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Analysis of Enthalpy Changes in Jackfruit Seed (*Artocarpus heterophyllus L.*) Fermentation Process Based on Yeast Mass

Dimas Ridho *, Moondra Zubir, Ani Sutiani, Amanda Revalona Sitepu, Dita Indah Lorencia Silitonga, Maria Yovinta Silitonga and Muhammad Fisal

Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Medan 20221, Indonesia
**Corresponding author : dimas@unimed.ac.id*

ABSTRACT

This study investigates the fermentation process of jackfruit seeds (Artocarpus heterophyllus L.) as a bioethanol production source due to their high carbohydrate content. The research focuses on the effect of yeast mass on temperature fluctuations and reaction enthalpy (ΔH) during fermentation. Jackfruit seed flour was prepared and hydrolyzed with 5M HCl before fermentation with varying yeast masses. Temperature changes during fermentation ranged from 28.5°C to 32°C, depending on yeast mass, indicating the activity of Saccharomyces cerevisiae. The reaction enthalpy values for the samples were -126 J, -168 J, -504 J, and -1008 J, confirming the exothermic nature of the fermentation process.

Keywords: Fermentation, jackfruit seeds, enthalpy change, yeast mass

1. INTRODUCTION

Fermentation is a widely used biochemical process that plays a crucial role in the food, energy, and industrial sectors.[1] It involves the transformation of organic substrates into valuable products through the metabolic activities of microorganisms, particularly the enzymes they produce.[2] During fermentation, microorganisms extract energy by metabolizing food substrates, which often generates heat and causes temperature fluctuations within the system.[3] These temperature variations are not merely incidental; they are key indicators of the ongoing metabolic processes.

Jackfruit seeds (Artocarpus heterophyllus L.) are particularly promising for fermentation due to their high starch content, which can be hydrolyzed into glucose, a suitable substrate for fermentation.[4] The enzymatic hydrolysis of starch typically occurs in two stages: liquefaction and saccharification. In the liquefaction stage, starch is broken down into smaller polysaccharides, which are then further converted into glucose during saccharification, enhancing their fermentability.[5] In this study, we utilize hydrochloric acid (HCl) hydrolysis to produce a glucose-rich hydrolysate from jackfruit seeds, optimizing it for use as a fermentation substrate.

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The fermentation process using Saccharomyces cerevisiae is characterized by exothermic reactions that release heat during sugar metabolism, leading to dynamic temperature changes.[6] These changes offer valuable information for calculating reaction enthalpy (ΔH), a thermodynamic parameter that quantifies the heat energy released or absorbed during a chemical reaction.[7,8] Gaining insights into these parameters can enhance our understanding of the energy efficiency of fermentation.

Although numerous studies have examined fermentation dynamics and the efficiency of enzymatic hydrolysis, there is a notable gap in research regarding the relationship between variations in yeast mass and temperature changes during jackfruit seed fermentation.[9] This study aims to investigate how different yeast masses affect fermentation temperature and to calculate the corresponding enthalpy changes. The results are intended to enhance our understanding of the thermodynamic aspects of fermentation, with potential implications for optimizing biochemical processes.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

The chemicals used in this study include jackfruit seeds (Artocarpus heterophyllus L.), which were sourced locally, hydrochloric acid (HCl) 5 M, bread yeast (Saccharomyces cerevisiae), along with aquadest (H_2O). The equipment involved in this experiment includes an oven, a blender, and a thermometer with a range of up to 100°C. The glassware used includes beakers 250 mL and 500 mL, a 100 mL measuring cup, and filter paper, a glass funnel, a spirit lamp, gauze, a tripod stand, and digital timer.

2.2. Research Procedure

Initially, jackfruit seeds were thoroughly washed until they were clean, followed by peeling the skin off. The seeds were then sliced into multiple pieces to ensure easier drying. These seed slices were placed in an oven and baked at a temperature of 50–60°C for a duration of 3–4 hours, ensuring they were completely dried out. Once dried, the seeds were ground using a blender or grinder until they formed a fine powder. After grinding, the mixture was passed through a sieve to obtain a finer flour.

