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Development of a Bio-Battery Based on Key Lime Juice and $MgSO_4$ Electrolyte in a Solid Tapioca Flour Matrix

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Abstract

Research on bio-batteries as environmentally friendly alternative energy sources continues to progress. This study aims to determine the optimal composition of key lime juice and $MgSO_4$ that yields the maximum current and voltage. Graphite sheets were used as the anode and aluminum sheets as the cathode. The volume of key lime juice was varied at 12 mL, 14 mL, 16 mL, 18 mL, and 20 mL, followed by the gradual addition of 27 g of tapioca flour and stirring until a solid electrolyte was formed. The solid electrolyte was then placed between the graphite and aluminum sheets. The optimum volume of key lime juice was subsequently combined with varying masses of $MgSO_4$ (0.1 g, 0.2 g, 0.3 g, 0.4 g, and 0.5 g) to achieve higher current and voltage outputs. Measurement results indicated that for the bio-battery using only key lime juice as the ion source, the maximum current and voltage obtained were 1.32 mA and 0.648 V, respectively, with an optimal volume of 16 mL. The battery incorporating both $MgSO_4$ and key lime juice as ion sources achieved a current of 3.72 mA and a voltage of 0.720 V, with an optimal $MgSO_4$ mass of 0.2 g. This study shows great promise for further development due to its simple methodology and the use of inexpensive, eco-friendly materials.

Keywords: Bio-battery, key lime juice, $MgSO_4$, tapioca flour, graphite, aluminum.

INTRODUCTION

Energy plays a vital role in sustaining human life. Globally, energy consumption is still dominated by fossil (non-renewable) sources such as petroleum, natural gas, and coal. The increasing demand for energy is not aligned with the long-term availability of non-renewable energy sources (Ansanay et al., 2014), particularly electrical energy. Electricity, which can be easily distributed and converted into various other forms of energy, has become a basic necessity for society (Nugraha, 2020; Nugraha et al., 2020; Nugraha & Arimbawa, 2019). This indicates that electricity is not merely a basic need, but also a critical factor supporting human life (Masthura & Abdullah, 2021). The high rate of electricity consumption has contributed to the depletion of fossil energy resources.

As a solution to the challenges of fossil energy depletion and the increasing demand for energy, there has been a shift toward sustainable alternatives such as the development of renewable energy technologies and improvements in energy efficiency. One rapidly advancing aspect in the field of energy storage is battery technology. Batteries have become a key component in supporting the implementation of renewable energy and enhancing energy efficiency, particularly in providing stable and accessible electrical energy under various conditions.

Batteries generate electrical energy by converting chemical energy into electrical energy at the electrodes through electrochemical redox reactions. A typical battery consists of zinc as the anode, carbon as the cathode, and a paste composed of carbon powder, NH_4Cl, and MnO_2 as the electrolyte (Fadilah et al., 2015). Batteries are widely used in household devices such as wall clocks, TV remotes, radios, flashlights, and children's electronic toys. However, most of these batteries are single-use, leading to serious environmental concerns due to battery waste. Battery waste contains various heavy metals such as mercury, manganese, lead, nickel, lithium, and cadmium, which are classified as hazardous and toxic waste (B3). These substances pose risks of contaminating soil and water, and can be harmful to human health.

Improper disposal of battery waste can lead to environmental pollution and cause negative health effects, including damage to the central nervous system, kidneys, reproductive system, and even contribute to cancer cases (Purwati et al., 2017). In addition to being hazardous and environmentally unfriendly, conventional batteries are also costly in terms of both equipment and the technology required for their production. Therefore, the use of nature-based energy sources for batteries is urgently needed as a solution to mitigate these negative impacts. Innovations aimed at reducing the use of harmful chemicals in batteries by replacing them with environmentally friendly materials are increasingly being explored. One promising solution is the development of bio-batteries, an energy source that utilizes organic materials and holds potential as an environmentally sustainable alternative.

