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Innovation of Environmentally Friendly Solid Electrolyte Biobattery Based on Carrageenan and Rotten Tomatoes

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ABSTRACT

This research aims to create and evaluate the performance of environmentally friendly biobattery based on carrageenan and rotten tomatoes to reduce B3 waste. To make a biobattery based on carrageenan and rotten tomatoes, five ratios of carrageenan and rotten tomatoes mixtures were used with the composition of carrageenan values of 1, 2, 3, 4, and 5% for each type of battery. The parameters observed in this study were the potential difference, current strength, and stability of the biobattery. Carrageenan was added to prevent battery leakage and maintain battery stability. As a result, the biobattery has a potential difference value equivalent to a commercial battery, namely 1.5 V, but the current generated is still low. On the other hand, biobatteries can be applied to alarm clocks. The difference in carrageenan concentration has no significant effect on the value of potential difference, current strength, power, recharging ability, and application on wall clocks, as well as the stability of the biobattery. The experiment was carried out with the hypothesis that husk ash can absorb rotten tomatoes, preventing electrolyte leakage. However, the resulting biobattery is still leaking. After that, we modified it again by using electrolytes made from rotten tomatoes and coconut dregs, but the leakage was still the same. Therefore, the biobattery made from a combination of carrageenan and rotten tomatoes was assumed to keep the battery more stable and prevent leakage. This research was expected to contribute to the development of environmentally friendly batteries to reduce B3 waste, along with the increasing need for batteries in the era of industrial revolution 4.0.

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1. INTRODUCTION

The battery is one of the examples of a product from the development of Industrial Revolution 4.0. In industrial revolution 4.0, the use of electronics requires batteries to be able to activate electronic devices. In dry cell batteries, zinc is used as the anode, carbon as the cathode, and a mixture of manganese dioxide, zinc chloride, and ammonium chloride as the electrolyte (Hidayat & Suparto, 2017). In addition, there are also heavy metals such as Pb, Cd, Ni, Co, Cr (Wahyuni & Sutomo, 2016), and lithium (Satriady *et al*., 2016). Ironically, battery waste is one type of waste that can pollute the environment and is included in the category of hazardous and toxic materials (B3) (Ruslinda & Permadi, 2018).

The quality standard for cadmium in water is stipulated in the Government Regulation of the Republic of Indonesia Number 82 of 2001, which is 0.01 mg/L (Marwah, 2015). Another example of metal contained in batteries is lead metal. Metal lead is a neurotoxin that is cumulative, destructive, and continuous in the hemophilic, cardiovascular, and renal systems. High lead concentrations have harmful health effects on humans resulting in anemia, hypertension, brain muscle weakness, and kidney damage (Boskabady *et al*., 2018). Children who have suffered from lead toxicity tend to show symptoms of hyperactivity, are easily bored, easily influenced, have difficulty concentrating on their environment, including lessons, and will experience disturbances in later adulthood that is the children become slow to think. Usually, people will experience lead poisoning if they consume lead of around 0.2 to 2 mg/day (Gusnita, 2012). Cases that occurred in battery recycling plants in China, Kenya, and Brazil, have been identified as a source of increased blood lead levels in surrounding communities (Zhang *et a*l., 2016). One case of battery poisoning has been reported that children living near formal sector lead battery manufacturing and recycling facilities had an average blood lead level (BLL) of 29 g/dl, in ten studies from seven developing countries (Gottesfeld & Pokhrel, 2011).

Regarding the accumulation of B3 waste, Wilyani *et al*., (2018) research stated that the estimated generation of electronic waste in Indonesia that has been issued by the STEP Initiative organization, the devices that become electronic waste in 2014 are predicted to be 745 metric kilotons or around 745 million kg, and there is no handling specifically from e-waste in controlling electronic waste in Indonesia (Wilyani *et al*., 2018). Based on the official EPA decision (2019): Resource Conservation and Recovery Act (RCRA) B3 waste must be managed. It aims to reduce B3 waste. Because if B3 waste continues to increase, it will cause damage to the human living environment. Therefore, it is necessary to plan other alternative materials in the manufacture of environmentally friendly batteries (Biobatteries).

Based on research by Abidin *et al*., (2020), it was previously reported that rotten tomatoes and coconut pulp can be used as environmentally friendly electrolytes in batteries (Abidin *et al*., 2020). From the research, it was reported that the battery leaked and resulting in low power, current, and stability tests. Furthermore, an experiment was carried out on making biobatteries using rotten tomatoes and husk ash to avoid leakage of electrolytes from rotten tomatoes. The experiment was carried out with the hypothesis that husk ash can absorb rotten tomatoes to prevent electrolyte leakage. However, the resulting biobattery is still leaking. Starting from several previous studies, in this study, the electrolyte of the biobattery was made in the form of a gel. Biobatteries were made from carrageenan and rotten tomatoes in combination with the hypothesis that battery stability is better maintained and can prevent leakage. Therefore, the innovation of solid electrolyte biobattery based on carrageenan and rotten tomatoes as an environmentally friendly battery product is one of the solutions to reduce the use of batteries classified as B3.

