Volume 9 Number 3, December 2024, pp. 332~342
P-ISSN:2477-7935
E-ISSN: 2548-6225
DOI: [10.59052/edufisika.v9i3.40532](https://doi.org/10.59052/edufisika.v9i3.40532)

EFFECT OF FERMENTATION DURATION ON THE ELECTRICAL PROPERTIES OF *KETAPANG* AND TAMARIND EXTRACTS

Ririn Mauliza[1], and Juniar Afrida[1]
[1]Department of Physics Education, Faculty of Tarbiyah and Teacher Training, Ar-Raniry State Islamic University, Banda Aceh, Indonesia.
Corresponding author email: 210204015@student.ar-raniry.ac.id

Article Info
Recieved: 02 Sep 2024
Accepted: 06 Nov 2024
Publication: 31 Dec 2024

Abstract :
Ketapang fruit (*Terminalia catappa L.*) and tamarind fruit (*Tamarindus indica L.*) contain electrolytes that have the potential to serve as alternative energy sources for bio-batteries. This study aims to examine the effect of fermentation duration of extracts from both fruits on pH, electrical voltage, electrical current, and electrical power. This is an experimental study. The fruit samples were fermented for 10 days with varying concentrations of 50, 100, 150, 200, and 250 ppm for each solution. Measurements were carried out using a digital pH meter and a multimeter to determine the electrochemical characteristics. The results showed that the pH of the solution tended to increase during fermentation, with the lowest pH recorded on day 0 in the tamarind solution (250 ppm, pH 6.4) and the highest on day 10 in the *ketapang* solution (50 ppm, pH 8.1). The electrical voltage of the *ketapang* solution at all concentrations showed a fluctuating trend. The electrical current consistently showed negative results (-0.010 to -0.020 mA), indicating that the direction of charge flow was opposite to conventional outputs. The electrical power was directly proportional to the voltage and current but showed instability in the *ketapang* solution. The alkalization process during fermentation contributed to changes in the electrochemical properties of the solution. The increase in pH influenced ion conductivity and electrochemical mechanisms, such as the movement of hydroxide ions (OH^-). This study indicates that *ketapang* and tamarind fruits can be utilized as alternative energy sources for bio-battery.

Keywords: Bio-battery, Fermentation, Fruits

INTRODUCTION

Fruits and vegetables possess electrical properties, making them potential sources of alternative energy in the form of bio-batteries. Among these are the *Ketapang* fruit (*Terminalia catappa L.*) and Tamarind fruit (*Tamarindus indica L.*). The utilization of renewable energy from these fruits is supported by their high citric acid content, which has the potential to serve as a source of electrical energy.(Tanjung, Masthura and Daulay, 2022)

Ketapang fruit (*Terminalia catappa L.*) and tamarind (*Tamarindus indica L.*) are processed into fermented extracts that can contain electrolytes for bio-batteries. The waste from *ketapang* fruit and leaves (*Terminalia catappa L.*) serves as a carbon source from organic waste, as it contains lignin, cellulose, and hemicellulose.(Fachrurozi *et al.*, 2019) The seed of *ketapang* contains carbohydrates, proteins, fats, fibers, iron, ascorbic acid, arachidic acid, β-carotene, linoleic acid, myristic acid, oleic acid, palmitic acid, palmitoleic acid, stearic acid, phosphorus, potassium, niacin, riboflavin, thiamine, and water. The fruit contains glucose, pentosans, corilagin, brevifolin, carboxylic acid, β-carotene, cyanidin-3-glucoside, ellagic acid, gallic acid, and tannins.(Nugroho and Nur, 2018) Additionally, it also contains fatty acids and abundant fiber. These compounds make *ketapang* (*Terminalia catappa L.*) a substitute for activated carbon, softening oils, methyl esters, and bio-battery electrolytes.

Tamarind (*Tamarindus indica L.*) is a type of plant commonly found in Indonesia, particularly on the island of Java, which is why it is named *Asam Jawa.*(Silalahi, 2020) The pulp of tamarind contains several types of acids, including tartaric acid, malic acid, citric acid, acetic acid, succinic acid, and apple acid, which enhance its electrical properties and have the potential to be developed into a bio-battery.(Gardjito, 2013) Thus, the acid content of *ketapang* (*Terminalia catappa L.*) and tamarind (*Tamarindus indica L.*) can be used as an alternative electrolyte to generate electrical energy.(Fitrya *et al.*, 2023)

The fermentation process is the conversion of carbohydrates (sucrose, fructose, and glucose) into CO_2 and ethanol. A solution with higher acidity from fermentation can become more electrolytic, generating a significant electrical voltage. Electrical conductivity increases as fermentation progresses. The longer the fermentation, the more H^+ ions are produced, and the fewer OH^- ions are generated.(Masthura, Putri and Daulay, 2021)

