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Exploring the Redox Reaction Potential of Local Fruits: Galvani Cell Trials Based on Areca nut (*Areca catechu*), Rimbang (*Solanum torvum*), and Bangkok starfruit (*Averrhoa carambola*)

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ABSTRACT

This research aims to explore the potential of three fruits, such as areca nut (Areca catechu), rimbang (Solanum torvum), and star fruit (Averrhoa carambola), as a natural electrolyte source in generating electricity through a simple Galvani cell test. The research method includes making Galvani cells using fruit pieces as electrolyte media, measuring the voltage and current produced, and testing the ability to light an LED as an indicator of electrical output. The measurement results showed that areca nuts produced the highest voltage and current compared to rimbang and Bangkok starfruit, demonstrating its effectiveness as a natural electrolyte. This finding indicates that local fruits have the potential to be an environmentally friendly electrochemical energy source material that can be applied in education and simple technology. This research opens opportunities for further development in utilizing local biological resources for electrochemical applications.

Keywords**:** Redox reactions, Galvanic cells, Local fruits, Natural electrolytes.

1. INTRODUCTION

Redox (reduction–oxidation) reactions are chemical processes that involve the transfer of electrons between reactant species and are characterized by changes in oxidation numbers. In these reactions, two simultaneous processes occur: **oxidation**, the loss of electrons by a substance, and **reduction**, which is the gain of electrons by another substance. Redox reactions play a vital role in chemical and biological systems, including energy generation in electrochemical cells, cellular respiration, and various industrial and environmental processes.

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Redox reactions can produce an electron flow through an arrangement known as a **Galvanic cell**. In such a system, a spontaneous reaction converts chemical energy into electrical energy. In contrast, **electrolysis** involves using electrical energy to drive a non-spontaneous redox reaction. Faraday described the qualitative relationship between electric current and product formation. **Electrochemistry**, the study of chemical processes that involve electricity, centers on these redox reactions.[2]

Luigi Galvani and Alessandro Volta first developed the Galvanic cell or voltaic cell. In this setup, a zinc rod is immersed in $ZnSO_4$ solution and a copper rod in $CuSO_4$ solution. Oxidation occurs at the anode (zinc), while reduction occurs at the cathode (copper). The electron transfer between electrodes via an external wire generates an electric current. Galvanic cells are used as power sources in lighting, heating, and small motor applications.[11]

Sour fruits such as oranges and mangoes have shown potential as **natural electrolytes** due to their acid content. Oranges contain citric acid ($C_6H_8O_7$), while mangoes have nitric acid (HNO_3), both contributing to increased electrical conductivity. The acidity level and specific composition of each fruit affect the current produced. For example, limes produce higher current than mangoes due to their lower pH. Such findings suggest that fruits can serve as an eco-friendly alternative energy source.[7]

Lemon (*Citrus limon*) and belimbing wuluh (*Averrhoa bilimbi*) have potential as natural electrolytes that can generate electricity. Both fruits contain high levels of acidity, especially citric acid, which functions as a strong electrolyte. When copper and zinc or magnesium electrodes are dipped into the fruit solution, the potential difference between the metal and the solution creates an electric current. Research shows that lemon and star fruit can produce significant voltages, with lemon reaching 2.927 Volts using Cu-Zn electrodes and 4.445 Volts with Cu-Mg.[5]

In addition to these fruits, local varieties such as **areca nut (Areca catechu)**, **rimbang (Solanum torvum)**, and **Bangkok starfruit (Averrhoa carambola)** also exhibit sour properties and may contain natural electrolytes. Rimbang fruit (*Solanum torvum*) contains various essential vitamins and minerals that play a role in maintaining a healthy body. According to the journal "Bibliometric Analysis of Rimbang (*Solanum torvum*) on Eye Health" by Syaifullah et al. (2024), rimbang fruit contains vitamins A, B1, and C, carotenoids, and minerals such as calcium and phosphorus. These minerals are included in the electrolyte group, which maintains the balance of body fluids, supports nerve function, and helps muscle contraction. Although the journal does not explicitly mention the sodium and potassium content, the presence of calcium and phosphorus as electrolytes suggests that rimbang fruit can be a natural source of electrolytes that are beneficial for health. This high mineral and vitamin content also supports the benefits of rimbang fruit in maintaining eye health and general body function.[15]