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2. METHODS

The method used in this research is the experimental method. The experimental design was made in several stages starting from electrolyte preparation, battery discharge, and biobattery manufacture. Then, to determine the performance of the bio battery, the biobattery was tested with several tests such as testing the potential difference, current strength, and initial power of the bio battery, testing the ability when applied to an alarm clock, testing the recharging ability, and stability of the biobattery.

2.1. Materials

The materials used in this study were AA batteries from Bandung and Banten, rotten tomatoes from Gegerkalong traditional market in Bandung, and carrageenan obtained from chemical stores.

2.2. Instrumentation

Some instruments used in this research are the VIPER DT830B Digital Multimeter and the METTLER TOLEDO Seven Excellent Multiparameter.

2.3. Procedure

The procedure for making this biobattery refers to Abidin *et al.* (2020) on Making Biobattery Based on Coconut and Rotten Tomato Dregs. However, there are several modifications as an innovation to complement the weaknesses of biobatteries in previous studies.

2.4. Biobattery preparation

Several steps involved in biobattery preparation were as follows.

2.4.1. Making rotten tomato juice

Rotten tomatoes were mashed for 10 minutes without additional liquid until they got smooth. Thus, rotten tomato juice was obtained. Next, the rotten tomato juice was filtered. The filtrate was taken and stored in a closed container.

2.4.2. Rotten tomato juice acidity test

Rotten tomato juice was filtered and tested for acidity using a pH meter.

2.4.3. Preparation of mixed carrageenan electrolyte and rotten tomato juice

Various concentrations of 1, 2, 3, 4, and 5 w/v% were mixed with rotten tomato juice. The carrageenan and rotten tomato juice were stirred until it got homogeneous. Then, it was heated until the carrageenan was completely dissolved.

2.4.4. Biobattery assembly

The AA battery was removed from the tube coating using a cutter and a flat-head screwdriver. Then, the top of the battery was opened, and the cathode was slowly pulled. Next, the battery was discharged until the zinc tube (anode) of the battery was empty (no electrolyte).

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The empty battery was filled with various electrolyte concentrations of rotten tomatoes and carrageenan. Then, the cathode obtained from the AA battery was inserted. Then, the battery cover was closed tightly. Next, the previously opened battery part was glued.

2.5. Biobattery test

Biobatteries were assembled and tested with several tests.

2.5.1 Potential difference, current strength, and initial biobattery power

The assembled biobattery was connected to a multimeter. In the potential difference test, the positive pole on the battery was connected to the positive pole on the multimeter, which was marked with a red wire. Meanwhile, the negative pole on the battery was connected to the negative pole on the black multimeter. In the current strength test, the multimeter setting was changed. The positive pole on the battery was connected to the positive pole on the multimeter, which was marked with a black wire. Meanwhile, the negative pole on the battery was connected to the negative pole on the multimeter, which was red. Biobattery power is known from the product of the multiplication of the potential difference value with the resulting strong current of the biobattery. Further analysis was done to determine the battery with the initial performance from the largest to the smallest performance. We calculated the power of each resulting battery using Equation (1).

$$P = V \times I \tag{1}$$

where P is the Power (W), V is the Potential Difference (V), and I is the Current Strong (A).

2.5.2 App on alarm clock

The biobatteries were connected to an alarm clock. Then, they were left until the hour hand on the alarm clock did not move anymore. During the testing, we recorded the length of time of the alarm clock that was switched on.

2.5.3 Recharging ability

Biobatteries were recorded for getting the potential difference, current strength, and power. They were connected to an AA Battery Charger for 30 minutes. Then, the potential difference, current, and voltage on each biobattery were measured.

2.5.4 Potential difference stability, current strength, and biobattery power

Biobatteries measured potential difference, current strength, and power for 3 consecutive days. Then, we compared the data every day.

3. RESULTS AND DISCUSSION

3.1 Potential difference, current strength, and initial biobattery power

The biobattery was made from an electrolyte mixture of carrageenan and rotten tomatoes. Carrageenan was chosen because it can make a liquid into a gel form. Meanwhile, rotten tomatoes were chosen because of their abundance and their potential has not been fully utilized. On the other hand, when compared to fresh tomatoes, rotten tomatoes have a higher acidity level than fresh tomatoes. Based on research by Rahayu *et al*, (2022) the pH of tomatoes will turn more acidic when the fruit is rotten. The pH value of tomatoes under ripe conditions was 4.90, decreased to 4.66 in ripe fruit conditions, then the pH value fell back to 3.53 in rotten fruit conditions.

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The completed biobattery was tested for potential difference, current strength, and power. Replication was carried out 3 times on batteries 1, 2, 3, 4, and 5% of carrageenan against rotten tomatoes, which can be seen in **Table 1.** The data was processed so that it gets the average value and was presented in the form of a curve. **Figure 1** is a curve of the effect of carrageenan concentration (%) on the average initial potential difference of the Biobattery.

Table 1. Results of initial potential difference, current strength, and biobattery power.