The acidity of a substance affects its electrical power. A battery can generate electricity because it contains two electrodes and an acidic electrolyte solution. The more acidic the electrolyte solution, the higher the concentration of hydrogen ions, which increases the current conductivity from the anode to the cathode. The acidity of a substance is related to fermentation. Fermentation is a process of energy production within cells in the absence of oxygen, and it is commonly carried out to produce acidity from a substance. The degree of acidity can be determined using a pH meter. In carbohydrates containing glucose, when mixed with water and left without air for some time, fermentation occurs, producing ethanol. The ethanol, when left to stand, will oxidize into acetic acid. Factors that influence the fermentation process include pH, temperature, microbial agents, oxygen, and nutrients. These factors affect microbial growth during the fermentation process.(Sigalingging, Panjaitan and Sigalingging, 2022; Yolanda, Masthura and Daulay, 2022)

An electrolyte solution can conduct electricity because it contains ions that move easily toward the electrode with the opposite charge of the ions.(Maharani, Muliyono and Putri, 2022) Bio-batteries function as an alternative to conventional batteries by utilizing the electrical properties of fruit and vegetable waste that contain abundant electrolytes.(Sintiya and Nurmasyitah, 2019) A bio-battery is a device that generates electrical energy by utilizing living organisms as its source. A bio-battery produces electrical energy through the transfer of electrons across a medium with the conductivity of two electrodes (anode and cathode), thereby generating electric current and voltage differences.(Abdullah and Masthura, 2021)

Two electrodes connected by an electrolyte and having a potential difference can generate electrical energy through an electrochemical reaction. The electrochemical process requires a conducting medium for electron transport in the reaction system, known as the solution. Solutions can be classified into three types: strong electrolytes, weak electrolytes, and non-electrolytes. A strong electrolyte solution is one that contains dissolved ions with a high ability to conduct electricity, allowing for a fast electron transfer process and relatively high energy output. In contrast, a weak electrolyte solution contains dissolved ions that are typically only partially ionized, resulting in a slower electron transfer process and a smaller amount of energy produced. However, electrochemical processes still occur. For non-electrolyte solutions, electron transfer does not occur because a substance cannot form ions and cannot move freely in the solvent.(Amirul and Pauzi, 2018; Bengi *et al.*, 2018; Pandia, Sumarni and Izzania, 2021)

Research on bio-batteries as an alternative energy source has been previously conducted by several researchers. Ety Jumiati et al. in 2023 conducted a study on mango fruit electrolyte solution as an alternative bio-battery energy source, using volumes of 200 ml, 300 ml, and 400 ml. The study focused on measuring the pH, voltage, current, and the ability of the mango juice solution to power a white LED light. The research used the galvanic cell method with Cu and Zn electrodes. The mango electrolyte solution testing resulted in a pH value of 2.3. The maximum voltage and current values were obtained at a volume of 400 ml, with values of 2.32 V and 4.24 mA. It can be concluded that the larger the volume, the higher the electrical output.(Jumiati, Sirait and Soraya, 2023)

Fahmi Salafa et al. in 2020 conducted research related to an innovative approach to reduce reliance on synthetic chemical materials for current batteries. The study found that orange peel has a pH of 3.8 and acidic properties, making it suitable for use as an electrolyte in batteries. The electrolyte produced by the orange peel generated a voltage of 0.81 volts and a current of 0.049 mA with a 4.7 KΩ resistor load. The battery, with dimensions of 4 cm in length, 2 cm in width, and 9 cm in height, produced a usable capacity of 4.752 mAH with a voltage of 0.8 volts.(Salafa, Hayat and Ma'ruf, 2020)

A study by Rafil Arizona in 2021 showed that bilimbi (*Averrhoa bilimbi*) can generate electricity, with its voltage and current increasing linearly with fermentation time. A voltage of 3 volts and a current of 6 mA were obtained at a solution volume of 750 mL with a fermentation duration of 2 days, while a voltage of 5 volts and a current of 7 mA were obtained at the same volume with a fermentation duration of 5 days.(Arizona *et al.*, 2021)

It is also known that the combination of several types of fruit, at the correct concentrations, can generate a better alternative electrical potential. A study by Aghisna Nuthfah Anshar in 2021 showed that a bio-battery with a 25% combination of orange peel and tamarind has the highest voltage and strongest current compared to solutions with higher concentrations. This occurs because the ion concentration at this level is not too concentrated, allowing ions to move more freely.(Anshar *et al.*, 2021a)

In this study, the researchers aimed to investigate the effect of fermentation duration of *ketapang* fruit (*Terminalia catappa L.*) extract and tamarind fruit (*Tamarindus indica L.*) extract on the electrical properties (pH, voltage, current, and electrical power)**.** Our preliminary studies have shown that an increase in pH was observed in the non-inoculated fermentation solution of fruit extract by yeast. The observed phenomenon of alkalization in the solution under these conditions could serve as a key finding and a novel outcome related to the weakening of the electrical properties of the solution. The weakening of the electrolyte solution under such conditions could support the findings of the previously mentioned studies bidirectionally, facilitating the identification and optimization of the solution and concentration to generate electrical energy.