Bangkok starfruit is rich in sodium and potassium, both crucial for electrolyte balance. Areca nut traditionally replenishes body electrolytes, suggesting it also has electrochemical potential. Utilization of belimbing wuluh (*Averrhoa bilimbi*) as an electrolyte solution in Galvani cells to produce electrical energy. Belimbing wuluh was chosen because it contains formic acid, an acidic compound known to function as an electrolyte solution. In the experiment, starfruit juice was used as an electrolyte. [14]

This study aims to investigate the potential of local fruits, such as areca nut (*Areca catechu*), rimbang (*Solanum torvum*), and Bangkok starfruit (*Averrhoa carambola*), as natural electrolyte sources in galvanic cells. The research involves observing and comparing the voltage, electric current, and the duration of LED illumination generated by each fruit individually and in combination. The selection of these fruits is based on their suspected content of electrolyte-related compounds, such as minerals and organic acids, which influence the electrical conductivity of a solution. While several acidic fruits like lemons and belimbing have been widely studied, scientific investigations into the electrochemical potential of areca nut, rimbang, and Bangkok starfruit remain limited.[1]

This study contributes in two significant ways. First, academically and educationally, the findings can serve as practical learning materials for redox and electrochemistry experiments through simple, low-cost

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setups. Second, from a practical standpoint, the research opens opportunities for utilizing local biological resources as eco-friendly and sustainable alternative energy sources.

2. EXPERIMENTAL

2.1. Chemicals, Equipment and Instrumentation

This research uses an experimental method to observe the ability of areca nut (*Areca catechu*), rimbang (*Solanum torvum*), and Bangkok starfruit (*Averrhoa carambola*) to conduct electricity and light the LED. The purpose of this study was to determine the comparison of the electrical conductivity of each fruit both singly and in certain combinations. The tools used in this study were a digital multimeter to measure voltage and current, cables and alligator clips, zinc (Zn) and copper (Cu) electrodes, stopwatches, digital scales, and green LEDs as indicators of electric current. Then the materials used in this study were fresh areca nut, rimbang, and Bangkok starfruit. All materials were tested under natural conditions without additional chemical treatment.

2.2. Sample Preparation

Areca nut, rimbang, and Bangkok starfruit were selected in fresh and young condition and weighed to ensure weight equivalence in single and combination tests. Zinc and copper electrodes were prepared and cleaned to avoid the influence of oxidation.

2.3. Test Setup

For each single fruit and combination (1:1, 1:2, and 2:1), zinc and copper electrodes were stuck into the flesh of the fruit without touching each other. The fruits were connected using crocodile claws from the zinc electrode to the copper electrode, then connected to a multimeter for voltage (Volt) and amperage (mA) measurements. The LED is connected to the circuit to observe whether it can light up and measure the duration of the flame using a stopwatch.

2.4. *Testing Combinations*

a. Same size: The test is conducted for each fruit with relatively equal weight.
b. 1:1 ratio: Two different fruits are combined in equal amounts.
c. Comparison 1:2: The first fruit is twice as much as the second.
d. Comparison 2:1: The first fruit is half the amount of the second fruit.
e. For combinations, electrodes are placed on two different fruits each, then connected to form a series circuit to form a Galvani cell.

2.5.Measurement and Recording

Voltage and current measurements were taken after the circuit was stable. The LED was turned on, and the turn-on time was measured using a stopwatch until the light dimmed or went out. All results were recorded in a table based on the combination category, then visualized as bar graphs and line graphs.

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3. RESULTS AND DISCUSSION

3.1. LED Flame Test of Areca Nut, Rimbang, and Bangkok Starfruit Individually and in Combination

The use of fruits as alternative energy sources has been the focus of research in recent years, mainly due to their natural electrolyte content that can generate electricity through chemical reactions. Research by Damayanti et al. (2023), which stated that fruits containing citric acid and acidic minerals such as hydrochloric acid are strong electrolytes that can be completely decomposed into ions in solution, thus capable of generating electrical energy through spontaneous redox reactions in galvanic cells.3 Pinang, rimbang, and belimbing or starfruit contain organic acids and other compounds that allow electrochemical reactions when used as galvanic cells with metal electrodes such as zinc and copper. This study tested these fruits' ability, individually and in combination, to generate sufficient voltage and current to power LEDs. Fruits with high acidity can generate significant voltage and current.