Carrageenan Concentration in Rotten Tomatoes (%)	Biobattery	Potential Difference (V)	Current (mA)	Power (mW)
1%	I	1.50	2.20	**3.30**
	II	1.58	2.40	**3.79**
	III	1.53	3.00	**4.59**
Average		1.54	2.53	**3.89**
Standard Deviation		0.04	0.42	**0.65**
2%	I	1.56	2.50	**3.90**
	II	1.53	2.30	**3.52**
	III	1.55	2.40	**3.72**
Average		1.55	2.40	**3.71**
Standard Deviation		0.02	0.10	**0.19**
3%	I	1.55	2.60	**4.03**
	II	1.52	2.40	**3.65**
	III	1.52	2.40	**3.65**
Average		1.53	2.47	**3.78**
Standard Deviation		0.02	0.12	**0.22**
4%	I	1.49	2.40	**3.58**
	II	1.50	2.00	**3.00**
	III	1.52	2.80	**4.26**
Average		1.50	2.40	**3.61**
Standard Deviation		0.02	0.40	**0.63**
5%	I	1.51	2.40	**3.62**
	II	1.54	2.10	**3.23**
	III	1.52	2.20	**3.34**
Average		1.52	2.23	**3.40**
Standard Deviation		0.02	0.15	**0.20**

Figure 1 shows that the average potential difference of all batteries is equivalent to the potential difference of a commercial battery, namely, 1.5 V. Some batteries have a potential difference that exceeds 1.5 V, that is, a battery with 1% carrageenan has an average potential difference of 1.54 V; 2% carrageenan has an average potential difference of 1.55 V; 3% carrageenan has an average potential difference of 1.53 V; 5% carrageenan has an average potential difference of 1.51 V. Thus, it is known that the difference in concentration of carrageenan does not significantly affect the difference in the potential difference of biobattery. It cannot be concluded whether the addition or reduction of carrageenan can affect the increase or decrease in the potential difference in the battery.

Next, the current strength was measured. **Figure 2** is a curve of the effect of carrageenan concentration (%) on the average initial strength of the Biobattery. **Figure 2** shows that the average current strength of all batteries is still small. Batteries with 1% carrageenan have an average current strength of 2.53 mA; 2% carrageenan has an average current of 2.54 mA; 3%

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carrageenan has an average current of 2.47 mA; 4% carrageenan has an average current of 2.4 mA; and 5% carrageenan has an average current of 2.23 mA. Based on the curve, it is known that the difference in carrageenan concentration does not significantly affect the difference in the current strength of the biobattery. It cannot be concluded whether the addition or reduction of carrageenan can affect the increase or decrease in the potential difference in the battery. The biobattery power was calculated by multiplying the value of the potential difference with the current strength. **Figure 3** is a curve of the effect of carrageenan concentration (%) on the average initial power of the biobattery.

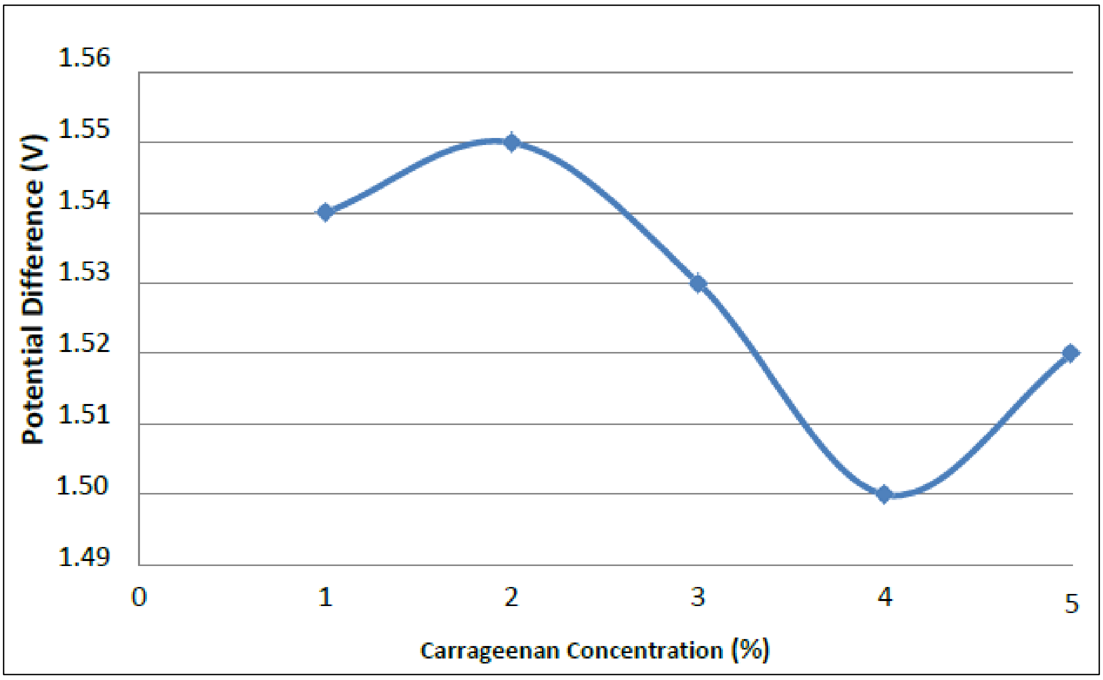

Figure 1. Comparison curve of carrageenan concentration (%) to the average initial potential difference of biobattery.