RESEARCH METHOD

Research Design

This was an experimental study. This design was chosen because the researchers aimed to periodically observe the trends in pH, voltage, current, and electrical power generated by the *ketapang* fruit (*Terminalia catappa L.*) and tamarind fruit (*Tamarindus indica L.*) extract solutions over a 10-day fermentation period. This study adapted the methodology of previous research on similar topics, building upon their approaches to better suit the specific objectives of this investigation.(Salafa, Latiful and Ma'ruf, 2020; Anshar *et al.*, 2021b; Arizona *et al.*, 2021)

Equipment/Tool/Material

The tools and materials used in this experiment are: stone mortar, blender, digital pH-meter, copper plate, zinc plate, measuring cylinder, plastic container, battery box, *ketapang* fruit, tamarind fruit, connecting cables, alligator clips, multimeter, label paper, knife, strainer, and digital scale.

Experiment

The experimental procedure; 1) The extract solutions of *ketapang* and tamarind were prepared from fruits with homogeneous ripeness. The fruits were washed thoroughly and cut into pieces, then crushed using a stone mortar and blended for approximately 5 minutes. The fruit solution was then squeezed and filtered to obtain the liquid extract. The *ketapang* and tamarind extracts were then fermented for 10 days. Once the extracts were prepared, they were poured into the bio-battery cells, ensuring that the entire surface area of the bio-battery was covered. The solution was divided into five variations of concentrations: 50 ppm, 100 ppm, 150 ppm, 200 ppm, and 250 ppm. Each sample was then labeled. 2) Electrode selection: Cu (copper) as the cathode and Zn (zinc) as the anode, each cut to the same size of 10 cm × 3 cm. 3) The bio-battery cell was constructed using the galvanic cell (voltaic cell) method, in a 1000 mL plastic container. Copper and zinc electrodes, measuring 10 cm × 3 cm, were attached to opposite sides of the container, and were connected with cables, alligator clips, and a digital multimeter.(Deninta, 2020)

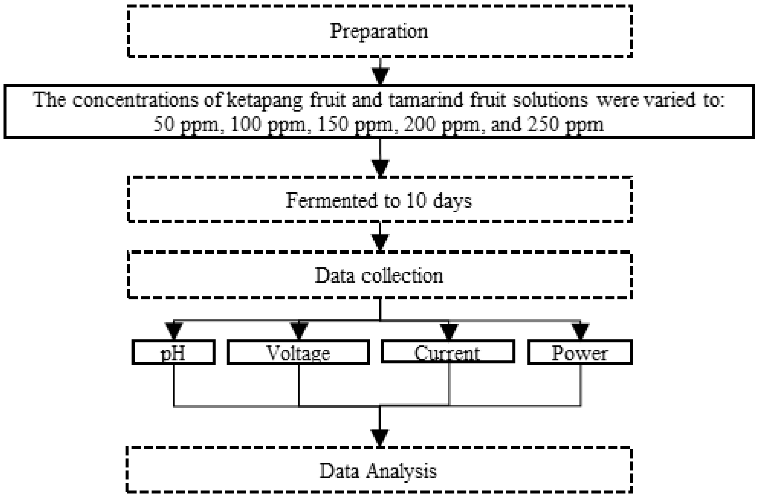


Figure 1. Flowchart of Testing and Preparation of Electrolyte Solution from Fermentation of *Ketapang* Fruit (*Terminalia catappa L.*) and Tamarind Fruit (*Tamarindus indica L.*) Extracts.

The performance of the biobattery tested includes the characteristics of pH, voltage, current, and electrical power. The pH value was measured using a digital pH-meter. Voltage and current were measured using a digital multimeter (Sanwa CD800a). The power value was calculated by multiplying the measured voltage by the current. pH and electrical measurements (voltage, current, and power) were taken at each fermentation time interval. This study generated data including pH values, electrical voltage, current, and power based on the solution concentration (ppm) over a fermentation period of 0-10 days. These data was then processed into graphs using OriginLab, followed by data analysis.