Bio-batteries can reduce the harmful environmental impacts commonly associated with the chemical processes in conventional batteries (Siddiqui & Pathrikar, 2013; Wang et al., 2012). They offer several significant advantages. First, because they are derived from environmentally friendly organic materials, bio-batteries eliminate the need for hazardous chemical substances and present economic benefits (Masthura & Abdullah, 2021). Like conventional batteries, bio-batteries consist of three main components: an anode (-), a cathode (+), and an electrolyte. The primary difference lies in the electrolyte, which in bio-batteries is based on organic rather than chemical compounds. The energy in bio-batteries is generated from sources such as carbohydrates, glucose, amino acids, and enzymes (Siddiqui & Pathrikar, 2013). Organic compounds with high potential as electrolytes can be found in microbes, fruits, and vegetables (Khan & Obaid, 2015; Anjarsari et al., 2024**;** Yanti et al., 2024**;** Hasrolita et al., 2024). Fruits such as lemons, corn cobs, and grapes are considered to have high potential as electrolyte sources in bio-batteries (Randhawa et al., 2014)

Previous studies have successfully developed environmentally friendly bio-batteries using natural materials such as fruits and vegetables. However, the implementation of this technology remains limited to electrical testing and has not yet reached the stage where these materials can fully function as complete batteries. Even in cases where functional batteries have been produced, the application has generally been restricted to replacing the electrolyte content, without advancing toward the development of entirely new battery frameworks. Atina (2015) utilized the acidic properties of tomatoes, pineapples, bilimbi, apples, and key limes as electrolytes for bio-batteries. The results showed that key lime produced a voltage of 1.005 V, bilimbi 0.976 V, apple 0.974 V, pineapple 0.920 V, and tomato 0.876 V. Research by Komariyah & Rohmawati (2021) demonstrated that spoiled tomato waste and coconut pulp can serve as eco-friendly natural materials, generating a potential difference of 1.46 V and a current of 2.1 mA. Fitrya et al. (2023) also conducted experiments using pineapple peel waste with the addition of potassium chloride (KCl). The highest voltage obtained was

3.9 V and the highest current was 0.8 mA, achieved by adding 1.5 g of KCl, with a light-emitting diode (LED) staying illuminated for 16 hours. Collectively, these studies have made important contributions to the development of bio-batteries as a sustainable solution for electrical energy.

Building upon previous bio-battery research—which has generally focused only on testing current and voltage—this study involves the fabrication of a battery with a new structural design using aluminum as the anode and graphite as the cathode. A paste mixture of tapioca flour, key lime juice, and $MgSO_4$ is employed as the electrolyte in the bio-battery. The selection of aluminum as the anode and graphite as the cathode is based on their chemical and physical properties, which are well-suited to ensure optimal battery performance. Aluminum is known for its high electrical conductivity, low cost, and low molecular weight, making it an attractive choice for anode material. Meanwhile, graphite possesses a crystalline structure that enables efficient storage and release of electrons, making it ideal for use as a cathode. Additionally, the mixture of tapioca flour, key lime juice, and $MgSO_4$ is chosen as the electrolyte due to its ability to conduct ions, which is essential for the electrochemical reactions within the battery. This combination not only has the potential to yield a battery with performance comparable to conventional types, but also offers significant ecological advantages through the use of natural, environmentally friendly materials and the potential substitution of fossil-based raw materials with renewable natural resources, aligning with the goals of sustainable development.

MATERIALS AND METHOD

The materials used in this study were key limes (Citrus aurantiifolia), magnesium sulfate ($MgSO_4$), and tapioca flour. The key limes were sliced and squeezed, and the juice was filtered to remove the seeds. The extracted juice was then collected in a beaker. The volume of key lime juice used was varied at 12 mL, 14 mL, 16 mL, 18 mL, and 20 mL. Next, 27 grams of tapioca flour were mixed into each juice variation to form a solid paste, resulting in a solid electrolyte.

This solid electrolyte was placed between graphite and aluminum sheets, which served as the electrodes. The setup was connected using alligator clip wires to a digital multimeter (Sanwa CD800a) to measure the current and voltage output, aiming to determine the optimal composition of the key lime juice-based solid electrolyte.

After identifying the optimal composition, $MgSO_4$ was added to the key lime juice in varying masses of 0.1 g, 0.2 g, 0.3 g, 0.4 g, and 0.5 g. Each mixture was then combined with 27 g of tapioca flour to form a new solid electrolyte. Current and voltage measurements were taken again to identify the optimal composition of the solid electrolyte containing both key lime juice and $MgSO_4$.

