Indonesian Journal of Chemical Science and Technology (IJCST)
State University of Medan, https://jurnal.unimed.ac.id/2012/index.php/aromatika

IJCST-UNIMED 2026, Vol. 09, No. 2, Page; 214 – 220
Received : Nov 6th, 2025 Accepted : Jul 9th, 2026 Web Published : Jul 31st, 2026

Development of Bio-battery from Pineapple Peel Waste (*Ananas Comosus* L. Merr) Using Table Salt (NaCl) as Ion Source and Tapioca Starch as Matrix

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ABSTRACT

This research discusses the utilization of pineapple peel waste (Ananas comosus L. Merr) as a base material for environmentally friendly bio-batteries, adding table salt (NaCl) as an ion source and tapioca starch as a matrix. The study aimed to examine the potential of pineapple peel waste in producing renewable electrical energy and to analyze the effect of NaCl and tapioca addition on bio-battery performance. The process began with preparing pineapple peel waste (drying and smoothing), which was then mixed with varying concentrations of NaCl and tapioca. The results showed that the bio-battery produced voltage and current with performance varying by composition. The optimal concentration of NaCl combined with a balanced tapioca matrix provided the most stable voltage and longer durability. This finding indicates that pineapple peel waste is a potential solution for organic waste management and an alternative eco-friendly energy source.

Keywords: pineapple peel waste, bio-battery, NaCl, tapioca starch, renewable energy

1. INTRODUCTION

Indonesia is one of the countries still dependent on petroleum and coal as its primary energy sources. Currently, the supply of these non-renewable resources is decreasing, while energy needs continue to increase, prompting the search for new alternative energy sources.[1] Alternative energy sources such as biofuel, solar, wind, and marine power are being explored, but they often face limitations in capacity, continuity, and environmental impact, making them unable to meet all high-intensity electricity demands.[2]

e-ISSN : 2622-4968, p-ISSN : 2622-1349

One potential solution to overcome these limitations is the utilization of organic waste, such as vegetables and fruits. Fruits contain various substances that can generate cell energy, including citric acid, ascorbic acid, and various electrolytes. This renewable alternative can take the form of a bio-battery, which utilizes the electrical properties of fruit and vegetable waste as a substitute for conventional batteries.[3] A bio-battery is a device that converts chemical energy into electrical energy through biochemical processes, often using organic materials as an electrolyte.

The processing of pineapple peel waste (Ananas comosus L. Merr) into bio-batteries is an innovative step aligned with global efforts to find renewable energy sources. This waste, often regarded as trash, has significant potential as a raw material for alternative energy. Its utilization not only reduces environmental pollution but also provides a solution to energy problems.[4] Previous research indicates that pure pineapple peel can produce a maximum voltage of about 2.410 Volts and a maximum current of 0.12 mA. However, to enhance this performance, other materials are needed, such as table salt (NaCl) as an ion source and tapioca starch as a matrix. NaCl functions to increase the electrolyte's conductivity, while tapioca provides stability and structure.[5]

Tapioca starch plays a crucial role in the physical stability of the bio-battery. Starch provides structure to the electrolyte, preventing phase separation and maintaining mixture consistency. Its hydrophilic nature helps retain moisture within the system, enhancing the efficiency of the chemical reactions. Thus, the combination of pineapple peel, NaCl, and tapioca starch is expected to yield a bio-battery with optimal performance.[6] The electrochemical process in this bio-battery involves oxidation-reduction reactions. At the negative electrode (anode), zinc (Zn) undergoes oxidation, while at the positive electrode (cathode), copper (Cu) undergoes reduction, creating an electron flow. Previous studies have shown that modifying electrolyte composition, such as adding sodium benzoate or used battery paste, can significantly improve performance, indicating that additives are critical.[7]

Although bio-battery research has progressed, results are often limited to laboratory-scale tests, and the methods are not yet simple enough for mass production or widespread application. While the potential of pineapple peel is known, its use is often limited to simple processing without optimization. The addition of NaCl to enhance conductivity is established, but the use of an organic matrix like tapioca starch for structural stability is an area that is rarely researched. This research introduces an innovative approach by utilizing tapioca starch as a matrix to reinforce the bio-battery structure, offering better mechanical stability and enhancing ion transfer efficiency.