RESULTS AND DISCUSSION

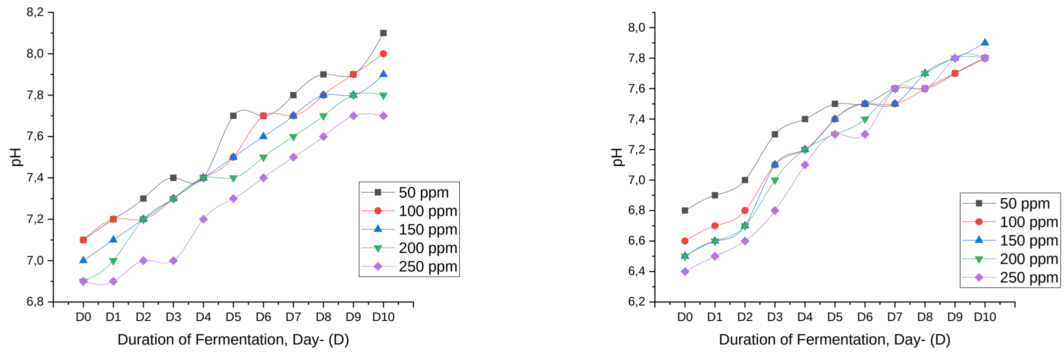
The voltage, current, and electrical power generated in this study can be explained using the principle of galvanic (voltaic) cells. When two different electrodes are immersed in an electrolyte solution, electrical energy is generated as a result of the spontaneous chemical reactions occurring. The chemical reactions involved are redox (reduction-oxidation) reactions. At the anode (Zn), oxidation occurs, while at the cathode (Cu), reduction takes place. Electrons move from the anode (oxidation process) to the cathode (reduction process). In the electrolyte solution, charge is transferred by cations toward the cathode and by anions toward the anode. This process continues to repeat, ultimately generating electrical energy.(Prakoso, Suwandi and Fitriyanti, 2020).

pH Testing of the Solution

The following is a figure showing the pH measurement using a pH-meter by the researcher. pH measurements were conducted for each concentration of *ketapang* and tamarind solution.

Figure 2. pH testing

The following is a figure showing the graph of the pH test results of the *ketapang* and tamarind solutions over a ten (10) day fermentation period.



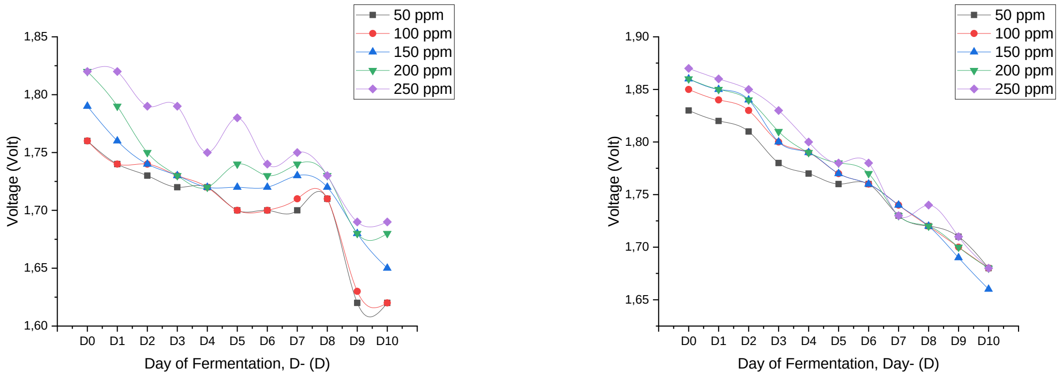
(A) (B)

Figure 3. pH Test Results of *Ketapang* Solution (A) and Tamarind Solution (B)

The results of this study revealed that the lowest pH on day 0 was found in the tamarind solution with a concentration of 250 ppm (pH 6.4), and the highest pH was found in the *ketapang* solution with a concentration of 50 ppm (pH 7.1). In general, the pH of each solution with different concentrations (*ketapang* and tamarind) showed an increasing trend over the 10-day fermentation period. On day 10, the highest pH was found in the 50 ppm *ketapang* solution, which was 8.1. These findings indicate that an alkali process occurred in each concentration of *ketapang* and tamarind solution. The researcher did not apply any mechanical, biological, or chemical intervention to these solutions. In this study, the researcher examined the natural properties of the solutions through fermentation, which was not assisted by yeast. These pH changes are important to note, as the acidity (pH) is a crucial parameter for determining the level of acid or base in the solution. Changes in the pH of water can lead to alterations in color, taste, and odor.(Purwanto, Iflah and Aunillah, 2020) The higher the pH value, the greater the alkalinity and the lower the concentration of free carbon dioxide.(Nurasia, 2019)

Electric Voltage Testing of the Solution

The following is a figure showing the graph of the voltage test results of the *ketapang* and tamarind solutions over a ten (10) day fermentation period.



