Indonesian Journal of Chemical Science and Technology (IJCST)

State University of Medan, https://jurnal.unimed.ac.id/2012/index.php/aromatika

IJCST-UNIMED 2025, Vol. 08, No. 2 Page ; 85 – 91

Received : Apr 15th, 2025 Accepted : Jul 11th, 2025 Web Published : Aug 26th, 2025

Electrical Properties of Tropical Fruit Extracts: Effects of EM4 Fermentation and Thermal Processing

Wulan Dwi Safitri[1*], Dian Wardana[1], Dwi Sapri Ramadhan[1], Jaman Fahmi[1], Grace shallomita[2], Putri Ayunicha[2], Irma Syahputri[2], Nuraini Siregar[2], Ahmad Nasir Pulungan[1], Moondra Zubir[1]

[1]*Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Medan 20221, Indonesia*
[2]*Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Medan 20221, Indonesia*

**Corresponding author : wulandwisft@unimed.ac.id*

ABSTRACT

This study examines the electrical properties of fermented pineapple and lime extracts subjected to Effective Microorganism 4 (EM4) fermentation and thermal treatment at varying temperatures. The fermentation process was conducted over a period of six days, with temperature conditions set at 30°C and 70°C. The results indicate that the lime extract generated higher voltage and current outputs compared to the pineapple extract, particularly on the sixth day of fermentation. Furthermore, the thermal treatment revealed a more pronounced electrical response in lime extract, as evidenced by a greater increase in current at elevated temperatures. These findings suggest that lime extract, when combined with EM4 fermentation and optimal thermal conditions, exhibits greater potential for application in alternative bioelectric energy generation.

Keywords: fermentation, effective microorganism-4 (EM4), pineapple extract, lime extract, bioelectric energy

1. INTRODUCTION

The rising global demand for electricity has stimulated the advancement of alternative energy sources that are sustainable, environmentally benign, and widely accessible. Among emerging innovations is the utilization of locally sourced organic materials, such as tropical fruits, as natural electrolytes in low-cost, bio-based electricity generation systems.[10] Pineapple (*Ananas comosus* L. Merr) and lime (*Citrus aurantiifolia*) are tropical fruits rich in organic acids particularly citric acid and ascorbic acid which can enhance electrical conductivity when utilized in electrolyte solutions.[12,13]

A previous study by Djamalu et al. demonstrated that fermenting pineapple peel over several days can increase voltage output, attributed to the rising concentration of ions in the solution.[1] A similar study by

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

Maulana and Sari reported that the fermentation of fruit extracts yields electrolytes with higher conductivity, particularly when the process is enhanced by the addition of bioactivators.[7] One widely used bioactivator is Effective Microorganism 4 (EM4), which contains a consortium of microorganisms—including lactic acid bacteria, *Actinomycetes*, and yeast—that facilitate the decomposition of complex compounds into simpler ionic forms.[6,13]

In addition to fermentation, temperature plays a crucial role in influencing both the fermentation process and ion activity in electrolyte solutions. Firmansyah and Nuraini reported that raising the temperature to an optimal level can accelerate microbial activity and enhance ion mobility, thereby increasing the resulting voltage output.[2] Handayani and Apriyanto also noted that elevated temperatures can reduce solution viscosity and accelerate the rate of electrochemical reactions.[3] Yuliani and Prasetyo demonstrated that fermented tomato extract subjected to heat treatment generated higher voltage compared to fermentation conducted at room temperature.[15] Similarly, Rahayu and Widodo demonstrated that tropical fruit substrates, when subjected to fermentation and heat treatment, can generate efficient microbial electrochemical systems.[9]

Another study by Harahap and Dewi on starfruit (*Averrhoa bilimbi*) extract demonstrated that the combination of fermentation and heat treatment produced a voltage of up to 1.2 V, exceeding that of fermentation alone.[4] Meanwhile, Kurniawati and Lestari found that the application of EM4 in fermented kaffir lime extract increased the solution's conductivity by up to 30%.[6] Putri and Wahyuni also discovered that fermenting fruit with EM4 at 40°C resulted in the highest current efficiency.[8] Additionally, Hidayat and Yusuf demonstrated that extending the fermentation duration—up to an optimal point—increases the electrical conductivity of pineapple and papaya peel extracts.[5]

Based on this review, the present study aims to compare the electrical properties (voltage and current) of two fruit extracts, pineapple and lime, subjected to different treatments: (1) fermentation with the addition of EM4 over several days, and (2) heat treatment following fermentation. The extracts are analyzed separately, rather than mixed, to evaluate the individual effects of fruit type, fermentation process, and temperature treatment on their electrical performance. This research is expected to contribute to the development of efficient, cost-effective, and environmentally friendly alternative energy sources derived from tropical biomass.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

This study employs an experimental approach to compare variations in voltage and current generated by pineapple and lime extracts. The primary objective is to identify which treatment yields higher electrical output in terms of current and voltage. The extracts were prepared by filtering the fruit pulps. The equipment used in the process includes a plastic container, grater, knife, measuring cup, water bath, multimeter, and filter. The materials involved are pineapple, lime, and EM4 bioactivator.