3.2. Individual Fruit Voltage

According to Putra et al. (2021), the voltage produced from fruits is influenced by electrolyte content, especially organic acids that play a role in redox reactions.[12] Oktaviani and Rahmadani's research (2020) also states that high oxalic acid and citric acid in tropical fruits can increase voltage production efficiency.[10]

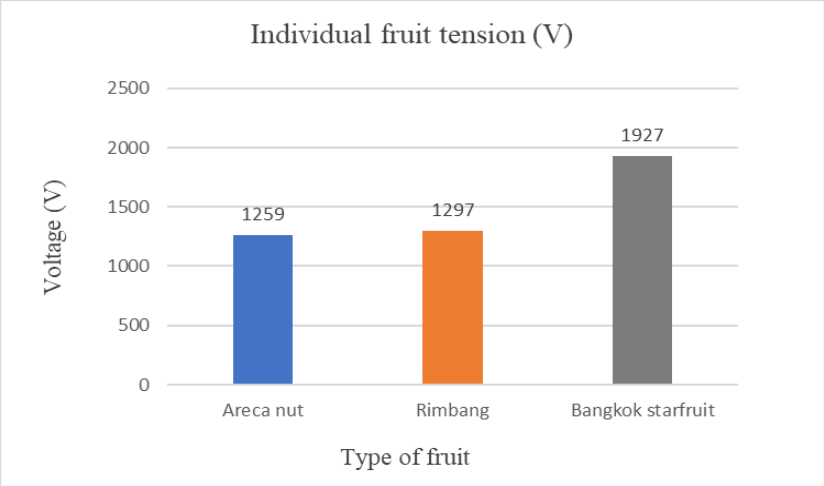

Figure 1. Voltage graph of areca nut, rimbang and Bangkok starfruit

Based on Figure 1, the results of the measurement of areca nut, rimbang, and star fruit using a multi meter, the star fruit produces the highest voltage of 1.927 V, compared to rimbang of 1.297 V and areca nut of 1.259 V. This is reinforced by the findings of Darmawan and Mulyani (2022), star fruit has a high concentration of citric acid compared to other fruits. This makes Bangkok star fruit produce high voltage compared to areca nut and rimbang.[4]

3.3. Individual Fruit Currents

Hamzah & Sari (2022) explain that the ionic conductivity of the solution in the fruit influences the electric current. The more free ions in the electrolyte solution, the higher the value of the generated electric current.[6]

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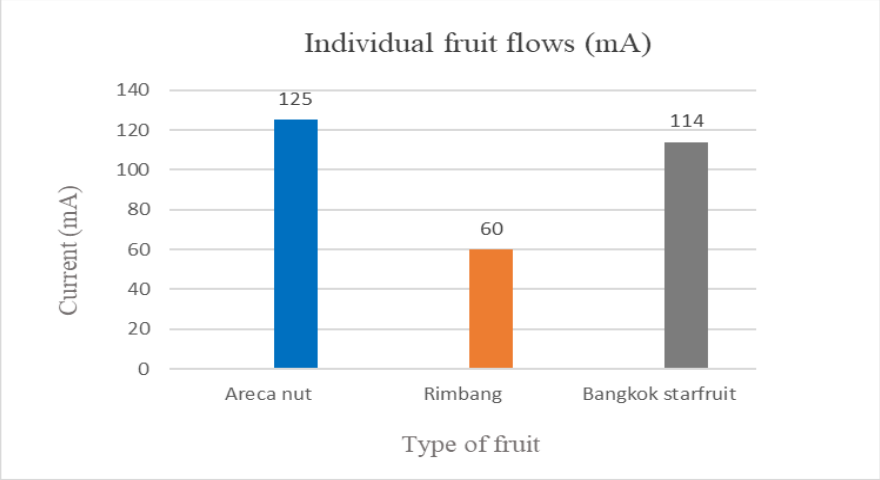

Figure 2. Current graph of areca nut, rimbang and Bangkok starfruit

Measurement of areca nut, rimbang, and Bangkok starfruit currents is illustrated in Figure 2: the nut produces the highest current of 125 mA, compared to 114 mA Bangkok starfruit, and the lowest rimbang of 60 mA. This indicates the areca nut is more effective in conducting current.