(A) (B)

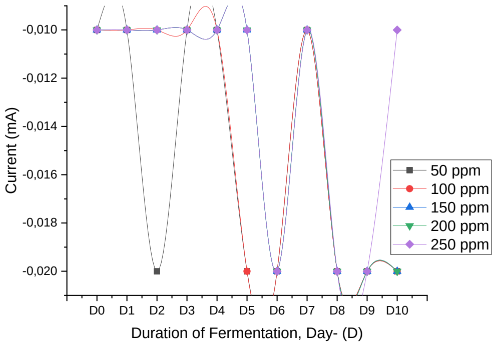
Figure 4. Voltage (Volt) Test Results of *Ketapang* Solution (A) and Tamarind Solution (B)

Based on the voltage test results, it was found that the voltage in the *ketapang* solution showed unstable (fluctuating) results, reaching the lowest value on day 10 of fermentation, which was 1.62 volts (obtained from *ketapang* solution concentrations of 50 and 100 ppm). Meanwhile, the tamarind solution showed the lowest value on day 10 of fermentation, which was 1.66 volts (for the 150 ppm tamarind solution). The final reduction in voltage levels for the *ketapang* 50 ppm, *ketapang* 100 ppm, and tamarind 150 ppm solutions over the 10-day fermentation period were 7.9%, 7.9%, and 10.75%, respectively. These findings indicate that the tamarind solution had a higher reduction in voltage compared to the *ketapang* solution, although it had a higher final voltage value. The alkalization of the solution (increasing pH) is one of the factors contributing to this occurrence.(Govindarajan, Xu and Chan, 2022; Liu *et al.*, 2024) An increase in pH can enhance the reactivity of ions in the solution, thereby accelerating the reduction process.

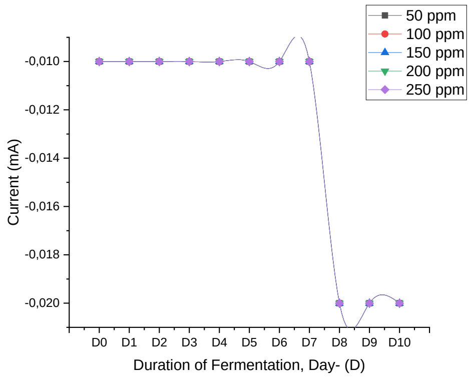
A study by Atina investigating the voltage and current strength of various fruits (tomato, pineapple, starfruit, apple, and orange) based on their acidic properties found that the pH values of each fruit sample were inversely related to the voltage and current generated. As the pH value decreased, the voltage produced increased, and vice versa. In the study, orange exhibited the highest voltage, followed by starfruit, apple, pineapple, and tomato, respectively. It is important to note that each fruit contains different fiber components and chemical elements, which means that the oxidation process affecting pH also indirectly contributes to the electrical properties, playing a significant role. Further research is needed to investigate the differences in the chemical composition and reactive properties of each solution, as well as the factors contributing to the underlying mechanisms that influence the electrical performance of the fruit extracts and/or solutions within the scope of electrochemistry.(Atina, 2015)

Electric Current Testing of the Solution

The following is a figure showing the graph of the current test results of the *ketapang* and tamarind solutions over a ten (10) day fermentation period.



(A)



(B)

Figure 5. Current (mA) Test Results of *Ketapang* Solution (A) and Tamarind Solution (B)

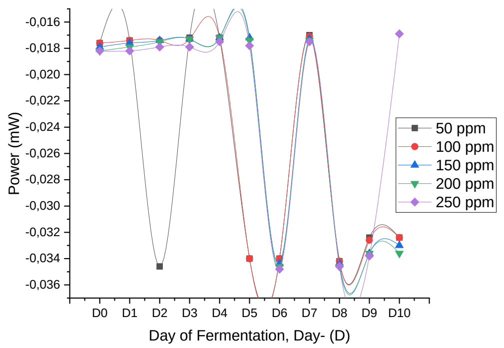
Similar to the findings for voltage, the *ketapang* solution also showed unstable current values. Both the *ketapang* and tamarind solutions exhibited negative electrical current outputs during the 10 days of fermentation (-0.010 to -0.020), with an absolute value of 0.010 mA. This study confirms that the alkalization process can strengthen the electrical current (increased conductivity), but it shows the flow of electrical charge in the opposite direction of conventional electricity flow (the flow of charge from the positive pole to the negative pole).(Kamberaj, 2022) This study did not further investigate the involvement of ions, including the increase in the number and movement of hydroxide ions, which could affect the flow of electrical charge. A study by Hana Kholida, which assessed the electrical current strength at varying acidity levels of fruit solutions (mango and orange), confirmed that the electrical current strength is inversely related to the acidity level (pH); as the pH value decreases, the electrical current strength increases. Conversely, as the pH value increases, the electrical current strength decreases.(Kholida, 2015)

The hydroxide ions (OH^-) produced during the alkalization process can contribute to the increased conductivity of the solution. The increase in the concentration of hydroxide ions in the solution can enhance its ability to conduct electrical current, which has implications for applications in electrochemical systems. Furthermore, the movement of ions in the solution is highly influenced by the pH, where alkaline conditions can accelerate ion mobility and improve conductivity. Therefore, further research on the involvement of ions, particularly hydroxide ions, in the alkalization process and their impact on the flow of electrical charge is essential to understand the mechanisms underlying this study.(Wanta *et al.*, 2019)

