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DEVELOPMENT OF POTATO NANO CARBON AS ELECTRODE FOR SUPERCAPACITORS ACHIEVES GREEN-SUSTAINABLE DEVELOPMENT GOALS

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ABSTRACT
The development of potato nanocarbon as an electrode from potatoes for supercapacitors will answer the energy needs that are needed and are continuously researched. This research was conducted in the laboratory by giving marinade treatment to potatoes and measured repeatedly and testing was carried out to determine the extent of the carbon content so that potatoes are very good to be used as electrodes with electroplating method. The results obtained were 0.8 grams of potatoes with a very high conductivity increase to 0.97 m S. The result TEM 160 nm after treatment an average size of 100 nm successfully coated on the surface of the particles. FTIR shows a wavelength of 3282.48 cm due to the width of potato absorption and overlapping with the C-H-O group. AAS shows the adsorption capacity of modified potato on metals occurs in the pH range 4.5-5.5. Analysis of potatoes to be made as electrodes with two positive and negative pieces showed better dispersion stability. The electrodes are made and have been tested using a smartphone. The acid in the potato forms a chemical reaction with zinc and copper and when electrons flow from one material to another energy is released.
Keywords: *Potato, Nano Carbon, Electrode, Supercapacitor, Green-Sustainable.*

1. Introduction

Nowadays the need for energy today is increasing and capacitors are able to reserve electrical energy on a large scale. One of them is our needs regarding electrical energy, the use of electrical energy of course also experiences improvement. The various technologies that exist today, most of them requires electrical energy to operate the device. As an examples cell phones, air conditioners (AC), laptops and our usual electronic devices Daily use requires a battery as a storage device energy. However, the use of batteries as storage devices is assessed less efficient, because it has a small power density and takes time a long time to store electrical energy into a storage device(William et al., 2022). Small power capacity results in short circuits usage period of the storage device, resulting in waste generation of course it is dangerous for the environment (Dayana & Satria, 2024).

In response to the problems above, many researchers have begun to develop an energy storage device rated to be capable of storing and releasing loads with high power density quickly over along life cycle prolonged, which is called a supercapacitor. Supercapacitor saves energy by accumulating the charge of the respective electrolyte solutions Each charge will move to the electrode surface during the storage process energy through electrostatic forces (Hoffmann et al., 2020).

This research refers to the type of electrode raw material used for supercapacitors. Generally, electrode raw materials are often used for supercapacitors are graphene, carbon nanotubes, nanocomposites, carbon air gels, metal oxides, and conductive polymers. However, the availability of materials Limited raw materials and relatively expensive prices are constraining factors making it. Therefore, renewable innovation is needed in cell manufacturing supercapacitors with cheap raw materials and high performance the same. One way is by using biomass as raw material activated carbon in making electrodes for supercapacitors (Rianna et al., 2024). The use of biomass as a supercapacitor material is considered friendlier environment and can reduce unused waste, by utilize discarded waste into active carbon which has a high selling value.

Activated carbon is widely used in various electrochemical applications the other is as an electrode material. This is because the price is cheap, basic ingredients that are easy to obtain from various types of natural ingredients, easy to use synthesize, can be obtained in the form of powder, fiber, and composite, widely large surface and adjustable pores. Easy carbon electrode polarized, stable in different solutions (acidic, basic and aprotic) and stable within a certain temperature range (Hermanto et al., 2024). Activated carbon can be used as an electrode for supercapacitors because has a unique morphological structure, good pore size distribution, good chemical stability, high specific surface area and conductivity high thermal and easy preparation process and lignocellulos(Dayana et al., 2019). A number of Biomass that contains lignocellulose includes coconut shells (Pertiwi et al., 2022), snake fruit peel (Din et al., 2023), banana peel (Zhong et al., 2022) , and potato peel(Dayana & Satria, 2024) .Compared with fruit skins, not many people have using potatoes as raw material for making activated carbon, even though potatoes is a very popular food. Even in several countries, including Indonesia, Potatoes are a substitute for staple food. In the world of agriculture, potatoes are one of the five types of important food commodities in the world, apart from wheat, corn, sorghum, and rice(Bukit et al., 2022). Potatoes can be used for various things, one of which is activated carbon. The presence of electrical content in potatoes because potatoes contain salt and water. One When salt reacts with water it becomes a salt solution that can generate electricity or called an electrolyte solution. Potatoes too contains starch, table salt (NaCl) and water (H_2O). Which is an electrolyte solution have three components, namely acid, base. Based on several studies, Potatoes can be used for various things, one of which is activated carbon(Dayana et al., 2021). Therefore, the experiments that will be carried out in this research will use potatoes as the raw material. The above things are the impetus for current research to development potato carbon nano as an electrode for supercapacitors.

