text{basis}} \times \frac{100}{5} \times 0,9}{W} \quad (3.9)$$

Process

Laboratory

DAFTAR PUSTAKA

- Aljami, N. M., Jwad, S. M., Alfartosi, W. H. A., dan Ameerghafil, R. A. (2025). Review on Bio and Chemical Reagents (Methods of Preparation and Uses). *Journal of Water Pollution & Purification Research*, 12(2).
- Ardiansyah, A., Nurlansi, N., & Musta, R. (2018). Waktu Optimum Hidrolisis pati limbah Hasil Olahan Ubi Kayu (*Manihot esculenta* Crantz var. Lahumbu) Menjadi Gula Cair Menggunakan enzim α -Amilase Dan glukamilase. *Indo. J. Chem. Res.*, 5(2), 86–95. <https://doi.org/10.30598/ijcr.2018.5-ard>.
- Compart, J., Singh, A., Fettke, J., dan Apriyanto, A. (2023). Customizing Starch Properties: A Review of Starch Modifications and Their Applications. *Polymers*, 15. <https://doi.org/10.3390/polym15163491>.
- Devitria, R. & Sepriyani, H. (2018). Optimalisasi Asam Klorida Pada Proses Hidrolisis Limbah Ampas Sagu (*Metroxylon, sp*) terhadap Kadar Glukosa. *Klinikal Sains: Jurnal Analis Kesehatan*, 6(2), 37-42.
- Groggins, P. H. (1958). *Unit Processes in Organic Synthesis*, 5th ed. 775 -777, McGraw–Hill Book Company, New York.
- Guo, H., Su, R., Huang, R., Qi, W., dan He, Z. (2015). Co-Optimization of Sugar Yield and Input Energy by The Stepwise Reduction of Agitation Rate During Lignocellulose Hydrolysis. *Food and Bioproducts Processing*, 95, 1-6.
- Harni, M., Anggraini, T., Rini, & Suliansyah, I. (2022). Review artikel: Pati pada berbagai sumber tanaman. *Agroteknika*, 5(1), 26-39. <https://doi.org/10.55043/agroteknika.v5i1.118>.
- Hutabarat, D. J. C. & Stevensen, J. (2023). Physicochemical Properties of Enzymatically Modified Starch: A Review. *IOP Conference Series: Earth and Environmental Science*. <https://doi.org/10.1088/1755-1315/1169/1/012093>.
- Milek, J., & Lamkiewicz, J. (2022). The starch hydrolysis by α -amylase bacillus spp.: An estimation of the optimum temperatures, the activation and deactivation energies. *Journal of Thermal Analysis and Calorimetry*, 147(24), 14459-14466. <https://doi.org/10.1007/s10973-022-11738-1>.
- Mauro, R. R., Vela, A. J., dan Ronda, F. (2023). Impact of Starch Concentration on the Pasting and Rheological Properties of Gluten-Free Gels. Effects of Amylose Content and Thermal and Hydration. *Foods*, 12. <https://doi.org/10.3390/foods12122281>.
- Nasution, S. F., Lubis, L. H., Haharap, S., & Siregar, A. U. (2023). Hidrolisis Pati Kacang Kedelai (*Glycine max* (L.) Merrill) dengan Pengaruh Jenis Katalis Asam.

Journal of Pharmaceutical and Health Research, 4(1), 141-146.
<https://doi.org/DOI 10.47065/jharma.v4i1.3187>.

Ozkan, C. K., Ozgunay, H., dan Akat, H. (2019). Possible Use of Corn Starch as Tanning Agent in Leather Industry: Controlled (Gradual) Degradation by H₂O₂. *International Journal of Biological Macromolecules*, 122, 610-618.
<https://doi.org/10.1016/j.ijbiomac.2018.10.217>.

Salsabila, A. L., & Fahrurroji, I. (2021). Hidrolisis Pada Sintesis Gula Berbasis Pati Jagung. *Edufortech*, 6(1), 32-38.