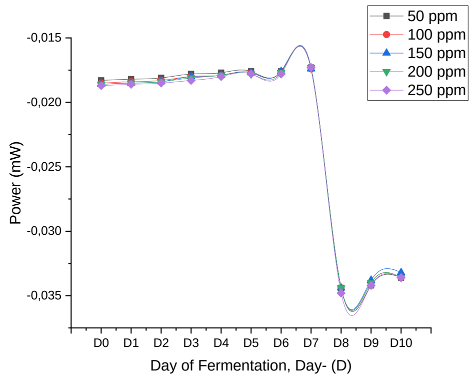
As mentioned in the electrical voltage section, Atina's study also stated that the pH of fruit-based acid solutions inversely affected the current generated. A lower pH resulted in a higher electrical current. Atina's findings ranked the fruits in the following order, from the highest to the lowest current source: orange, starfruit, apple, pineapple, and tomato.(Atina, 2015)

Electric Power Testing of the Solution

The following is a figure showing the graph of the power test results of the *ketapang* and tamarind solutions over a ten (10) day fermentation period.



(A)



(B)

Figure 6. Power (mW) Test Results of *Ketapang* Solution (A) and Tamarind Solution (B)

The electrical power of the *ketapang* and tamarind solutions is directly proportional to the findings of the voltage and current of the related solutions as shown in the previous test results. The instability of the *ketapang* solution also contributes to its unstable electrical power. Theoretically, the electrical power (P in mW) can be explained in relation to the voltage (V in Volts) and current (A in mA) through the following equation:

$$P = V \, x \, I$$

Information: P = Power (mW); V = Voltage (Volt); I = Current (mA)(Abidin *et al.*, 2020)

The *ketapang* solution showed fluctuating voltage values over a ten-day observation period, as indicated in Figure 4.A. Furthermore, the *ketapang* solution also exhibited the same trend (fluctuating increases and decreases) in current values as shown in Figure 5.A. This caused the power measurements, in line with the equation above, to produce unstable electrical power findings for the *ketapang* solution.

The tamarind solution showed a more stable electrical power test result up to the seventh day of observation. The minimal variation between increases and decreases in electrical power over the observed period in this solution was also influenced by the more stable reduction in voltage (shown in Figure 4.B) when compared to the *ketapang* solution, as well as the stable current test values with no significant fluctuation until the seventh day (shown in Figure 5.B). The electrical current deflection in the tamarind solution occurred on the eighth day, but it continued to show a stable trend without significant difference until the tenth day.

The opposite direction between voltage and current (positive voltage and negative current) indicates the presence of an energy flow back to the power supply (reabsorption) by the source. Over time (the alkalization process), the sources (*ketapang* and tamarind solutions) exhibited the role of energy absorbers.

In addition to pH, another critical physical factor that must be considered is the electrical resistance of the solution, which plays a significant role in determining the power output in a complex and interconnected way. As the distance between the electrodes increases, the electrical potential (both voltage and current) generated across the solution decreases, leading to a reduction in overall power output. Conversely, reducing the distance between the electrodes lowers the resistance, resulting in higher potential and consequently greater power output. Any manipulation of these factors could introduce biases, potentially compromising the reliability of the study's findings. However, such manipulations were intentionally avoided in this study. The resistance between the electrodes remained constant for each solution and concentration throughout the experimental process, ensuring that it did not affect the results in any way.(Imamah, 2013)

In conclusion, this study reveals that the transition to basic properties (alkalization) can reduce the electrical potential of the electrolyte solution, as reflected in the decreased values of voltage, current, and power in line with the increasing pH of the solution. This study is the first to investigate the impact of alkalization phenomena during the fermentation process of fruit extract solution without the use of yeast on the weakening of the electrical properties of the solution. Therefore, the development of electrolyte solutions using methods that support and maintain acidic conditions may yield better electrical potential from naturally sourced solutions, such as fruit extracts.

CONCLUSION

Ketapang fruit (*Terminalia catappa L.*) and tamarind (*Tamarindus indica L.*) have the potential as alternative electrolytes for bio-batteries. In general, the pH increases over time, indicating an alkalization process that affects the electrical characteristics of the solution, including voltage, current, and electrical power. The role of hydroxide ions (OH^-) in enhancing the conductivity of the solution is crucial. The alkalization process increases the reactivity of ions in the solution; however, the mechanisms of ion behavior and other factors influencing performance still require further research for the development of bio-batteries sourced from *ketapang* and tamarind fruits to achieve optimal performance. The researchers recommend that future research focus on investigating similar sources (*ketapang* and tamarind) using an alternative approach, specifically by incorporating yeast as a biological agent for the fermentation of the solution, and determining the optimal concentration for generating electrical potential. Another crucial recommendation is to examine the effects of alkalization, the causes and factors contributing to alkalization, as well as the ion mechanisms involved in the weakening of the solution's electrical potential. This will directly contribute to the development of more robust and sustainable bio-batteries.