The subsequent stage involved the hydrolysis process. Jackfruit seed flour was placed into a beaker, and a 5 M HCl solution was added to it. The mixture was then heated at a temperature ranging from 50–70°C until the hydrolysis process was deemed complete. The results of the hydrolysis were filtered using filter paper and a glass funnel, which served to separate the hydrolysate solution from the solid residue (cake).

During the fermentation phase, the hydrolysate solution was transferred to a beaker, where yeast was incorporated according to specified variations. This mixture underwent fermentation for a varying period, during which temperature changes were monitored periodically using a thermometer.

3. RESULTS AND DISCUSSION

3.1. Results of Experiment

In the fermentation experiment, a ratio of 1:4 between yeast mass and hydrolysate was used. The first sample had a yeast mass of 5 grams and a hydrolysate mass of 20 mL, with an initial hydrolysate temperature

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of 28.5°C which increased to 30°C after fermentation for 30 minutes. The second sample with a yeast mass of 10 grams and a hydrolysate mass of 40 mL showed a temperature increase from 28°C to 29°C. The third sample with a yeast mass of 15 grams and a hydrolysate mass of 60 mL had an initial temperature of 29°C which increased to 31°C. The fourth sample, with a yeast mass of 20 grams and a hydrolysate mass of 80 mL, showed a temperature increase from 29°C to 32°C.

3.2. Hydrolysis Process

The starch in jackfruit seeds is broken down into simpler sugars through the hydrolysis process. Enzymes such as amylase play a role in converting starch into fermentable sugars under mild conditions.[10] The process of breaking down starch into glucose is also carried out by acid. Heating jackfruit seed flour with HCl at a temperature of 50-60°C will produce a solution containing glucose, provided that the time and temperature conditions are properly controlled. This glucose can be used for fermentation processes or other applications such as biochemical raw materials.[11]

The combination of jackfruit seed flour and a 5M HCl solution, when heated to a temperature range of 50-70°C, yields a thick brown solution. Following this, the starch and hydrolysate solution undergo separation. The resulting hydrolysate solution appears as a cloudy brown and emits a strong odor. Jackfruit seeds are known for their high starch content, which comprises 50–80% of their dry weight, positioning them as a promising source for glucose production via hydrolysis. The presence of 5M HCl during the hydrolysis process at this specified temperature effectively breaks down starch molecules into simpler sugars, including glucose.

3.3. Temperature Change in Each Sample

The allowable temperature change for medium- or high-temperature anaerobic fermentation ranges from ±1.5°C to 2.0°C. When there is a change of ±3°C, the fermentation rate is inhibited. When there is a sharp change of ±5°C, gas production is suddenly stopped, and organic acid is accumulated in a large amount to halt the anaerobic fermentation. Therefore, the anaerobic fermentation process requires the temperature to be relatively stable, and the range of variation within 1 day is within ±2°C.[12]

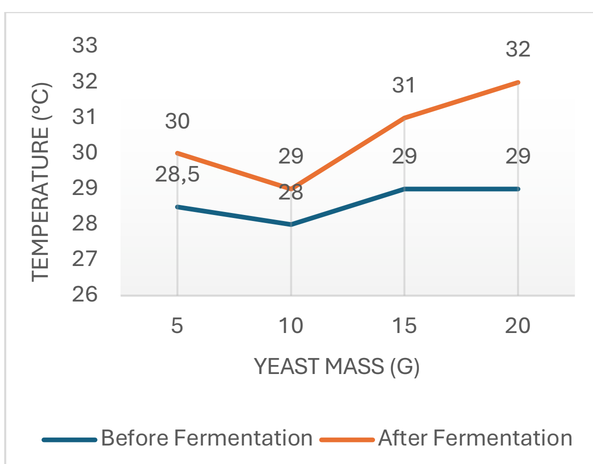

Figure 1. Temperature change in fermentation

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The hydrolysate's temperature before fermentation ranged from 28. 5°C to 29°C, while it rose to between 29°C and 32°C after fermentation. This increase in temperature is directly proportional to the quantity of yeast employed, with a larger yeast mass (20 grams) resulting in a more substantial temperature rise (from 29°C to 32°C), in contrast to a smaller yeast mass (5 grams), which resulted in a lesser rise (from 28. 5°C to 30°C). The graph demonstrates a uniform increase in the final fermentation temperature as the yeast mass increases, reflecting the heightened metabolic activity of the microorganisms involved.