To analyze the changes in current and voltage, the resistance of the solid electrolyte was also measured using an ohmmeter (Sanwa CD800a), providing information about its conductivity.

RESULTS AND DISCUSSION

In the initial stage of this bio-battery study, measurements were limited to the current and voltage outputs. These measurements aimed to determine whether the new structural design of the bio-battery was capable of generating electrical current and voltage—both of which are key characteristics of a functional battery. The influence of key lime juice deposited into a solid tapioca flour matrix on the performance of the bio-battery, based on current and voltage parameters, is presented in Figure 1 and Table 1 below:

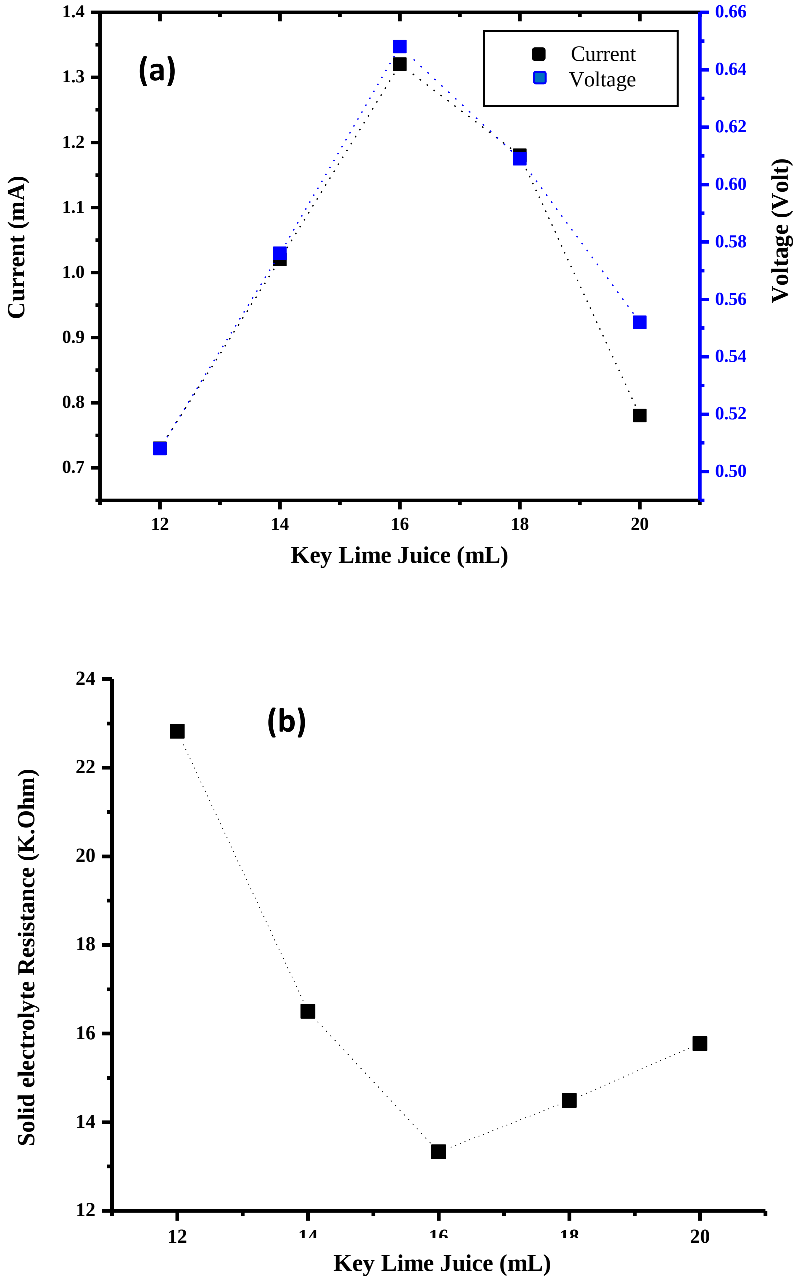

Figure 1. (a) Voltage and current, and (b) Solid electrolyte resistance for various volumes of key lime juice.