Wang, S., & Copeland, L. (2015). Effect of acid hydrolysis on starch structure and functionality: A review. *Critical Reviews in Food Science and Nutrition*, 55(8), 1081–1097. <https://doi.org/10.1080/10408398.2012.684551>.

Zhang, Y. dan Chen, Q. (2020). Improving Measurement of Reducing Sugar Content in Carbonated Beverages Using Fehling's Reagent. *Journal of Emerging Investigators*, 2.

Zuhair Ds, N. (2022). Pengaruh Waktu Hidrolisis dan Konsentrasi Katalis Asam Klorida Terhadap Hidrolisis Kulit Gandum Pollard. *Journal of Industrial Process and Chemical Engineering (JOICHE)*, 2(1), 76-80.

Process

Laboratory

HAZARD IDENTIFICATION AND RISK ANALYSIS

MATERIAL : STARCH HYDROLYSIS

HAZARD IDENTIFICATION										
A	Mechanical		D	Environment		E	Chemical		G	Other risks
A1	Manual handling		D1	Noise		E1	Toxicant	√	G1	Compressed gas
A2	Moving parts		D2	Vibration		E2	Irritant	√	G2	Ionising radiation
A3	Rotating parts		D3	Lighting		E3	Corrosive		G3	UV radiation
A4	Cutting		D4	Humidity		E4	Carcinogenic		G4	Fatigue
B	Biology		D5	Temperature	√	E5	Flammable		G5	Cramped space
B1	Bacteria		D6	Dangers of travel		E6	Explosive		G6	Crowded
B2	Virus		D7	Slippery surface	√	E7	Cryogenics		G7	Thermometer
B3	Mold		D8	Solid waste		F	Equipment			
C	Electrical		D9	Air quality		F1	Pressure vessel			
C1	High voltage	√	D10	Solitary work		F2	Heating equipment	√		
C2	Static electricity		D11	Splashes/drops/floods	√	F3	Laser			

Process Laboratory

C3	Cable	√	D12	Pile of powder	√	F4	Glass vessel			
RISK ANALYSIS										
IB	Risks (after control measures)				Risk identification	Control measures to minimise risk	First aid measures			
	High	Medium	Low	Minimal						
1. PREPARATION / INITIAL PRACTICAL										
D7, D11				√	During pycnometer calibration and reagent preparation, there is a risk of distilled water (aquadest) spilling, which may cause the working surface or floor to become slippery.	Exercise caution when handling distilled water. If transferring distilled water to containers or areas prone to spillage, use a funnel to minimize the risk of creating slippery surfaces.	If a slip occurs, examine the injured area and provide appropriate first aid treatment. If the injury is severe or worsens, immediately take the victim to the nearest hospital or clinic.			

Process

Laboratory

D12			√	During the starch density calculation, there is a risk that spilled starch powder may contaminate the laboratory area and cause respiratory irritation or obstruction if inhaled.	Exercise caution when transferring starch powder to prevent spillage.	Clean up any spilled starch powder immediately. If inhaled, remove the exposed person from the contaminated area and ensure the airway is clear. If the condition worsens, take the victim to the nearest hospital or clinic for further medical attention.
2. MAIN PRACTICAL						
C1, C3		√		The presence of damaged or exposed electrical cables may result in short circuits or electric shock.	Conduct proper inspection and ensure that all equipment is in good and safe working condition before use.	Disconnect the power source immediately to stop the flow of electricity.

Process

Laboratory

D5, F2		√			There is a risk of contact with the electric stove or equipment heated on the electric stove, which may cause burns.	Exercise caution with hot surfaces during the heating process and ensure that the apparatus is positioned in a secure location to avoid any accidental contact.	Discontinue the heating process, cool the burn, and administer an analgesic. If the condition persists, proceed to the nearest clinic or hospital
RISK ANALYSIS							
IB	Risks (after control measures)				Risk identification	Control measures to minimise risk	First aid measures
	High	Medium	Low	Minimal			