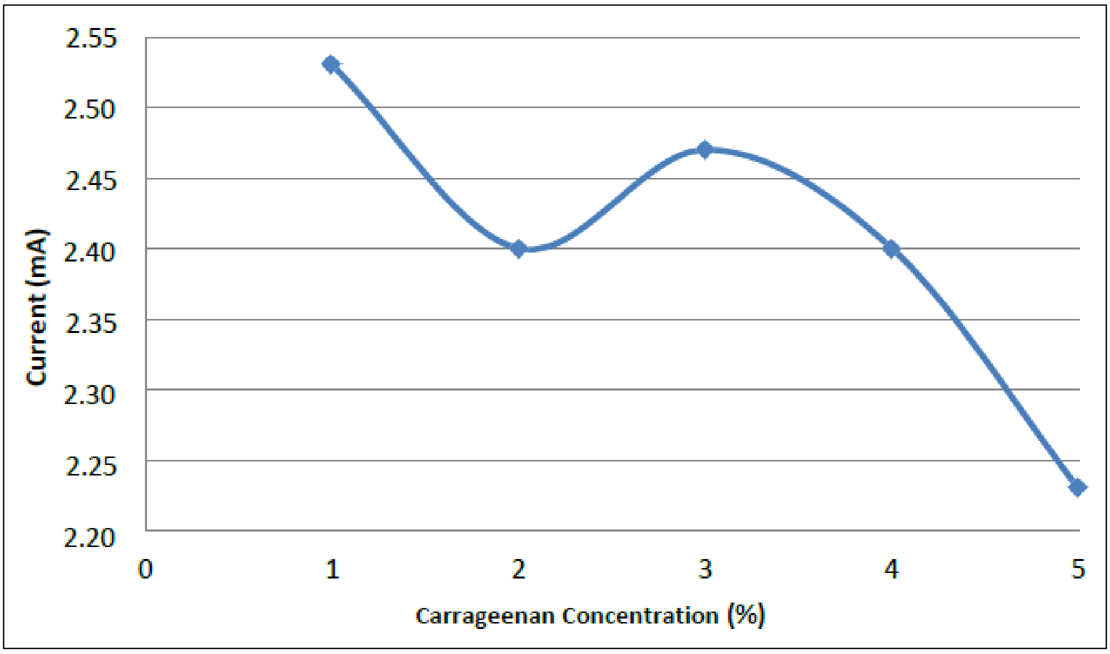

Figure 2. Comparison curve of carrageenan concentration (%) to the average initial current strength of biobattery.

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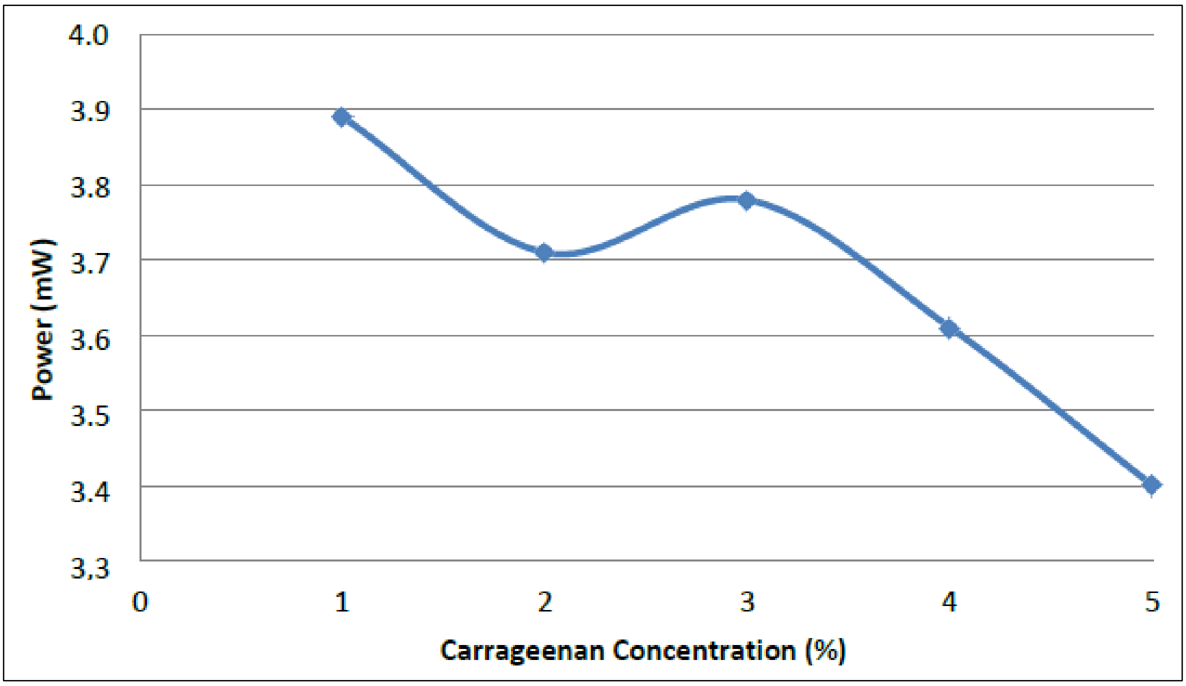

Figure 3. Comparison curve of carrageenan concentration (%) to initial average power (mW).