2. Literature Review

Capacitor

Capacitors are electronic components that function to store electric current. For those of you who are involved in the electronics sector, you are certainly familiar with what is called a capacitor. In this post we will thoroughly examine capacitors, starting from the definition, function, how they work, formulas, and also how to calculate them.

Capacitors (condensers) are electronic components that are used to store energy and electric current for a certain period of time. To be able to store electrical energy, capacitors need to collect the internal imbalance of an electric charge. When a capacitor is connected to a voltage source, what happens next is that the plates will contain electrons. If both plates of the capacitor contain electrons, then both plates will contain an electric charge. Furthermore, this electric charge will continue to be stored in the condenser for a certain period of time(Setiadi et al., 2019).

Capacitors were discovered in 1975. This object was made by a scientist named Michael Farad. Apart from that, capacitors were also made separately by a scientist named Pieter van Musschenbroek from the Netherlands in 1946, At first glance, capacitors have a shape and appearance that resembles a jar. However, over time, capacitors have undergone rapid and rapid changes. Apart from its smaller shape, this object is also increasingly being applied to various electronic circuits.

A capacitor is an electronic component consisting of two conductors. Where the two are separated by two partitions called chips. Simply put, capacitors function to store electrical energy, but there are many more functions of capacitors that you should know.

Acts as an insulator, its function is to slow down DC current (direct current). Functions as a filter in a power supply circuit. Acts as a frequency generator in the oscillator device. Functions to store voltage and current strength for a certain period. In the antenna circuit, the capacitor is the frequency. In neon lights, the function of the capacitor is to save electrical power. Another benefit of capacitors is that they can eliminate bouncing when installing a switch. Functions as a clutch, phase shifter and also a conductor.

The way a capacitor works is by flowing electrons into the capacitor. When the two plates are separated by an insulator, the capacitor will be neutral. However, when the battery is connected, the point at the negative end will repel electrons. Meanwhile, the positive end of the pole will receive it. When the capacitor is full of electrons, the voltage will change. Then the electrons contained in this capacitor will be channeled to other circuits that are needed. So, these electrons will later generate reactions in the circuit(William et al., 2022). If two or more plates are facing each other, then the plates are limited by a partition.

When each plate is electrified, a condenser will form. The two plates facing each other, the electrum material, and the distance between the two plates will affect the capacity value of a capacitor. Panic capacitance occurs when components are close to each other(Zhong et al., 2022). Then it causes a wild capacitor to occur. Unit for a capacitor is the farad, the farad unit is taken from the name of the inventor of the device, Michael Farad. One Farad in a capacitor has a very large value. You want to use it in a circuit, it must be converted first to use a smaller unit.

Supercapacitor Nano

Supercapacitors, which are known for their very fast charging and discharging power, also get improved performance thanks to nanotechnology. The use of nanocarbon materials, such as graphene, has been proven to be able to increase the capacitance of supercapacitors by more than 100% compared to conventional materials (Zhong et al., 2022). More efficient and effective supercapacitors.

Data shows that nanomaterial-based batteries can increase energy density up to 2-3 times compared to conventional batteries. For example, lithium-ion batteries using carbon nanotubes have recorded an increase in energy density from 150 Wh/kg to around 300 Wh/kg (Setiadi et al., 2019). This figure is very important to use in today's life which requires high energy reserves for all electrical equipment used.

Apart from that, nanotechnology also makes it possible to create solid electrolyte materials that are more stables and safe to use in extreme conditions. This material is able to withstand high temperatures, shocks and strong electromagnetic fields (Hoffmann et al., 2020). This makes the battery last longer.

However, one of the challenges in developing nanotechnology-based energy storage systems is the availability of raw materials and production costs. Although this technology is promising, the production processes for nanoparticles and other nanomaterials are often expensive and require complex infrastructure.

In addition, nanomaterials, such as graphene, still face challenges in mass production scale for widespread use in all fields (Petrichenko et al., 2024).

Nevertheless, the future prospects for nanotechnology-based energy storage systems remain bright. Research continues to find cheaper material alternatives and more efficient production processes. In the next few years, we may see further developments in ultra-light batteries and high-performance supercapacitors.

Nano Carbon

Activated carbon is a porous solid which is the result heating at high temperatures of materials containing carbon (Petrucci et al., 2021). Activated carbon can also be defined as an amorphous carbon compound has high porosity and area (Dayana et al., 2020) Lots of activated carbon used in various applications, such as dye adsorbents (Frida et al., 2023), adsorbents heavy metals (Bukit et al., 2023), gas adsorbent(Riana et al., 2024), catalyst supports, supercapacitor electrodes (William et al., 2022), and as a basic material carbon sulfur composite as a lithium sulfur battery cathode (Mungkin et al., 2023). Due There are various applications of activated carbon, so the need for active carbon for domestic industry
Domestic and exports are currently quite high as can be seen in Table 1.