2.2. Screening of Samples

The pineapple was peeled and the eyes were removed before being grated. The extract was then obtained by straining the grated pulp. The lime was cut and squeezed, and the juice was filtered to remove the seeds.

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

2.3. Preparation of Fermentation

Preparation: 100 mL of pineapple extract and lime extract were each placed in separate plastic containers. Subsequently, 1 mL of EM4 bioactivator was added to each container, resulting in a 1:100 ratio. Both containers were then sealed tightly to commence the fermentation process.

2.4. Temperature Adjustment of the Extract

Each 50 mL of pineapple and lime extract was placed in separate measuring cups. A water bath was prepared and filled with water. Initial voltage and current measurements were taken at room temperature for both extracts. Subsequently, the measuring cups were immersed in the water bath, where the temperature was controlled at 30°C and 70°C during the measurements.

3. RESULTS AND DISCUSSION

3.1. Voltage Development During the Fermentation Process

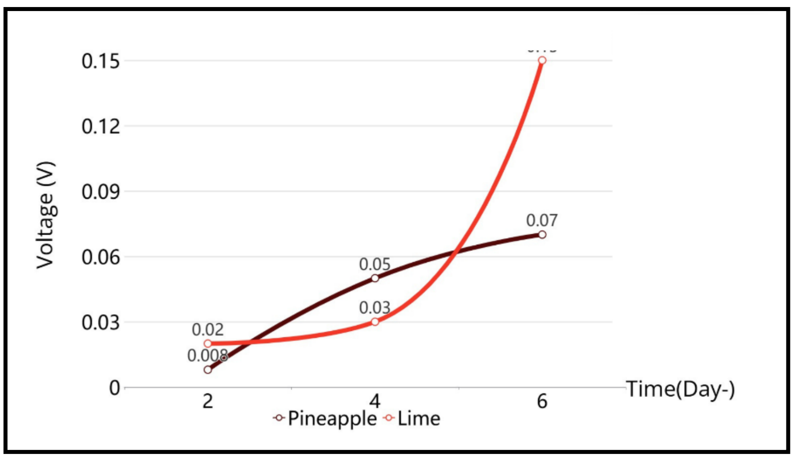

Figure 1. Voltage Measurements Under EM4 Fermentation Conditions

Figure 1 illustrates the voltage output (in Volts) measured during the six-day fermentation process of pineapple and lime extracts using EM4. On day two, lime generated a voltage of 0.02 V, whereas pineapple produced only 0.008 V, indicating that lime exhibited a stronger initial electrical response. However, by day four, pineapple surpassed lime with a voltage of 0.05 V, compared to lime's 0.03 V. A notable shift occurred on day six, where lime experienced a sharp increase in voltage output, reaching 0.15 V, while pineapple showed only a moderate rise to 0.07 V. These results highlight distinct fermentation dynamics between the two fruit extracts.

Lime exhibited an exponential increase in voltage production, whereas pineapple showed a steady, relatively linear growth throughout the fermentation period. The voltage spike observed in lime is likely attributed to its higher acid content, which promotes more vigorous microbial activity during fermentation. In

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

contrast, the lower voltage output from pineapple may be due to its less favorable chemical composition for supporting microbial processes. These findings suggest that lime is more effective than pineapple in generating electrical energy through EM4-assisted fermentation, particularly after the fourth day.