Table 1. Relationship between key lime juice volume, current, voltage, and the resistance of solid and liquid electrolytes in the battery.

Volume of Key Lime Juice (ml)	Current (mA)	Voltage (Volt)	Solid Electrolyte Resistance (K.Ohm)	Liquid Electrolyte Resistance (K.Ohm)
12	0,73	0,508	22,82	8,68
14	1,02	0,576	16,50	7,87
16	**1,32**	**0,648**	**13,33**	**7,59**
18	1,18	0,609	14,49	9,70
20	0,78	0,552	15,77	10,89

The battery current increased with the addition of key lime juice volume deposited among the tapioca flour particles, rising from 0.73 mA at 12 mL to a peak of 1.32 mA at 16 mL. Beyond this point, the current began to decline as the volume exceeded 16 mL. This trend was mirrored in the voltage behavior, which increased from 0.508 V at 12 mL to a maximum of 0.648 V at 16 mL, followed by a decrease at higher volumes.

The changes in current and voltage were analyzed by measuring the resistance of both the solid and liquid electrolytes in the battery using an ohmmeter, as a substitute for Electrochemical Impedance Spectroscopy (EIS), to assess their conductivity (Rahman et al., 2021). The measurement results indicate that variations in current and voltage are influenced by changes in the resistance of the solid and liquid electrolytes. The electrolyte resistance decreased with increasing volume of key lime juice, indicating an enhancement in electrolyte conductivity. For the solid electrolyte, the resistance initially measured 22.82 kΩ at 12 mL of key lime juice and continued to decrease, reaching a minimum of 13.33 kΩ at 16 mL. Beyond this volume, resistance increased again, signifying a decline in the conductivity of the solid electrolyte. A similar trend was observed in the liquid electrolyte, where resistance decreased from 8.68 kΩ at 12 mL to 7.59 kΩ at 16 mL, then rose again as the volume exceeded 16 mL, indicating a reduction in electrolyte conductivity

A similar study was conducted by Liubysh et al., who investigated the conductivity of Deoxyribonucleic Acid (DNA) solutions with KCl salt. Their findings showed that conductivity increased with rising ion concentration up to a critical point of approximately 0.4 M, after which the conductivity began to decline. Below this critical concentration, the conductivity of the DNA solution was higher than that of pure KCl solution. At a concentration of 0.2 M, for instance, the conductivity of the DNA solution could surpass that of the pure KCl solution. However, at concentrations above the critical point, such as 1.0 M or higher, the conductivity of the DNA solution decreased and even became lower than that of the pure KCl solution, indicating an ion-neutralization effect by the DNA (Liubysh et al., 2014).

An increase and subsequent decrease in conductivity based on the concentration of lithium trifluoromethanesulfonate ($LiCF_3SO_3$) salt in a liquid electrolyte solution was also reported by Dissanayake (2006). The conductivity was influenced by the concentration of salt dissolved in the solvent. The data presented showed that conductivity increased with rising salt concentration, reaching a maximum at 0.85 mol kg^{-1}. This increase in conductivity was attributed to the greater availability of charge carriers as the salt concentration increased. Beyond this critical point, however, rising viscosity and the formation of electrically neutral ion pairs began to dominate, resulting in a decrease in conductivity. Therefore, the balance between the concentration of charge carriers, viscosity, and ion pair formation plays a crucial role in determining the conductivity of the liquid electrolyte

Table 2. Electrical conductivity of liquid electrolyte at room temperature with various concentrations of $LiCF_3SO_3$ salt (Source: Dissanayake & Perera,, 2006).

Salt Concentration (mol kg^{-1})	**Conductivity (S cm^{-1})**
0.74	2.13×10^{-3}
0.80	2.37×10^{-3}
0.85	**2.80×10^{-3}**
0.87	2.21×10^{-3}
0.97	2.12×10^{-3}
1.03	2.00×10^{-3}
1.15	1.85×10^{-3}
1.20	1.64×10^{-3}
1.25	1.60×10^{-3}