ACKNOWLEDGMENTS

This research did not receive any funding from public or private sector grants. The authors would like to express sincere appreciation to the Department of Physics Education of Ar-Raniry State Islamic University, Banda Aceh, Indonesia for providing the laboratory facilities necessary to conduct this research. Special thanks to Juniar Afrida for her tireless assistance throughout the research process and in the process of the submission. Their valuable support greatly contributed to the successful completion of this research.

REFERENCES

Abdullah, A. and Masthura, M. (2021) 'Pemanfaatan Sari Nenas Sebagai Sumber Energi Alternatif Pembuatan Bio-Baterai', *CIRCUIT: Jurnal Ilmiah Pendidikan Teknik Elektro*, 5(1), p. 51. Available at: https://doi.org/10.22373/crc.v5i1.8494.

Abidin, M. *et al.* (2020) 'Pembuatan Biobaterai Berbasis Ampas Kelapa dan Tomat Busuk', *al-Kimiya*, 7(1), pp. 28–34.

Amirul, G. and Pauzi, G.A. (2018) 'Analisis Potensi Elektrik Berbagai Elektrolit Alam Sebagai Sumber Energi Terbarukan', *Jurnal Teori dan Aplikasi Fisika*, 06(01), pp. 91–100.

Anshar, A.N. *et al.* (2021a) 'Electrical Analysis of Combination of Orange Peel and Tamarind for Bio-battery Application as an Alternative Energy', *Indonesian Journal of Multidiciplinary Research*, 1(1), pp. 125–128. Available at: https://doi.org/10.17509/ijomr.v1i1.33793.

Anshar, A.N. *et al.* (2021b) 'Electrical Analysis of Combination of Orange Peel and Tamarind for Bio-battery Application as an Alternative Energy', *Indonesian Journal of Multidiciplinary Research*, 1(1), pp. 125–128. Available at:

https://doi.org/10.17509/ijomr.v1i1.33793.

Arizona, R. *et al.* (2021) 'Pengaruh Lama Fermentasi terhadap Karakteristik Kelistrikan yang Dihasilkan oleh Ekstrak Buah Belimbing Wuluh (Averrhoa bilimbi) sebagai Solusi Energi Alternatif Ramah Lingkungan', *Jurnal Teknik Mesin*, 10(1), pp. 1–5.

Atina (2015) 'Tegangan Dan Kuat Arus Listrik Dari Sifat Asam Buah', 12(2), pp. 28–42. Available at: https://garuda.kemdikbud.go.id/documents/detail/858264.

Bengi, F.M. *et al.* (2018) 'Perbandingan Arus dan Tegangan Larutan Elektrolit berbagai Jenis Garam', *Jurnal Pendidikan Fisika Dan Sains*, (1), pp. 32–36.

Deninta, T. (2020) 'Perbandingan Tegangan Listrik Yang Dihasilkan Buah Pedada (Sonneratia Caseolaris) Utuh Dengan Buah Yang Dibelah', *GRAVITASI: Jurnal Pendidikan Fisika dan Sains*, 3(02), pp. 5–10. Available at: https://ejurnalunsam.id/index.php/JPFS/article/view/2907.

Fachrurozi, R. *et al.* (2019) 'Studi Penambahan Polietilen untuk Meningkatkan Kualitas Biobriket Ketapang', *Jurnal Mineral, Energi, dan Lingkungan*, 3(2), pp. 83–88. Available at: https://doi.org/10.31315/jmel.v3i2.2920.

Fitrya, N. *et al.* (2023) 'Peningkatan Kinerja Bio-Baterai Nanas Dengan Penambahan Pasta Aki Bekas dan Natrium Benzoat', *Positron*, 13(2), p. 125. Available at: https://doi.org/10.26418/positron.v13i2.70052.

Gardjito, M. (2013) *Bumbu, Penyedap, dan Penyerta Masakan Indonesia*. Jakarta: PT Gramedia Pustaka Utama.

Govindarajan, N., Xu, A. and Chan, K. (2022) 'How pH affects electrochemical processes', *Science*, 375(6579), pp. 379–380. Available at: https://doi.org/10.1126/science.abj2421.

Imamah, A. (2013) 'Efek Variasi Bahan Elektroda Serta Variasi Jarak Antar Elektroda Terhadap Kelistrikan Yang Dihasilkan Oleh Limbah Buah Jeruk (Citrus sp.)', *Teknik Listrik* [Preprint].

Jumiati, E., Sirait, R. and Soraya, N. (2023) 'Hubungan Antara Tegangan dan Arus Listrik Terhadap Bio-Baterai Larutan Sari Buah Mangga', *Einstein*, 11(2), p. 104. Available at: https://doi.org/10.24114/eins.v11i2.45000.