3.4. Effect of Adding Yeast Mass to the Fermentation Process

Yeast is a microorganism that plays a role in converting carbohydrates into alcohol and carbon dioxide gas. By increasing the yeast mass, the number of yeast cells available for fermentation increases, which can accelerate the fermentation rate because more enzymes are produced to break down substrates. The combination of yeast mass and fermentation time is also very important; if the yeast mass is too high but the fermentation time is too short, the fermentation process may not be optimal. Conversely, fermentation time that is too long can cause over-fermentation.[13]

In line with the experimental data, which shows that the increase in temperature after fermentation is directly correlated with the mass of yeast used. At a yeast mass of 5 grams, the temperature increased from 28.5°C to 30°C, while at a yeast mass of 20 grams, the temperature increased from 29°C to 32°C. This increase in temperature reflects higher metabolic activity due to the addition of yeast mass, where more enzymes are produced to break down substrates, such as sugar in the hydrolysate solution. This activity not only produces alcohol and carbon dioxide but also heat as a by-product. However, it is important to note that although the temperature increase remains within the tolerance limit of anaerobic fermentation (±2°C), if the yeast mass is too high without appropriate fermentation time settings, there is the potential for over-fermentation which can affect product quality.

3.5. Enthalpy Value in Fermentation Process

Variations in yeast mass affect enthalpy changes during fermentation because an increase in yeast mass increases the number of active microorganisms involved in the metabolic process. Therefore, an increase in yeast mass not only accelerates the reaction but also increases energy release detected as temperature change, which is important in controlling fermentation efficiency and exothermic reactions.[14] The resulting enthalpy graph will most likely show a decrease as the fermentation process progresses, reflecting the exothermic nature of the reaction and the conversion of higher-energy substrates into lower-energy products.[15]

Calculations reveal that the reaction enthalpy (ΔH) for samples 1, 2, 3, and 4 are -126 J, -168 J, -504 J, and -1008 J. This rise in temperature indicates that the fermentation process is generating heat, which is the hallmark of an exothermic reaction. The enthalpy graph in an exothermic reaction generally falls because energy is released to the environment in the form of heat. In this case, the rise in temperature of the system indicates the release of such energy. Therefore, from the table data, we can conclude that. The total enthalpy of the system will decrease during the fermentation process. The greater the mass of yeast used, the greater the temperature rise, so the energy released in the fermentation process is also greater.

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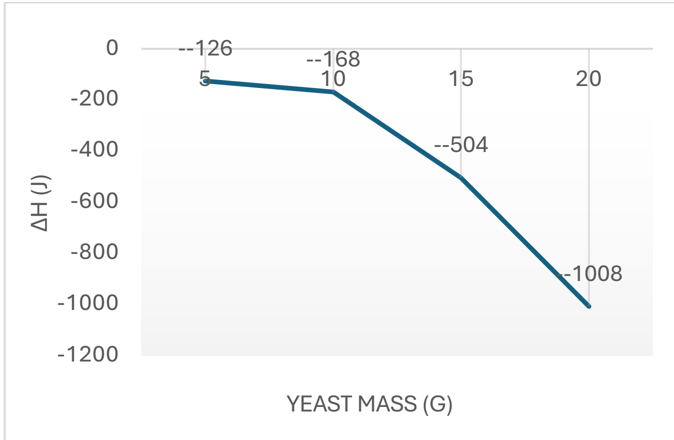

Figure 2. Energy change in fermentation

4. CONCLUSION

The variation in yeast mass significantly influences temperature fluctuations throughout the fermentation process of jackfruit seed hydrolysate. An increase in the yeast mass correlates with a rise in the final fermentation temperature. This phenomenon can be attributed to the heightened metabolic activity of microorganisms that generate heat as a by-product. In this experiment, for a yeast mass of 5 grams, the temperature escalated from 28. 5°C to 30°C, for a yeast mass of 10 grams, the temperature escalated from 28°C to 29°C, for a yeast mass of 15 grams, the temperature escalated from 29°C to 31°C, while for a yeast mass of 20 grams, it rise from 29°C to 32°C. This temperature increase serves as an indication of the intensified fermentation activity associated with the growing number of enzymes produced by the microorganisms.