Therefore, this study aims to process pineapple peel waste (Ananas comosus L. Merr) into a bio-battery with the addition of table salt (NaCl) as an ion source and tapioca starch as a matrix. The specific objective is to determine the optimum composition of pineapple peel extract and NaCl that produces the maximum current and voltage. This research will be conducted experimentally by preparing pineapple peel extract, which is then combined with tapioca starch and varying concentrations of NaCl to form a solid electrolyte. The bio-battery's performance will be evaluated by measuring the resulting current and voltage using a digital multimeter to identify the optimal composition.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

e-ISSN : 2622-4968, p-ISSN : 2622-1349

The chemicals used in this study were pineapple peel (*Ananas comosus L. Merr*), table salt (NaCl), tapioca starch, and distilled water (aquades). The main equipment and instrumentation included a digital analytical balance, a blender, and a digital multimeter (Sanwa cd800a) used to measure current (mA), voltage (V), and resistance (kΩ). Electrodes were prepared using graphite and aluminum sheets. General laboratory equipment included beaker glasses, measuring glasses, stirring rods, knives, and filter paper.

2.2. Research Procedure

The research was conducted in two main stages. First, the optimization of the pineapple peel mass was performed. Pineapple peels were washed and cut , then blended with 10 mL of distilled water for 2 minutes to create an extract. The extract was prepared in several mass variations (12 g, 14 g, 16 g, 18 g, and 20 g) and placed in beaker glasses. For each variation, 20 g of tapioca starch was added and mixed to form a solid electrolyte paste. This paste was then placed between a graphite sheet and an aluminum sheet, which served as the electrodes. The current (mA) and voltage (V) were measured using the digital multimeter to determine the optimum mass of pineapple peel extract.

In the second stage, the optimum mass of pineapple peel extract determined from the first stage was used. This extract was combined with varying masses of NaCl (2 g, 2.5 g, 3 g, 3.5 g, and 4 g). Subsequently, 20 g of tapioca starch was added to each NaCl variation to form the solid electrolyte paste. The current and voltage were measured again to find the optimal composition of NaCl. Finally, the resistance (kΩ) of the solid electrolytes was measured using the ohmmeter function of the multimeter to analyze conductivity changes.

3. RESULTS AND DISCUSSION

The analysis in this study focused on measuring the current (mA) and voltage (V) generated by the bio-battery. The performance was evaluated based on two main variables: the mass of the pineapple peel extract and the mass of the added NaCl, with tapioca starch serving as the solid electrolyte matrix.

3.1. Effect of Pineapple Peel Mass

The first stage optimized the mass of the pineapple peel extract. The performance of the bio-battery, measured by current, voltage, and solid electrolyte resistance, is presented in Table 1 and Figure 1.

Table 1. Relationship between pineapple peel mass, current, voltage, and resistance

Mass of Pineapple Peel Extract (g)	Current (mA)	Voltage (V)	Solid Electrolyte Resistance (kΩ)
12	0.25	0.389	4.80
14	0.38	0.422	5.90
16	0.53	0.488	5.79

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18	0.83	0.532	5.60
20	0.48	0.436	5.83