3.4. Fruit Combination Voltage

Studies by Nurhidayat (2020) confirmed that the combination of electrolyte materials can increase or decrease the efficiency of galvanic cells depending on their ionic compatibility. The combination of Pinang + Belimbing/Bangkok starfruit (2:1) produced the highest voltage of 1.929 V.[9] This result is in line with research by Wulandari & Setiawan (2019), which found that the combination of two electrolyte materials with different acidity and ionization can create synergistic interactions in increasing voltage output.[16]

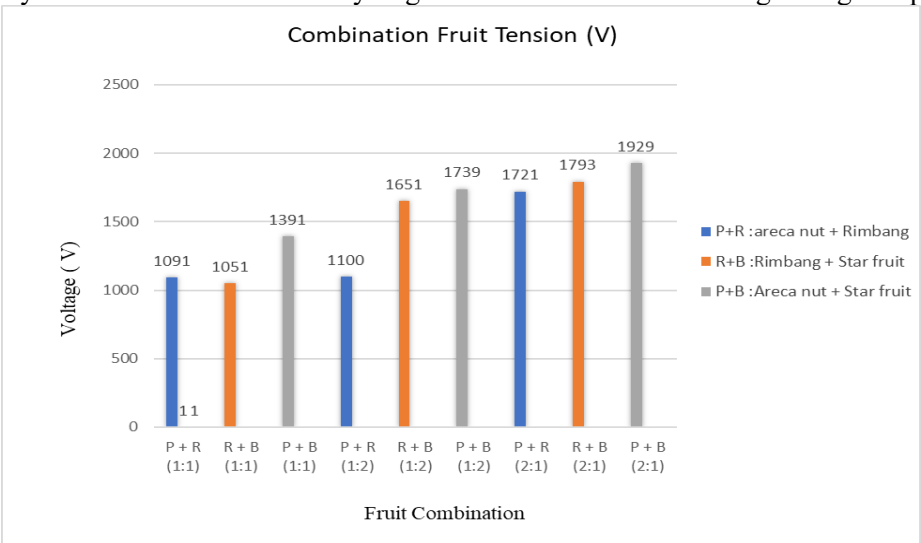

Figure 3. Combined fruit tension graph

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3.5. Fruit Combination Current

In a study by Anwar and Fitria (2023), the current in the fruit combination was determined by the electrode surface area and electrolyte distribution. The combination of Pinang + Rimbang (1:1) produced the highest current of 124 mA.[1] This is also corroborated by studies from Ramadhan & Lazuardi (2022), which mention that the combination of materials with different pH values can increase the ion transfer rate, which has an impact on increasing the current.[13]

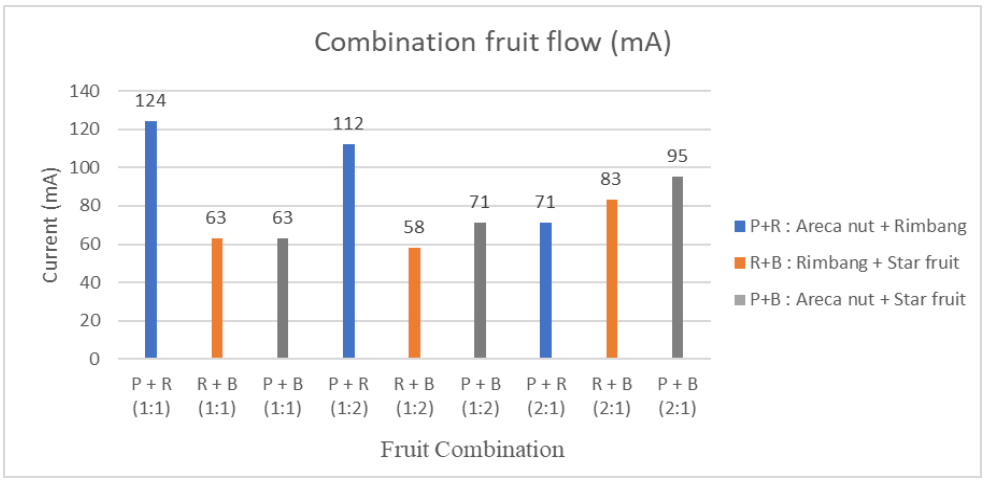

Figure 4. Combined fruit flow graph

3.6. LED Flash Time

According to Lestari (2021), the duration of the LED flame is directly proportional to the durability and stability of the current in the galvanic cell. The combination of rimbang + starfruit (2:1) lit up the longest, which was 19 minutes.[8]