A study by Abdelcareem and Jawad investigated the effect of salt type and concentration specifically potassium iodide (KI) and rubidium iodide (RbI) on the conductivity of a polymer electrolyte based on polyethylene oxide (PEO). The results indicated that at low to moderate ion concentrations, the conductivity of the electrolyte tends to increase. This behavior is attributed to the rise in the number of free ions that can move through the polymer matrix, thereby facilitating the flow of electric current. The electrolyte doped with 50% KI exhibited the highest conductivity, reaching 7.22×10^{-3} S/cm, while the conductivity for 50% RbI ranged from 6.4×10^{-3} to 1.39×10^{-2} S/cm. However, at very high salt concentrations, conductivity began to decline due to enhanced ion–ion interactions, leading to the formation of ion pairs and aggregates, which reduce the number of free charge carriers available for conduction (Abdelcareem & Jawad, 2019).

The fluctuation in the conductivity of both solid and liquid electrolytes containing ions is closely related to the interionic distances. At a citrus extract volume of 16 mL, the relatively large distance between ions slows down their movement in the electrolyte. As the number of ions increases, the distance between them decreases, facilitating easier ion migration. However, an excessive number of ions in the electrolyte can hinder ion movement due to strong electrostatic repulsion between closely packed ions (Aji et al., 2012).

To enhance the performance of the bio-battery, $MgSO_4$ was introduced as a secondary electrolyte. Upon addition to the system, $MgSO_4$ dissociates into magnesium ions (Mg^{2+}) and sulfate ions (SO_4^{2-}), potentially interacting with the citric acid present in the citrus extract. These interactions can alter the overall ionic concentration of the solution, thereby influencing its conductivity and effectiveness as an electrolyte.

Manjunatha et al. also investigated the incorporation of RbBr salt into a Polyethylene Oxide (PEO)-based solid polymer electrolyte (SPE) system, which demonstrated a significant effect on ionic conductivity. The ionic conductivity was measured as a function of salt concentration in the PEOxRbBr system. At an O/Rb ratio of 60, the highest ionic conductivity was achieved, reaching 4.02 × 10^{-6} S/cm. For O/Rb ratios lower than 60, ionic conductivity increased continuously with the rising salt concentration, attributed to the increased number of charge carriers (ions). However, for O/Rb ratios greater than 60, ionic conductivity began to decrease due to the formation of ion pairs, which reduced ion mobility within the polymer matrix. Therefore, the variation in salt composition within the SPE system significantly influences ionic conductivity, with an optimum composition yielding the best conductivity performance (Manjunatha et al., 2014).

A study by Manjunatha et al. also examined the incorporation of two types of ions by evaluating the effect of sodium (Na) ion addition to a $PEO_{30}LiBr$ system, which initially exhibited a maximum ionic conductivity of 3.33 × 10^{-6} S/cm at an O/Li ratio of 30. This system was selected due to its optimal conductivity enhancement before the onset of ion pair formation, which typically reduces the mobility of charge carriers. The introduction of Na ions significantly increased the conductivity by nearly one order of magnitude, reaching a maximum of 9.76 × 10^{-6} S/cm at the optimal Na concentration. However, further increases in Na concentration led to a decline in conductivity, likely due to the formation of charge complexes that hinder ion mobility (Manjunatha et al., 2019).

Chandra et al. conducted a study on the effect of salt incorporation into a polymer host, which led to a significant enhancement in ionic conductivity. The addition of salt resulted in a drastic increase in conductivity, indicating substantial complexation between the polymer matrix and the salt. The study revealed a maximum conductivity at a specific salt concentration (x = 30 wt.%), suggesting an optimal composition at which ionic transport is most efficient. Beyond this optimal point, further addition of salt caused a decline in conductivity, indicating potential limitations or inhibitory phenomena associated with excessive salt content (Chandra et al., 2020).

The addition of $MgSO_4$ to the solid electrolyte based on key lime juice at its optimum composition influences the performance of the bio-battery, particularly in terms of current and voltage, as observed in Figure 2 and Table 3. The battery current increases with the increasing mass of $MgSO_4$ added to the key lime juice-based solid electrolyte. Initially, the battery current was 3.14 mA when 0.1 g of $MgSO_4$ was added, and it increased to 3.72 mA at 0.2 g of $MgSO_4$. However, the current decreased again when the mass of $MgSO_4$ exceeded 0.2 g. A similar pattern was observed in the battery voltage parameter. Initially, the voltage was 0.690 V at 0.1 g of $MgSO_4$ and increased to a maximum of 0.720 V at 0.2 g. The voltage then decreased when the mass of $MgSO_4$ exceeded 0.2 g.