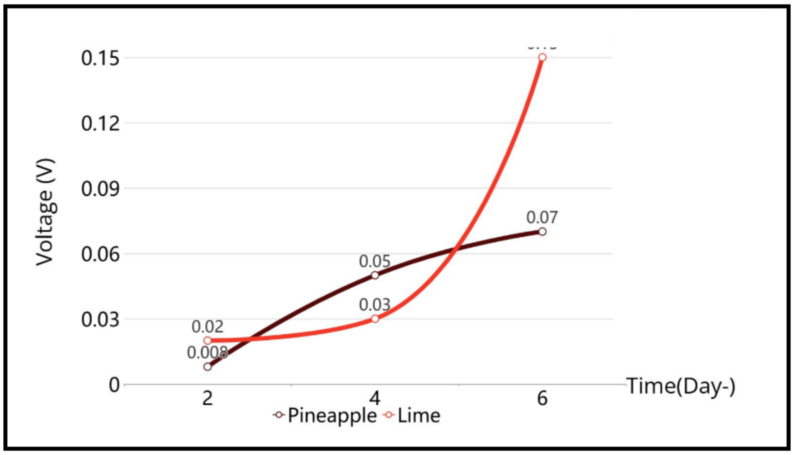

Figure 2. Current Measurements Under EM4 Fermentation Conditions

The graph illustrates a clear upward trend in current output for both fermented pineapple and lime extracts over the six-day fermentation period. While both extracts exhibit relatively low and similar current values on day two (pineapple: 4 µA; lime: 3 µA), a notable increase is observed by day four, with pineapple reaching 12 µA and lime 10 µA. By day six, the difference becomes more pronounced, as lime produces a current of 42 µA, surpassing pineapple, which generates 29 µA. These results indicate that although both extracts respond positively to EM4 fermentation in terms of current generation, lime shows a stronger enhancement, particularly in the later stages of fermentation.

This difference suggests that lime possesses a higher fermentative potential than pineapple in generating bioelectricity through the EM4 fermentation process. This enhanced performance may be attributed to differences in acid and sugar content between the two substrates, which affect microbial activity within the EM4 culture and influence the production of ions that contribute to electrical conductivity.

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

3.2. Comparative Thermal Response of Pineapple and Lime Extracts

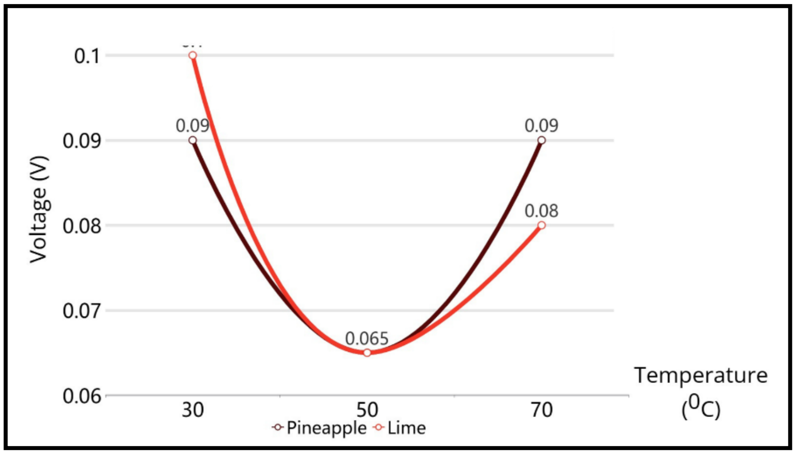

Figure 3. Voltage Output at Varying Temperature Conditions

Figure 3 presents a comparison of the electrical voltage generated by pineapple and lime extracts under two different temperature conditions: 30°C and 70°C. Voltage is measured in volts (V), while temperature is expressed in degrees Celsius (°C). At 30°C, lime generated a voltage of 0.10 V, slightly higher than that of pineapple, which produced 0.09 V.

When the temperature was increased to 70°C, the voltage produced by lime decreased to 0.08 V. In contrast, pineapple maintained a relatively constant voltage of 0.09 V, indicating that the temperature increase had minimal effect on the voltage generated by pineapple. These results suggest differential responses of the two fruit extracts to temperature variations.

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

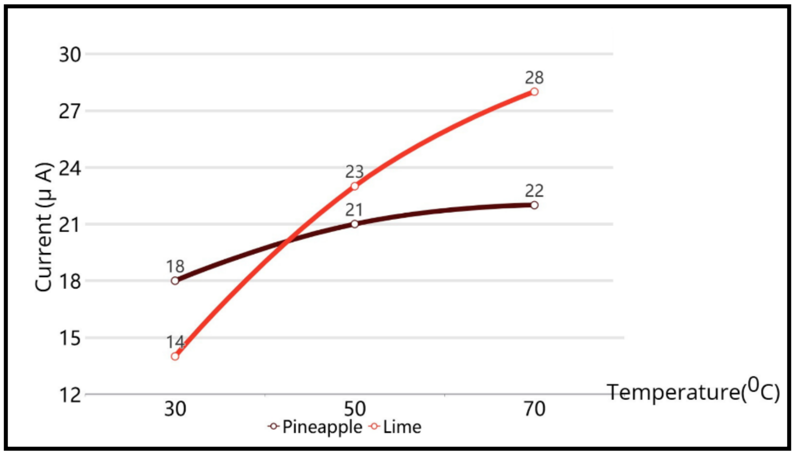

Figure 4. Current Output at Varying Temperature Conditions

Figure 4 illustrates the electrical current generated by pineapple and lime extracts at temperatures of 30°C and 70°C. At 30°C, pineapple produced a current of 18 µA, which was higher than lime's 14 µA. This suggests that, at this temperature, pineapple exhibits a greater capacity for current generation compared to lime. However, when the temperature increased to 70°C, lime showed a more pronounced rise in current, reaching 28 µA, whereas pineapple's current increased to 22 µA. These findings indicate that temperature influences the electrical current generation of the fruit extracts, with the response varying according to the chemical properties of each fruit. The elevated temperature likely accelerates chemical reactions and ionic mobility within the extracts, thereby enhancing the magnitude of the current produced.