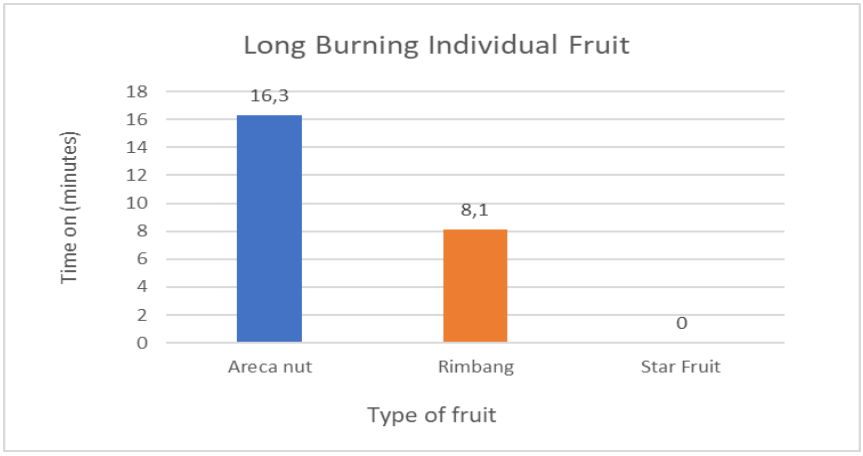

Figure 5. The duration of the LED light for Areca nut, Rimbang, and Bangkok starfruit.

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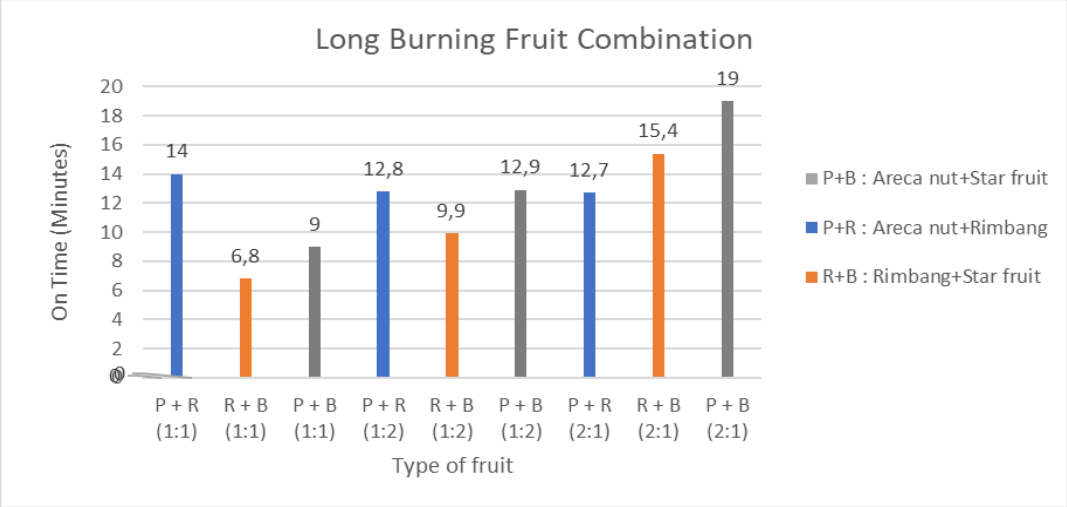

Figure 6. The duration of the LED light of the fruit in combination

4. CONCLUSION

Areca nut, rimbang, and Bangkok starfruit could conduct electricity with varying levels of effectiveness. Areca nut and rimbang were able to power an LED individually, whereas Bangkok starfruit could not light the LED when tested alone. The research showed that the 2:1 ratio of areca nut and starfruit delivered the best performance, producing the highest power output and the longest LED illumination time. This finding proves that locally available fruits can be utilized as environmentally friendly alternative energy sources, contributing to the development of simple renewable energy technologies.

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