Figure 3 shows that the average power of all batteries is still small, in mW. This is influenced by the small current generated. Batteries with 1% carrageenan have an average power of 3.89 mW; 2% carrageenan has an average power of 3.71 mW; 3% carrageenan has an average power of 3.78 mW; 4% carrageenan has an average power of 3.61 mW; 5% carrageenan has an average power of 3.40 mW. Based on the curve, it is known that the difference in carrageenan concentration does not significantly affect the difference in the current strength of the biobattery. However, it can be concluded that the condition of the battery with the largest performance to the smallest performance is 1% battery; 3%; 2%; 4%; and 5% carrageenan against rotten tomatoes.

3.2 App on alarm clock

The following is the ability of the biobattery to be tested against an alarm clock to find out whether the biobattery has the potential to be applied or not. Tests were carried out using batteries with the best performance from each concentration of carrageenan (i.e. 1, 2, 3, 4, and 5%) compared to rotten tomatoes as shown in **Table 2**.

Table 2. Table of experimental results of biobattery applications on alarm clocks.

Carrageenan Concentration in Rotten Tomatoes (%)	Battery	Time (s)
1	II	60
2	III	4205
3	II	2065
4	II	130
5	II	0

The following is an experimental curve of the Biobattery application on the alarm clock, it can be seen in **Figure 4**. **Figure 4** shows that all batteries can turn on the alarm clock, except for the biobattery with a 5% carrageenan. A biobattery with 1% carrageenan can turn on the alarm clock for 60 seconds (s); a biobattery with 2% carrageenan can turn on the alarm clock for 4205 s; a biobattery with 3% carrageenan can turn on the alarm clock for 2065 s; a biobattery with 4% carrageenan can turn on the alarm clock for 130 s.

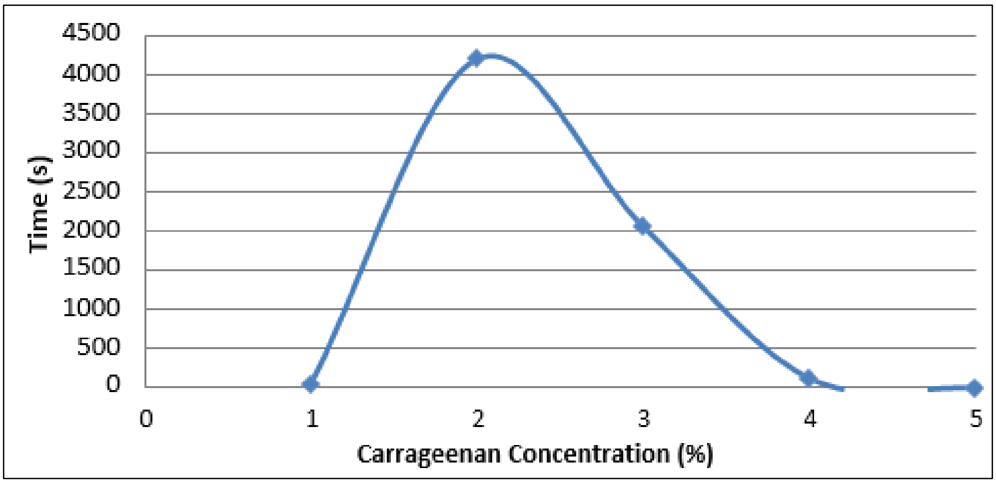

Figure 4. Comparison curve of carrageenan concentration (%) against time (s) in the first experiment.

3.3 Recharging ability

Biobatteries are tested for their recharging ability to determine whether they are categorized as primary batteries (one use only) or secondary batteries (rechargeable batteries). First, the potential difference, current strength, and initial power of biobattery were measured. After that, the battery was recharged for 30 minutes and the potential difference, current strength, and power after recharging were recorded as shown in **Table 3**. Next, the biobattery was applied to the alarm clock until the alarm clock needle did not move anymore. Then, the potential difference, current, and power were measured before recharging. Furthermore, it was recharged for 30 minutes. The results of the measurement of potential difference, current, and power after recharging were recorded as shown in **Table 4**.

Table 3. Results of the first experiment of recharging biobatteries.

Carrageenan Concentration in Rotten Tomatoes (%)	Battery	Potential Difference (V)	Current (mA)	Power (mW)
1	II	1.73	1.10	1.90
2	III	1.74	3.50	6.09
3	II	1.67	2.50	4.18
4	II	1.60	1.80	2.88
5	II	0.70	0.59	0.41

Table 4. Results of the second experiment of recharging biobatteries.

Carrageenan Concentration in Rotten Tomatoes (%)	Battery	Potential Difference (V)	Current (mA)	Power (mW)
2	III	2.12	2.60	5.51
3	II	2.15	2.70	5.81
4	II	2.09	3.70	7.73
5	II	2.20	2.10	4.62