Process

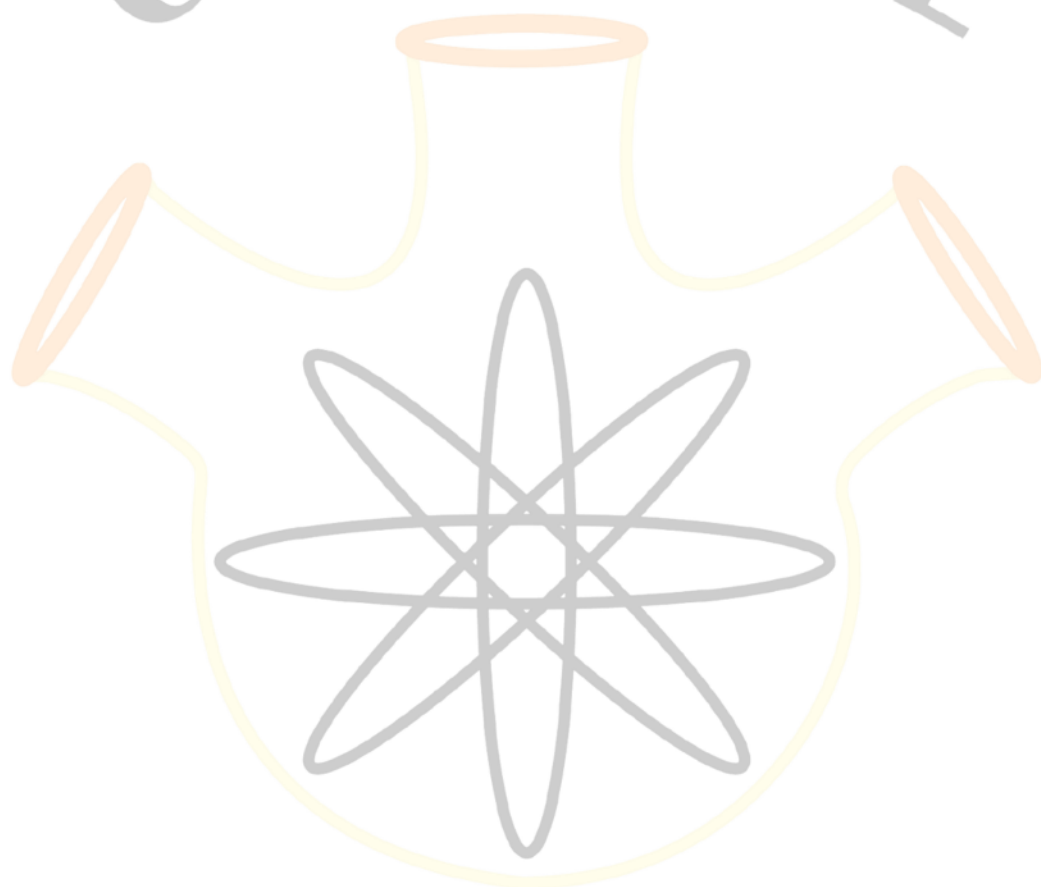
Laboratory

E1, E2		√			The use of acidic and basic reagents in this laboratory practice carries the risk of skin contact, which may cause irritation, and accidental ingestion may result in poisoning.	Wear latex gloves during the laboratory session and replace them if torn or punctured, while exercising caution when handling acidic and basic reagents.	If the reagent comes into contact with the skin, immediately wash the affected area thoroughly with running water. If ingested, promptly drink mineral water and rinse the mouth to minimize the hazard. If the condition worsens, take the individual to the nearest hospital or clinic.
3. ANALYS / FINAL PRACTICAL							
D7, D11				√	During titration, there is a risk of solution spillage, which may result in slippery surfaces.	Exercise caution when handling distilled water. If directing it toward an area prone to spillage, use a funnel to minimize the risk of creating slippery surfaces.	If a slip occurs, examine the injured area and provide appropriate treatment. If the injury is severe or worsens, take the individual to the nearest hospital or clinic.

Process

Laboratory

CHEMICAL



Process

Laboratory