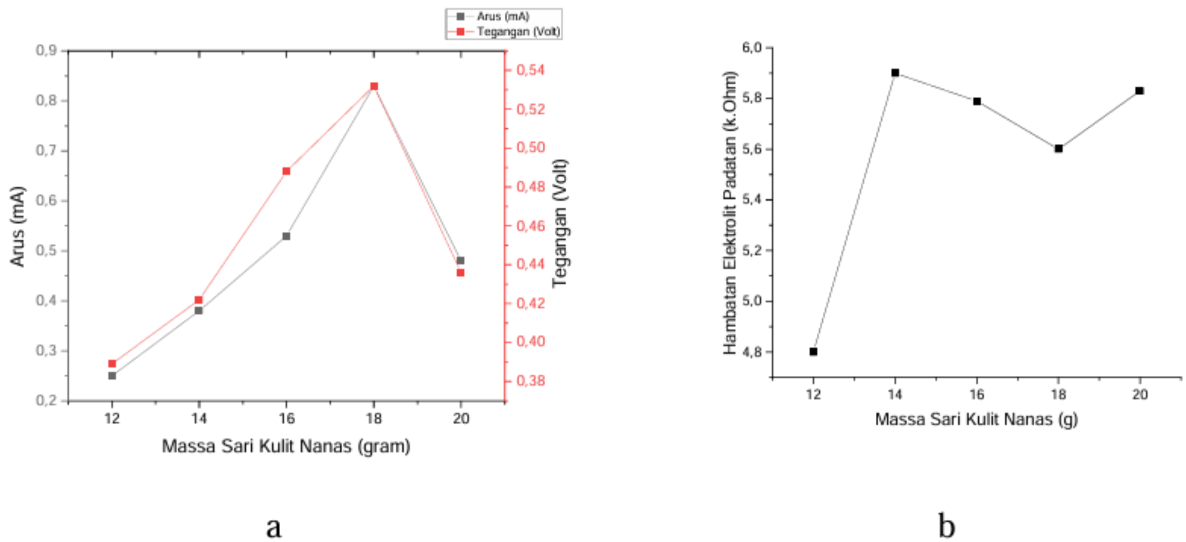

Figure 1. (a) Graph of the relationship between pineapple peel mass, current, and voltage. (b) Graph of the relationship between pineapple peel mass and solid electrolyte resistance.

As shown in Table 1 and Figure 1, the battery's current and voltage increased as the mass of the pineapple peel extract deposited into the tapioca starch matrix increased. The current rose from 0.25 mA (at 12 g) to a peak of **0.83 mA** (at 18 g). Similarly, the voltage increased from 0.398 V (at 12 g) to a maximum of **0.532 V** (at 18 g). However, when the mass exceeded 18 g, both the current and voltage decreased.

This fluctuation in performance is directly related to the resistance of the solid electrolyte. Resistance measurements, used as a proxy for conductivity analysis, showed an inverse trend. The resistance decreased as the pineapple peel mass increased, reaching its lowest point of **5.60 kΩ** at 18 g, indicating the highest conductivity. When the mass exceeded 18 g, the resistance increased again, signifying lower conductivity.

This phenomenon aligns with studies on Solid Polymer Electrolytes (SPEs). Research shows that the ionic conductivity of SPEs increases with the concentration of inorganic salt (in this case, the natural ions from the pineapple extract). However, a critical concentration exists beyond which conductivity decreases due to the formation of ion pairs. When the ion concentration is too low, the large distance between ions hinders movement, resulting in low conductivity. As concentration increases, ions become closer, facilitating movement and increasing conductivity. If the concentration becomes excessive (beyond 18 g in this study), ion-ion repulsion forces and ion pairing occur, hindering mobility and decreasing overall conductivity.

3.2. Effect of NaCl Addition

e-ISSN : 2622-4968, p-ISSN : 2622-1349

In the second stage, the optimal mass of pineapple peel extract (18 g) was combined with varying masses of NaCl. The performance results are shown in Table 2 and Figure 2.

Table 2. Relationship between NaCl mass, current, voltage, and resistance

Mass of NaCl (g)	Current (mA)	Voltage (V)	Solid Electrolyte Resistance (kΩ)
2.0	1.68	0.405	4.70
2.5	2.75	0.450	4.60
3.0	3.62	0.678	4.50
3.5	3.91	0.775	4.20
4.0	3.73	0.640	5.80