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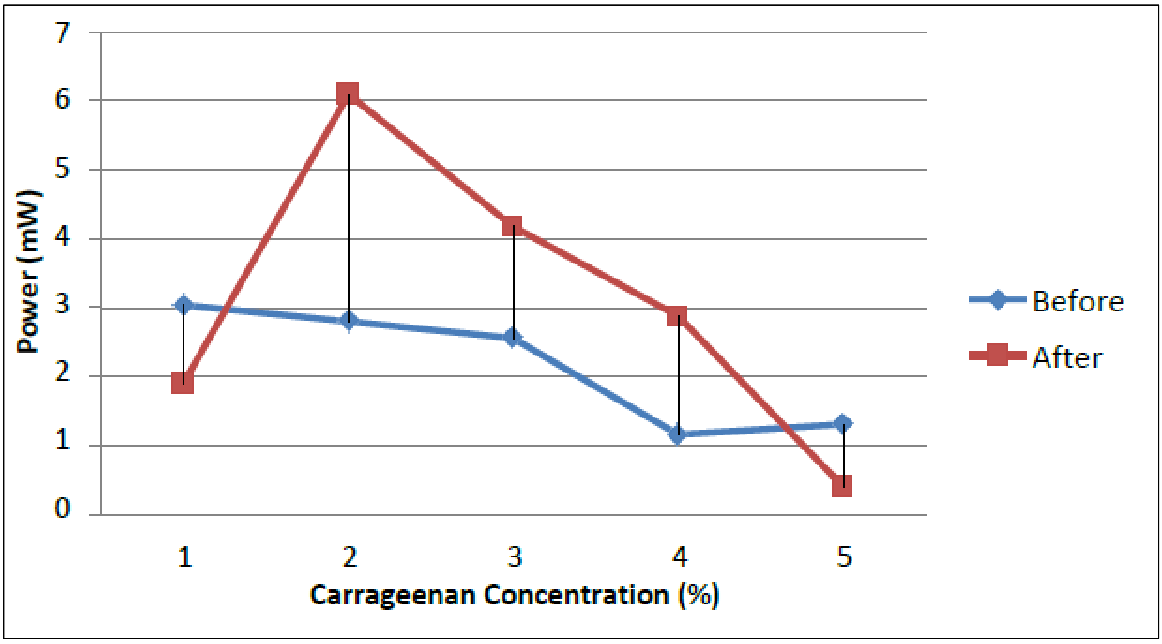

Figure 5. Power comparison curve before and after recharging in the first experiment.

The curve in **Figure 5** presents data that the biobattery recharging process went well at a carrageenan concentration of 2, 3, and 4%. Biobattery with 2% carrageenan has increased power from 2.8 to 6.09 mW. Biobattery with 3% carrageenan has increased power from 2.56 to 4.18 mW. Biobattery with 4% carrageenan has increased power from 1.17 to 2.88 mW. In contrast to those three biobatteries, biobatteries with carrageenan concentrations of 1% and 5% experienced a decrease in power. Biobattery with 1% carrageenan has decreased power from 3.04 to 1.90 mW. Biobattery power with 5% carrageenan concentration decreased from 1.31 to 0.41 mW. Biobatteries with 1% carrageenan concentration experienced a decrease in power due to electrolyte leakage during recharging. This results in a reduced volume of electrolytes in the biobattery. Indeed, this phenomenon will be in line with the decrease in power in the biobattery with a carrageenan concentration of 1%. Meanwhile, the cause of decreased biobatteries power with 5% carrageenan concentration was presumably because, during the recharging process, there was no incoming electricity but outgoing electricity.

This happens because the capacity of the battery recharging area is 4 batteries, but the biobattery recharging process with a 5% carrageenan only fills one of those recharging areas. The validation process shows that the phenomenon of biobattery with a carrageenan concentration of 5% was true, then a second experiment was carried out on recharging the biobattery using a biobattery with a carrageenan concentration of 2, 3, 4, and 5%. The following **Figure 6** is a curve of the second experiment of recharging biobatteries.

Figure 6 presents data that the biobattery recharging process is going well on all biobatteries. Biobatteries with a carrageenan concentration of 1% are ignored because they have leaked. Biobattery with 2% carrageenan has increased power from 3.537 to 5.510 mW. Biobattery with 3% carrageenan has increased power from 2,390 to 5.810 mW. Biobattery with 4% carrageenan has increased power from 3.11 to 7.730 mW. Biobattery with 5% carrageenan has increased power from 0.820 to 4.620 mW. Based on the two recharging experiments, it can be seen that the biobattery is a secondary battery as evidenced by the increase in power from the condition of the biobattery before to after recharging.

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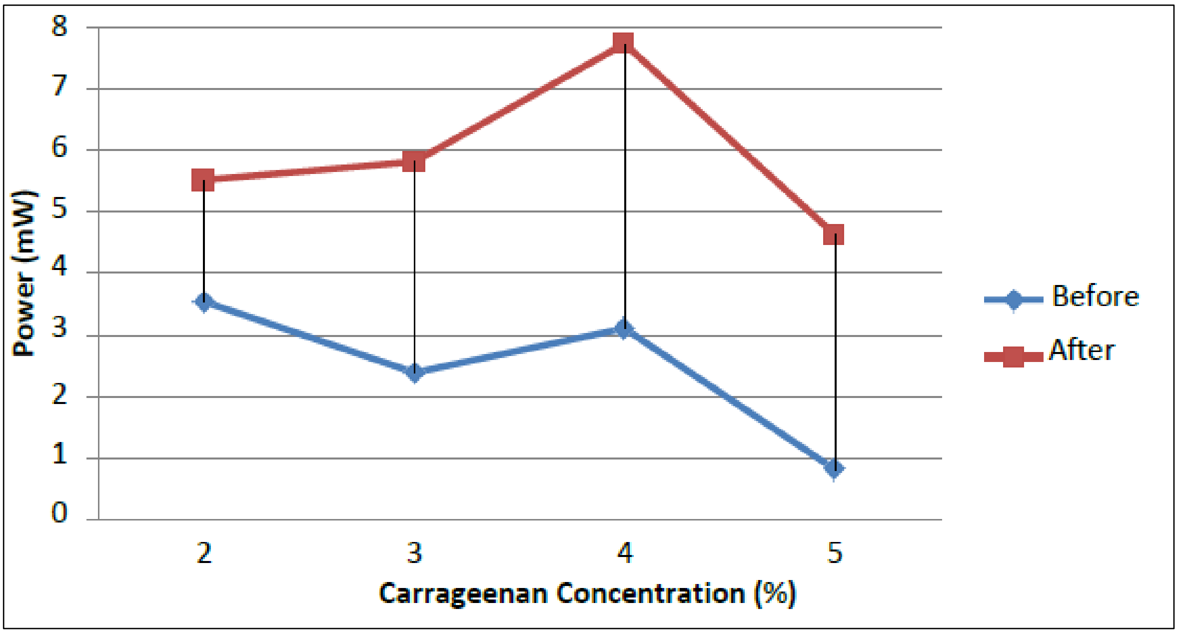