4. CONCLUSION

Both pineapple and lime extracts can generate electricity through EM4 fermentation. Lime showed higher voltage and current, especially on day six, indicating more active microbial fermentation. When heated to 70°C, lime exhibited a significant increase in current, while pineapple's voltage remained stable with moderate current rises. These results suggest that lime extract, combined with EM4 fermentation and moderate heat treatment, has greater potential as an alternative bioelectric energy source compared to pineapple.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the lecturers of the Matter and Energy course for their valuable assistance and guidance throughout the research and preparation of this manuscript. The authors also extend their appreciation to all individuals who provided support and encouragement during this process.

REFERENCES

1. Djamalu AF, Jumriani AINN, Rasyid SR Al Islami, Nasir S, Musarrafa, Al Irsyad. (**2022**). Analisis Sifat Kelistrikan Kulit Nanas (*Ananas comosus L. Merr*) Dengan Variasi Waktu Fermentasi Sebagai Larutan Elektrolit Sel Akumulator (Energi Terbarukan). Lembaga Penelitian Mahasiswa (LPM) Penalaran - Universitas Negeri Makassar.
2. Firmansyah F, Nuraini R. (**2021**). Pengaruh Variasi Suhu terhadap Tegangan Listrik pada Fermentasi Buah Pisang sebagai Sumber Energi Alternatif. Jurnal Energi dan Lingkungan. 8(2), 55–61.
3. Handayani R, Apriyanto D. (**2020**). Pengaruh Suhu dan Lama Fermentasi terhadap Konduktivitas Elektrolit dari Ekstrak Buah Mengkudu. Jurnal Kimia Riset. 9(1), 13–20.
4. Harahap R, Dewi R. (**2022**). Pemanfaatan Fermentasi Buah Belimbing Wuluh Sebagai Elektrolit pada Sel Galvanik. Jurnal Teknologi Terapan. 6(2), 102–8.
5. Hidayat T, Yusuf M. (**2022**). Efektivitas Kulit Buah Tropis yang Difermentasi dalam Menghasilkan Energi Listrik Alternatif. Jurnal Inovasi Energi. 7(1), 30–6.
6. Kurniawati D, Lestari P. (**2021**). Pengaruh EM4 dalam Fermentasi Ekstrak Jeruk Purut terhadap Konduktivitas Larutan Elektrolit. Jurnal Sains Terapan. 5(3), 77–84.
7. Maulana R, Sari D. (**2020**). Pemanfaatan Limbah Buah untuk Pembangkit Listrik Ramah Lingkungan. *Jurnal Sains Lingkungan*. 4(1), 45–51.
8. Putri ME, Wahyuni E. (**2021**). Efektivitas EM4 dan Variasi Suhu terhadap Peningkatan Arus Listrik Fermentasi Buah. Jurnal Energi Hijau. 3(2), 63–9.
9. Rahayu L, Widodo H. (**2020**). Sistem Elektrokimia Berbasis Mikroba dengan Substrat Buah Tropis. Jurnal Bioelektrokimia Indonesia. 2(2), 22–8.
10. Sugiharto T, Pramono E. (**2019**). Perbandingan Daya Hantar Listrik Ekstrak Buah Nanas dan Jeruk. Jurnal Kimia dan Energi. 5(2), 51–6.
11. Suryani T, Aditya R. (**2020**). Potensi Buah Tropis sebagai Elektrolit pada Baterai Organik. Jurnal Teknologi Energi Baru. 4(3), 101–7.
12. Sutanto W, Huda A. (**2021**). Analisis Kandungan Asam Sitrat dan Potensinya sebagai Elektrolit. Jurnal Kimia Terapan. 6(1), 12–8.
13. Utami ND, Wahid AH. (**2022**). Pemanfaatan Fermentasi Buah Lokal untuk Energi Alternatif. Jurnal Teknologi Berkelanjutan. 7(1), 39–44.
14. Wulandari A, Hasan M. (**2021**). Efisiensi Elektrolit Buah Tropis terhadap Tegangan Listrik. Jurnal Energi dan Inovasi. 4(2), 25–31.
15. Yuliani S, Prasetyo B. (**2020**). Pengaruh Perlakuan Suhu pada Fermentasi Buah Tomat terhadap Output Tegangan. Jurnal Bioteknologi Tropis. 3(1), 58–64.