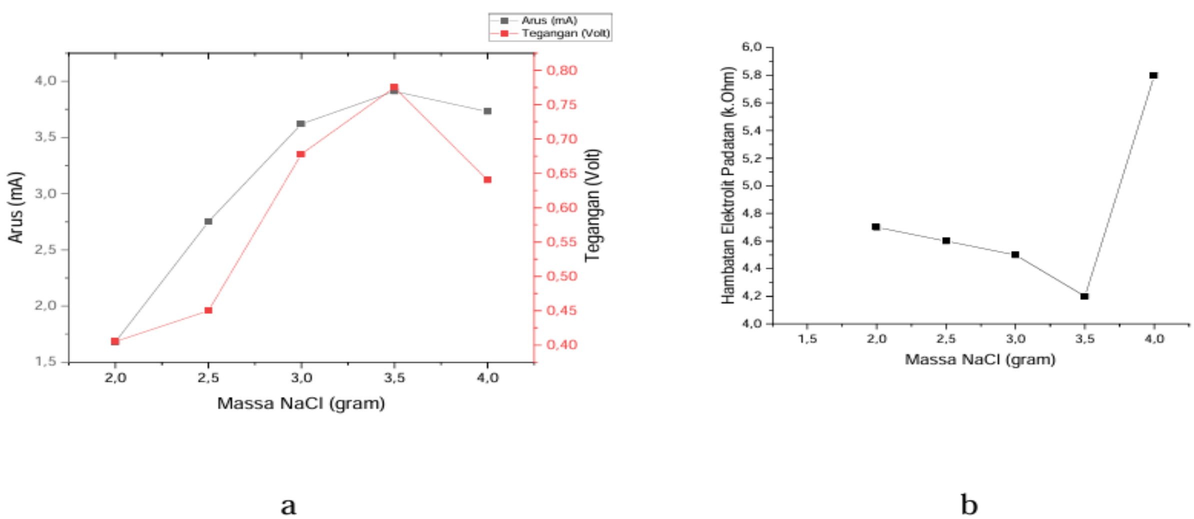

Figure 2. (a) Graph of the relationship between NaCl mass, current, and voltage. (b) Graph of the relationship between NaCl mass and solid electrolyte resistance.

The addition of NaCl significantly improved the bio-battery's performance. As shown in Figure 2, the current and voltage increased with the addition of NaCl. The current rose from 1.68 mA (at 2 g NaCl) to a maximum of **3.91 mA** (at 3.5 g NaCl). Likewise, the voltage increased from 0.405 V to a peak of **0.775 V** (at 3.5 g NaCl). When the NaCl mass exceeded 3.5 g, both current and voltage dropped.

e-ISSN : 2622-4968, p-ISSN : 2622-1349

This trend mirrors the results from the first stage, where performance is governed by electrolyte resistance. The resistance decreased as NaCl mass increased, reaching its minimum value of **4.20 kΩ** at the 3.5 g NaCl addition. Beyond this point, resistance sharply increased. The addition of NaCl (a strong electrolyte) provides a high concentration of mobile ions (Na^+ and Cl^-), which greatly enhances the conductivity of the electrolyte paste.

The drop in performance after 3.5 g NaCl reinforces the concept of an optimal ion concentration. Similar studies, such as those using PVA:LiOH polymer electrolytes, also observed that conductivity reaches a maximum at a specific concentration (e.g., 9 wt%) and then decreases. This decrease is attributed to ion pair formation at high concentrations, which reduces the number of free charge carriers. In this study, the optimal balance of ions from both the pineapple extract and the added NaCl was achieved at 18 g of extract and 3.5 g of NaCl, resulting in the lowest resistance (4.20 kΩ) and the highest electrical output.

4. CONCLUSION

Based on the research, the bio-battery using pineapple peel extract, NaCl, and tapioca starch matrix showed that mass variations significantly affect current, voltage, and resistance. Performance increased up to an optimum of 18 g of pineapple extract (0.83 mA; 0.532 V) and 3.5 g of NaCl (3.91 mA; 0.775 V). Conductivity increased due to enhanced ion mobility, but decreased after the optimum point due to ion pairing and repulsion. Thus, the combination of 18 g pineapple extract and 3.5 g NaCl yielded the best performance, proving the potential of these natural materials as an effective, eco-friendly electrolyte for renewable energy.

ACKNOWLEDGEMENT

The authors would like to express their deepest gratitude to the supervising lecturer, Putri Faradilla, M.Si., for the invaluable guidance and direction. Appreciation is also extended to the laboratory staff of the Chemistry Department, State University of Medan, for facilitating this research. This research was fully funded by the State University of Medan through the PNBP (Student Grant) Fund for the 2025 Fiscal Year (Rector's Decree No. 0194/UN33/KPT/2025).

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e-ISSN : 2622-4968, p-ISSN : 2622-1349