Figure 6. Power comparison curve before and after recharging in the second experiment.

3.4 Biobattery stability

The stability of the biobattery was tested to determine the phenomenon of self-discharging of the biobattery and to determine the percentage of self-discharging of the biobattery. The stability test data was presented along with the potential difference value. This test was not presented in the value of the stability of biobattery power because there are irregularities in **Table 5** of the effect of the concentration of carrageenan on the value of the stability of the power of the battery. The data on the effect of carrageenan concentration on the stability value of the potential difference was quite representative to explain the self-discharging phenomenon as shown in **Table 6**.

Table 5. Biobattery power stability values.

Battery	Potential Difference (V)		
	Day 1	Day 2	Day 3
1	3.89	2.90	1.65
2	3.71	2.37	1.52
3	3.78	2.25	3.03
4	3.61	0.78	2.79
5	3.40	0.99	1.68

Table 6. Stability values for biobattery potential differences.

Battery	Potential Difference (V)		
	Day 1	Day 2	Day 3
1	1.54	1.29	1.24
2	1.55	1.29	1.00
3	1.53	1.30	1.23
4	1.50	1.07	1.06
5	1.52	1.27	1.18

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Figure 7 shows the curve of the effect of carrageenan concentration on the stability value of the potential difference of biobattery. In **Figure 7**, the curve shows that there is a self-discharging phenomenon in the biobattery. Although, the voltage drop from day to day is not very significant, however, this phenomenon needs special attention in the next research.

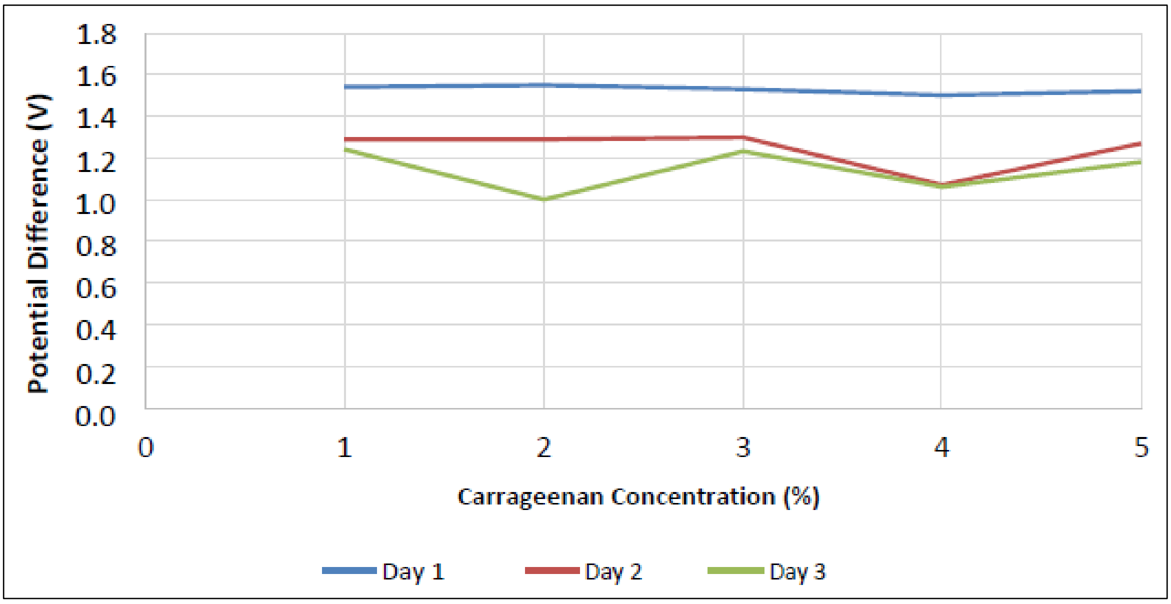

Figure 7. The curve of the effect of carrageenan concentration (%) on the stability value of the potential difference (V).