Furthermore, the enthalpy of reaction generated from the fermentation process displays a direct correlation with both the mass of water and the temperature variations. Calculations reveal that the reaction enthalpy (ΔH) for samples 1, 2, 3, and 4 are -126 J, -168 J, -504 J, and -1008 J, respectively. These values demonstrate that the reaction enthalpy is exothermic, indicating that energy is released during fermentation. The extent of energy released is contingent upon the intensity of fermentation activity, which is further influenced by the quantity of yeast utilized.

REFERENCES

1. Maicas, S. (**2020**). The Role of Yeasts in Fermentation Processes. *Microorganisms*, *8*(8), 1142.
2. Yanti, N. A., Jamili., Ardiansyah., & Ahmad, S. W. (**2023**). *Teknologi Fermentasi Pangan*. Pekalongan: Nasya Expanding Management.
3. Tesema, B. D., Workneh, S., & Omar, C. (**2020**). Dynamic Heat Transfer Modeling, and Simulation of Biomass Fermentation during Beer Processing. *International Journal of Trend in Scientific Research and Development*, *5*(1), 2456-6470.

4. Fajar, M. N., Mulyadi, D., & Muharam, S. (**2023**). Pembuatan Bioetanol dari Limbah Biji Nangka (Artocarpus heterophyllus) dengan Variasi Konsentrasi HCl. *Journal of Scientech Research and Development, 5*(2), 703-713.
5. Roni, K. A., Kartika, D., Apriyadi, H., & Herawati, N. (**2019**). The Effect of Type and Concentration Yeast with Fermentation Time and Liquifaction Variations on The Bioethanol Concentration Resulted by Sorgum Seeds with Hydrolysis and Fermentation Processes. *Journal of Computational and Theoretical Nanoscience*, *16*(12), 5228-5232.
6. Maicas, S. (**2023**). Yeast Fermentation and the Make of Biotechnological Products. *Microorganisms*, *11*(6), 1463.
7. Rathakrishnan, E. (**2015**). High Enthalpy Gas Dynamics. Singapore: Wiley.
8. Strąk-Graczyk, E., & Balcerek, M. (**2020**). Effect of Pre-hydrolysis on Simultaneous Saccharification and Fermentation of Native Rye Starch. *Food and Bioprocess Technology*, *13*, 923–936.
9. Vilela, A. (**2019**). The Importance of Yeasts on Fermentation Quality and Human Health-Promoting Compounds. *Fermentation, 5*(2), 46.
10. Van, C. K., Nguyen, T. H., Nguyen, T. T. N. H., Nguyen, P. T. N., Tran, T. T., & Hoang, Q. B. (**2023**). Comparison of the Effects of Jackfruit Seed Flour and Jackfruit Seed Starch in the Cookie Manufacturing Process. *Processes*, *11*(11), 3194.
11. Arifiyanti, N. A., Kartini, D. N. A., & Billah, M. (**2020**). Bioetanol dari Biji Nangka dengan Proses Likuifaksi dan Fermentasi menggunakan Saccharomyces Cerevisae. *Chempro: Journal of Chemical and Process Engineering, 1*(1), 51-55.
12. Youcai, Z., & Ran, W. (**2020**). *Biomethane Production from Vegetable and Water Hyacinth Waste*. Netherlands: Elsevier.
13. Fathurahmi, S., Spetriani., Asrawaty., & Siswanto, P. H. (**2020**). Penambahan Ragi Roti dan Lama Fermentasi pada Proses Pengolahan Virgin Coconut Oil. *Jurnal Pengolahan Pangan, 5*(2), 48-53.
14. González-Hernández, Y., Michiels, E., & Perré, P. (**2024**). Heat of Reaction in Individual Metabolic Pathways of Yeast Determined by Mechanistic Modeling in an Insulated Bioreactor. *Biotechnol Biofuels Bioprod, 17*(1), 137.
15. Brahma, R., & Ray, S. (**2023**). Finding out various potentials and possibilities of jackfruit seed and its usage in the industry: a review. *Food Production, Processing and Nutrition*, *5*, 55.

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