Table 1 - Data on Export-Import of Active Carbon in Indonesia(Kujawska et al., 2024)

Year	Net (ton/Year)	
	Import	Export
2020	4.846	22.741
2021	5.778	24.791
2022	5.445	21.652
2024	6.650	25.225

Activated carbon is usually made using coal as raw material. However, Coal is a non-renewable energy source and is quite expensive. Besides Therefore, coal is not a clean fuel, coal can produce large amounts of pollutants and greenhouse gases. Therefore, activated carbon began to be made from other materials that are renewable, easy to obtain, environmentally friendly and cheap, even from waste. The raw material is biomass which contains lignocellulose. Lignocellulose is an element that contains a lot of carbon(Hartati et al., 2024).

Table 2 - Characteristics of Some Lithium Battery Cathode Materials (Wang et al., 2022)

Cathode material	Capacity (mAhg^{-1})	Voltage discharge (V)	Relative Price
CoO_2	275	3,7	1
$LiNiO_2$	274	3,4	0,86
$LiMn_2O_4$	148	3,8	0,17
S_8	1672	2,1	0,017

Dehydration is a process of elimination Activated carbon that has been activated can be used for various applications, one of which is to make carbon sulfur composites. This carbon sulfur composite can then be used as a cathode for lithium batteries (Dayana & Satria, 2024). Lithium batteries are rechargeable batteries that are widely used as an energy storage medium because they have better storage capacity, do not have memory effects and can be recharged(Saleh et al., 2024). Commercial lithium-ion batteries usually use lithium cobalt oxide (LiCoO2) as the cathode. However, the LiCoO2 compound is toxic and the price is quite expensive, so we are looking for several alternatives to replace LiCoO2 as a lithium battery cathode, including those in Table 2. If you look at Table 2, sulfur has the largest theoretical capacity value and the cheapest price among other materials. However, in its elemental form, sulfur is non-conductive, but when combined with carbon at high temperatures it becomes highly conductive. This allows carbon sulfur composites to be used in lithium battery technology (Kheildar et al., 2023).

Potato and Bio-Electrode

Generally, electrode raw materials are often used for supercapacitors are graphene, carbon nanotubes, nanocomposites, carbon air gels, metal oxides, and conductive polymers. However, the availability of materials Limited raw materials and relatively expensive prices are constraining factors making it. Therefore, renewable innovation is needed in cell manufacturing supercapacitors with cheap raw materials and high performance same. One way is by using biomass as raw material activated carbon in making electrodes for supercapacitors (Rianna et al., 2024). The use of biomass as a supercapacitor material is considered friendlier environment and can reduce unused waste, by utilize discarded waste into active carbon which has a high selling value. Activated carbon is widely used in various electrochemical applications the other is as an electrode material. This is because the price is cheap, basic ingredients that are easy to obtain from various types of natural ingredients, easy to use synthesize, can be obtained in the form of powder, fiber, and composite, widely large surface and adjustable pores. Easy carbon electrode polarized, stable in different solutions (acidic, basic and aprotic) and stable within a certain temperature range (Hermanto et al., 2024). Activated carbon can be used as an electrode for supercapacitors because has a unique morphological structure, good pore size distribution, good chemical stability, high specific surface area and conductivity high thermal and easy preparation process and lignocellulos(Dayana et al., 2019). A number of Biomass that contains lignocellulose includes coconut shells (Pertiwi et al., 2022), snake fruit peel (Din et al., 2023), banana peel (Zhong et al., 2022) , and potato peel(Dayana & Satria, 2024). Compared with fruit skins, not many people have using potatoes as raw material for making activated carbon, even though potatoes are a very popular food. Even in several countries, including Indonesia, Potatoes are a substitute for staple food. In the world of agriculture, potatoes are one of the five types of important food commodities in the world, apart from wheat, corn, sorghum, and rice(Bukit et al., 2022).

3. Research Methods

Materials

Cellulose nanocrystals obtained through synthesis in the Basic Physics USU lab, Indonesia as a precursor to the preparation of Carbon nanodots (CNDs). Ethanol and Distilled water were bought from CV. Rudang Jaya, Indonesia. Acetic acid (3 % CH_3COOH) were bought from Sigma Alderich in Germany (Hamid et al., 2024).