Biobatteries with 1% carrageenan experienced a decrease in potential difference, initially from 1.54 to 1.29 V on the 2nd day and 1.24 V on the 3rd day. Biobatteries with 2% carrageenan experienced a decrease in potential difference, initially from 1.55 to 1.29 V on the 2nd day and 1V on the 3rd day. Biobatteries with 3% carrageenan experienced a decrease in potential difference, initially from 1.53 to 1.3 V on the 2nd day and 1.23 V on the 3rd day. Biobatteries with 4% carrageenan experienced a decrease in potential difference, initially from 1.50 to 1.07 V on the 2nd day and 1.06 V on the 3rd day. Biobattery with 5% carrageenan experienced a decrease in potential difference, initially from 1.52 to 1.27 V on the 2nd day and 1.18 V on the 3rd day. Stability testing was continued by calculating the percentage of voltage drop produced by the biobattery from day to day as listed in **Table 7**.

Table 7. Percentage of decrease in biobattery potential difference.

Battery	Percentage (%)	
	Day 2	Day 3
1	16.2	19.5
2	16.8	35.5
3	15.0	19.6
4	28.7	29.3
5	16.4	22.4

Figure 8 is a curve of the effect of carrageenan concentration on the percentage of decrease in the value of the biobattery potential difference. **Figure 8** shows that the self-

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discharging phenomenon in the biobattery occurs every day. This was evidenced by the increase in the percentage of decrease in the value of the biobattery potential difference.

Biobatteries with a concentration of 1% carrageenan experienced an increase in the percentage of decrease in potential value, at first 16% on the 2nd day and became 19% on the 3rd day. Biobatteries with a concentration of 2% carrageenan experienced an increase in the percentage of decrease in potential value, at first 17% on the 2nd day and to 35% on the 3rd day. Biobatteries with a concentration of 3% carrageenan experienced an increase in the percentage of decrease in potential value, at first 15% on the 2nd day and to 20% on the 3rd day. Biobattery with a concentration of 4% carrageenan experienced an increase in the percentage of decrease in potential value, initially 28.7% on the 2nd day and became 29.3% on the 3rd day. Biobatteries with a concentration of 5% carrageenan experienced an increase in the percentage of decrease in potential value, at first 16% on the 2nd day and became 22% on the 3rd day.

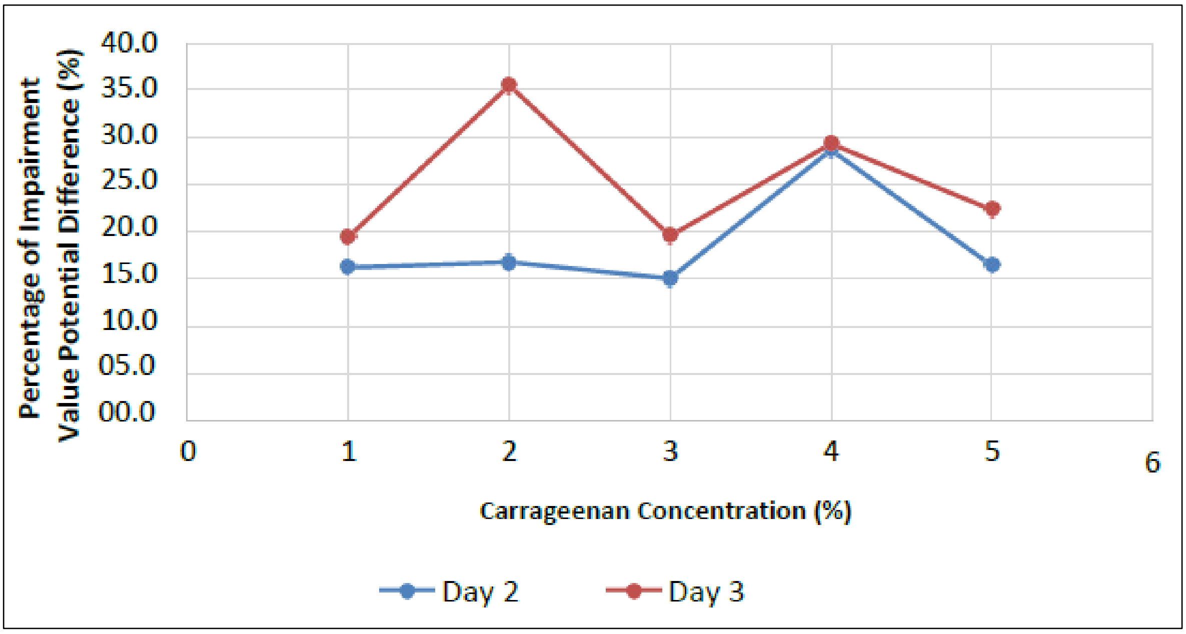

Figure 8. The curve of the effect of carrageenan concentration on the percentage of decrease in the value of potential difference.

4. CONCLUSION

Based on the research that has been carried out, several factors can be concluded including the difference in carrageenan concentration does not significantly affect the difference in potential difference, current strength, and power of the biobattery. On the other hand, the potential difference value of the biobattery has reached the potential difference value of a commercial battery, which is 1.5 V. Furthermore, in the application of the clock, the experimental results show that all batteries can turn on the alarm clock, except for the Biobattery with a 5% carrageenan. Then, the ability to recharge the biobattery was evidenced by the increase in power from the condition of the biobattery before recharging to after recharging. Thus, this biobattery can be called a secondary battery, and this biobattery also experiences a self-discharging phenomenon.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

7. REFERENCES

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