To understand the cause of current and voltage variations in the battery, measurements were conducted on both solid and liquid electrolytic resistance. The results indicate that the changes in current and voltage are attributed to variations in electrolyte resistance. As the resistance of the solid electrolyte decreases or increases, the battery's current and voltage also change accordingly. A decrease in the resistance of the solid electrolyte was observed with the increasing mass of $MgSO_4$, indicating an increase in the conductivity of the solid electrolyte. Initially, the resistance of the solid electrolyte was 6.11 kΩ at 0.1 g of $MgSO_4$, which decreased to a minimum of 4.16 kΩ at 0.2 g of $MgSO_4$. The resistance increased again when the $MgSO_4$ mass exceeded 0.2 g, indicating a decrease in conductivity. For the liquid electrolyte, the resistance was 8.68 kΩ at 0.1 g of $MgSO_4$ and decreased to a minimum of 7.59 kΩ at 0.2 g. The resistance of the liquid electrolyte

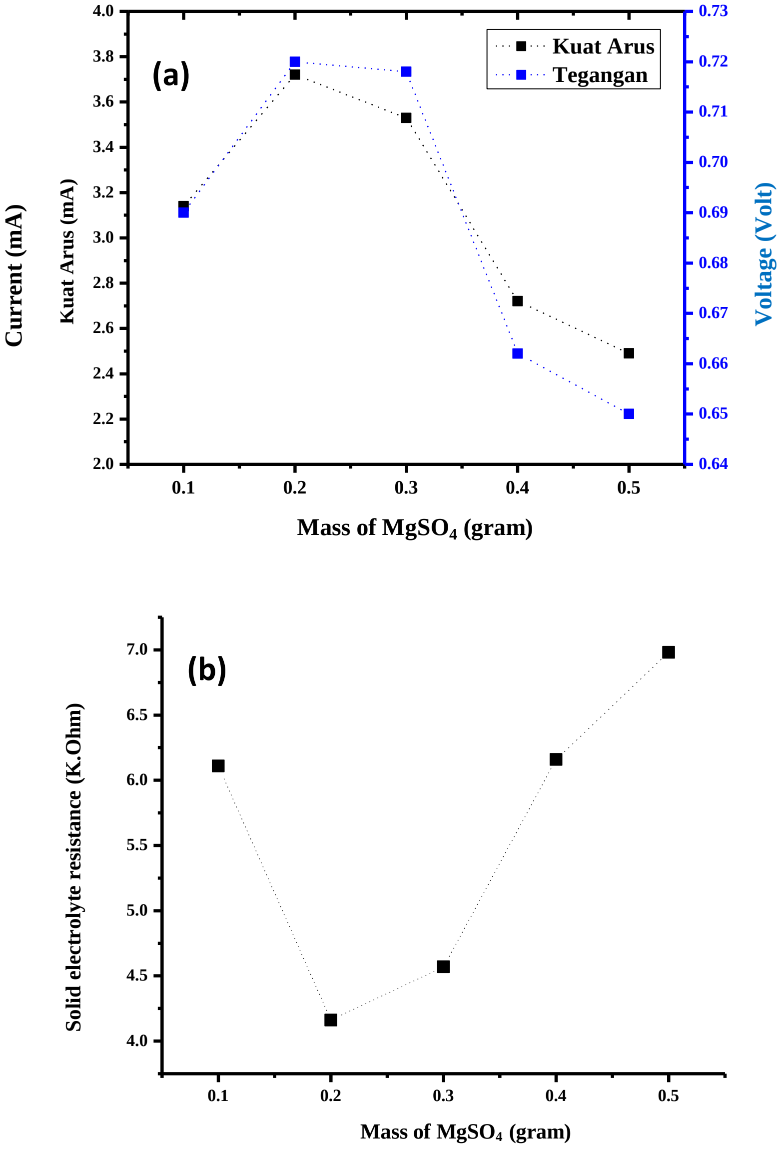

Figure 2. (a) Voltage and current, (b) Solid electrolyte resistance for various masses of $MgSO_4$ in the optimum volume of key lime juice..