Kamberaj, H. (2022) 'Electric Current', in, pp. 109–129. Available at: https://doi.org/10.1007/978-3-030-96780-2_5.

Kholida, H. (2015) 'Hubungan Kuat Arus Listrik dengan Keasaman Buah Jeruk dan Mangga', 6, pp. 42–46.

Liu, S. *et al.* (2024) 'Mechanism in pH effects of electrochemical reactions: a mini-review', *Carbon Letters*, 34(5), pp. 1269–1286. Available at: https://doi.org/10.1007/s42823-024-00724-2.

Maharani, S., Muliyono, S. and Putri, E.R. (2022) 'Kaitan konduktivitas listrik dengan konsentrasi larutan garam dapur', *Progressive Physics Journal*, 3(2), p. 157. Available at: https://doi.org/10.30872/ppj.v3i2.906.

Masthura, Putri, N. and Daulay, A.H. (2021) 'Analisis Pengaruh Penambahan Volume Dan Lama Fermentasi Terhadap Kelistrikan Biobaterai Sari Buah Nenas (Ananas Comosus)', *Jurnal Fisika Dan Terapannya* , 8(2), pp. 25–31. Available at: https://doi.org/10.24252/jft.v8i2.22164.

Nugroho, R.A. and Nur, F.M. (2018) *Potensi Bahan Hayati Sebagai Imunostimulan Hewan Akuatik*. Yogyakarta: Deepublish.

Nurasia (2019) 'Analisis Kualitas pH, Suhu, Warna dan TDS Air PDAM Kota Palopo', *Jurnal Dinamika*, 10(1), pp. 16–21.

Pandia, B.A., Sumarni, W. and Izzania, R.A. (2021) 'Pengembangan Alat Peraga Uji Daya Hantar Listrik Berbasis STEM Dan Pengaruhnya Terhadap Literasi Kimia Peserta Didik', *Journal of Chemistry In Education*, 10(2252), pp. 30–37.

Prakoso, J.W., Suwandi and Fitriyanti, N. (2020) 'the Effect of Variations of Electrode Sector Area and Concentration of Electrolite Solutions on the Potential Volta Cells Using Electro Chemical Cell Method', *e-Proceeding of Engineering*, 7(2), pp. 4400–4407.

Purwanto, E.H., Iflah, T. and Aunillah, A. (2020) 'The Effect of Cocoa Nib Alkalization on Chemical Content and Color of Cocoa Powder', *Prosiding Seminar Nasional Lahan Suboptimal*, pp. 253–260.

Salafa, F., Hayat, L. and Ma'ruf, A. (2020) 'Analisis Kulit Buah Jeruk (Citrus Sinensis) Sebagai Bahan Pembuatan Elektrolit Pada Bio-Baterai', *Jurnal Riset Rekayasa Elektro*, 2(No. 1), pp. 1–9.

Salafa, F., Latiful, H. and Ma'ruf, A. (2020) 'Analisis Kulit Buah Jeruk (Citrus Sinensis) Sebagai Bahan Pembuatan Elektrolit Pada Bio-Baterai', *Riset Rekayasa Elektro*, 2(1), pp. 1–9.

Sigalingging, R., Panjaitan, V.C.S. and Sigalingging, C. (2022) 'The effect of fermentation time on fruits as a producer electrical energy', *IOP Conference Series: Earth and Environmental Science*, 1115(1), p. 012088. Available at: https://doi.org/10.1088/1755-1315/1115/1/012088.

Silalahi, M. (2020) 'Bioaktivitas Asam Jawa (Tamarindus indica) dan Pemanfaatannya', *Jurnal Biologi dan Pembelajarannya*, 7(2), pp. 85–91.

Sintiya, D. and Nurmasyitah (2019) 'Pengaruh Bahan Elektroda Terhadap Kelistrikan Jeruk Dan Tomat', *Jurnal Pendidikan Fisika Dan Sains*, 2(2), pp. 1–6.

Tanjung, A.F., Masthura and Daulay, A.H. (2022) 'Pembuatan Bio-Baterai Dengan Memvariasikan Elektroda Berbahan Dasar Sari Buah Tomat (Solanum Lycopersicum)', *Jurnal Einstein*, 10(1), pp. 59–64.

Wanta, K.C. *et al.* (2019) 'Pengaruh Derajat Keasaman (pH) dalam Proses Presipitasi Hidroksida Selektif Ion Logam dari Larutan Ekstrak Spent Catalyst', *Jurnal Rekayasa Proses*, 13(2), p. 94. Available at: https://doi.org/10.22146/jrekpros.44007.

Yolanda, N., Masthura and Daulay, A.H. (2022) 'Pengaruh Variasi Waktu Fermentasi terhadap Kelistrikan Sel Volta dengan Menggunakan Larutan Buah Tomat', *Jurnal Einstein*, 10(2), pp. 61–66.