Table 2. Relationship between the mass of $MgSO_4$ in the optimum volume of key lime juice, current, voltage, solid electrolyte resistance, and liquid electrolyte resistance.

Mass of $MgSO_4$ (g)	**Current (mA)**	**Voltage (Volt)**	**Solid electrolyte resistance (K.Ω)**	**Liquid electrolyte resistance (K.Ω)**
0,1	3,14	0,690	6,11	6,66
0,2	**3,72**	**0,720**	**4,16**	**6,25**
0,3	3,53	0,718	4,57	6,78
0,4	2,72	0,662	6,16	7,38
0,5	2,49	0,650	6,98	7,40

increased when the $MgSO_4$ mass exceeded 0.2 g, indicating a reduction in its conductivity

CONCLUSION

A bio-battery with a novel structure utilizing graphite as the cathode, aluminum as the anode, and a solid electrolyte matrix based on tapioca flour combined with key lime juice as the ion source has been successfully fabricated. Experimental results indicate that the battery using key lime juice as the ion source reaches its optimal concentration at 16 ml, producing a voltage of 0.648 V and a current of 1.32 mA. In contrast, the battery with the addition of magnesium sulfate ($MgSO_4$) achieves optimal performance at a concentration of 0.2 grams of $MgSO_4$, generating a voltage of 0.720 V and a current of 3.72 mA. This study holds strong potential for further development due to its use of cost-effective, environmentally friendly materials and a simple fabrication method.

REFERENCES

Abdelcareem, S. M., & Jawad, M. K. (2019). Effect of potassium iodide (KI) and rubidium iodide (RbI) type and concentration on the conductivity of polyethylene oxide (PEO) polymer electrolyte. Iraqi Journal of Physics, 17(42), 42–50.

Aji, M. P., Masturi, Bijaksana, S., Khairurrijal & Abdullah, M. (2012). A general formula for ion concentration‐dependent electrical conductivities in polymer electrolytes. American Journal of Applied Sciences, 9(9), 946–954

Anjarsari, S., Rahman, D. Y., & Sulistyowati, R. (2024). Pembuatan Bio-Baterai Berbahan Dasar Sari Belimbing Wuluh dan NaCl sebagai Sumber Ion serta Onggok Singkong sebagai Matriks. Jurnal Penelitian Fisika dan Terapannya (JUPITER), 6(1), 1-10.

Ansanay, Y., Kolar, P., Sharma-Shivappa, R. R., & Cheng, J. J. (2014). Niobium oxide catalyst for delignification of switchgrass for fermentable sugar production. Industrial Crops and Products, 52, 790–795.

Atina, A. (2015). Tegangan dan kuat arus listrik dari sifat asam buah. Sainmatika: Jurnal Ilmiah Matematika Dan Ilmu Pengetahuan Alam, 12(2).

Azhar, M., & Satriawan, D. A. (2018). Implementasi kebijakan energi baru dan energi terbarukan dalam rangka ketahanan energi nasional. Administrative Law and Governance Journal, 1(4), 398–412.

Chandra, A., Basak, S., Khan, M. Z., Dhundhel, R. S., & Bhatt, A. (2020). Synthesis and ionic conductivity measurement of a new potassium ion conducting solid polymer electrolytes. IOP Conference Series: Materials Science and Engineering, 798(1), 012007.

Dissanayake, M. A. K. L., and Kumudu Perera. 2006. "Conductivity Variation of the Liquid Electrolyte, EC:PC:$LiCF_3SO_3$ with Salt Concentration." Sri Lankan Journal of Physics 7: 1–5.

Fadilah, S., Rahmawati, R., & Pkim, M. (2015). Pembuatan Biomaterial dari Limbah Kulit Pisang (Musa Paradisiaca). Prosiding Simposium Nasional Inovasi Dan Pembelajaran Sains, 4(2), 25–29.

Fitrya, N., Halwani, P., & Wirman, S. P. (2023). Uji Karakteristik Elektrolit Ampas Kulit Nanas dengan Penambahan MgCl2, NaCl, dan

KCL. Photon Jurnal Sain Dan Kesehatan, 13(2), 35–40.

Hasrolita, W., Sulistyowati, R., & Rahman, D. Y. (2025). Pengembangan Bio-Baterai Berbasis Sari Tomat Rampai dan NaCl dengan Tepung Tapioka sebagai Matriks Elektrolit Padatan. Jurnal Penelitian Fisika dan Terapannya (JUPITER), 6(2), 1-8.

Khan, A. M., & Obaid, M. (2015). Comparative bioelectricity generation from waste citrus fruit using a galvanic cell, fuel cell and microbial fuel cell. Journal of Energy in Southern Africa, 26(3), 90–99.

Komariyah, A. Y., & Rohmawati, L. (2021). Pemanfaatan Limbah Tomat Busuk dan Ampas Kelapa sebagai Baterai Alami yang Ramah Lingkungan. Prosiding Seminar Nasional Fisika (SNF), 5, 161–166.

Liubysh, O. O., Alekseev, O. M., Tkachov, S. Y., & Perepelytsya, S. M. (2014). Effect of ionic ordering in conductivity experiments of DNA aqueous solutions. ArXiv Preprint ArXiv,32(2), 80-88.

Manjunatha, H., Damle, R., & Kumaraswamy, G. N. (2019). Effect of Mixed Ions and Ion Irradiation on Ionic Conductivity of Solid Polymer Electrolytes. IOP Conference Series: Materials Science and Engineering, 577(1), 012195.

Manjunatha, H., Kumaraswamy, G. N., & Damle, R. (2014). Effect of low energy oxygen ion beam irradiation on ionic conductivity of solid polymer electrolyte. AIP Conference Proceedings, 1591(1), 1372–1374.

Masthura, M., & Abdullah, A. (2021). Pemanfaatan Sari Nenas Sebagai Sumber Energi Alternatif Pembuatan Bio-Baterai. Circuit: Jurnal Ilmiah Pendidikan Teknik Elektro, 5(1), 51–58.

Mungkin, M., & Ikhsan, T. (2016). Filtrasi Jeruk Nipis Yang Ditambahkan Nacl + Na-Edta Sebagai Elektrolit Baterai Dengan Charger Solar Cell (Vol. 16, Issue 1).11-13.

Nugraha, I. M. A. (2020). Penggunaan Pembangkit Listrik Tenaga Surya Sebagai Sumber Energi Pada Kapal Nelayan: Suatu Kajian Literatur. Jurnal Sumberdaya Akuatik Indopasifik, 4(2), 101–110.

Nugraha, I. M. A., & Arimbawa, P. A. R. (2019). Solar Home System Dapat Meningkatkan Kesehatan Masyarakat Desa Ban di Bali. Bali Health Journal, 3(1), 21–26.

Nugraha, I. M. A., Desnanjaya, I., Serihollo, L. G. G., & Siregar, J. S. M. (2020). Perancangan Sistem Hibrid PLTS dan Generator Sebagai Catu Daya Tambahan Pada Tambak Udang Vaname: Studi Kasus Politeknik Kelautan dan Perikanan Kupang. Majalah Ilmiah Teknologi Elektro, 19(1).

Purwati, W. W., & Mulud, T. H. (2017). Analisis pemanfaatan limbah kulit pisang sebagai energi alternatif pada baterai. Eksergi: Jurnal Teknik Energi, 13(2), 61–67.

Randhawa, M. A., Rashid, A., Saeed, M., Javed, M. S., Khan, A. A., & Sajid, M. W. (2014). Characterization of organic acids in juices of some Pakistani citrus species and their retention during refrigerated storage.7(2), 22-25.

Siddiqui, U. Z., & Pathrikar, A. K. (2013). The Future of Energy Bio Battery. In IJRET: International Journal of Research in Engineering and Technology. 3(5), 18-20.

Yanti, W., & Rahman, D. Y. (2024). Pemanfaatan Sari Buah Mengkudu dan Garam Dapur (NaCl) sebagai Sumber Ion serta Tepung Tapioka sebagai Matriks untuk Pembuatan Bio-Baterai. Jurnal Penelitian Fisika dan Terapannya (JUPITER), 6(1), 11-18.