Preparation Nano Carbon

Russel potatoes were extracted using maceration methods with distilled water. Sweet potatoes of 2 kg were mashed and added to distilled water with a 1:5 ratio until sediment was formed. After the sediment was formed, the potato was filtered to separate the sediment from the filtrate. The sediment was then dried at 50˚C. Nano carbon is ready to be processed(Hamid et al., 2023).

Dissolve 15 grams of Nano Carbon Russel potato (Solanum tuberosum) with 5 mL of distilled water and stir with a stirrer at 85 C on a hot plate then add 5 mL of 3% acetic acid with a stirring time of 25 minutes. After being homogeneous, 10 mg of nano carbon synthesized from burning cellulose nanocrystals were added in a microwave and stirred for 1 hour. A total of 20 mL of potato/nanocarbon which had dissolved was put into a beaker glass to be used as an electrolyte solution in the coating process and marinize according to previous experiments (Dayana et al., 2021), (William et al., 2022).

Method

Cu electrodes were strung together in parallel and dipped into the Russel potato/nanocarbon solution then a voltage of 1Volts was applied for 30 seconds with electro plating. Then the sensitive material which has been attached to the surface of the electrode is dried at 45 C after that it is tested and analyzed using several measurements and characterizations according to previous experiments (Dayana et al., 2020). Measurements and characterizations Electric conductivity, TEM, FTIR and AAS which conditionally describes the diffuse halo peak (I_{am})(Dayana et al., 2019). Intensity of reflection at 19–20° (Equation (1)) is determined for the most frequently used hydrated form of potato, while intensity of either (Equation (2)) is determined for the anhydrous form of potato.

$$CrI = (I_{200} - I_{am})/I_{200} \tag{1}$$

$$CrI = (I_{110} - I_{am})/I_{110} \text{ or } CrI = (I_{020} - I_{am})/I_{020} \tag{2}$$

$$CrI = S_{crystalline}/S_{total} \tag{3}$$

$$CrI = S_{crystalline}/S_{crystalline} + S_{am} \tag{4}$$

$$CrI = (S_{total} - S_{am})/S_{total}, \tag{5}$$

The crystallinity index is calculated from the ratio between the integral intensities of crystalline and amorphous scattering (Equation (6) (Zhong et al., 2022),(William et al., 2022).

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$$CrI = \int I_{cr}\, d\theta / \int I_{total}\, d\theta = F_{cr}/F_{cr} + F_{am}, \tag{6}$$

$$Csp = \int Idv \,/\, 2m\, \Delta Vv \tag{7}$$

$$Csp = It/m\Delta V \tag{8}$$

where:

C_{sp} (F/g): Specific Capacitance (Gravimetric) ; I (A): Current (during discharge)
T (s): Total time to discharging ; M (g): Mass of electrode, ΔV
(V): Range of potential, ; ν (V/s): Potential scan rate

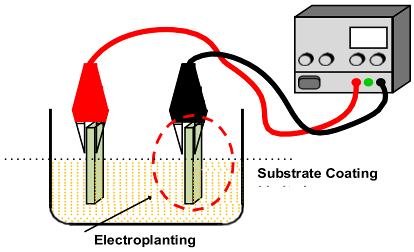

Fig. 1. Element of electroplating and process of electroplating

4. Results and Discussions

Electrical conductivity

Conductivity is the ability of a material to move an electric charge (electron) over a certain distance, conductivity depends on the resistance of a material. Conductivity meter is a method of measuring electrical conductivity aimed at determining the ability of ions in water to conduct electricity and predicting mineral content in water (Tetuko et al., 2019),(Dayana et al., 2020). Potato/PVA/glycerol/LiClO4 with a ratio of 10/90/20/20, 30/70/20/20, 50/50/20/20, 70/30/20/20 and 90/10/20/20. Produces electrical conductivity of 2.01 x 10-7 S/cm, 2.52 x 10-6 S/cm, 8.62 x 10-6 S/cm, 4.8 x 10-5 S/cm and 4.23 x 10-5 S/cm. It can be seen that the highest conductivity in the composition of 70/30/20/20 is 4.8 x 10-5 S/cm. This composition is sufficient to be applied as an electrolyte in batteries.

Tabel 3. Electrical conductivity of potato

Aquades (ml)	Potato (g)	Electrical conductivity (mS)
100	0	0,01
100	0,1	0,05
100	0,4	0,23
100	0,6	0,28
100	0,8	0,97

Conductivity test was conducted by mixing with 100 ml of aquades solution, in 100 ml of aquades solution without potato mixture obtained conductivity of 0.01 mS, when 0.1 grams were added conductivity became 0.05 mS, on the addition of 0.4 grams conductivity increased rapidly to 0.23 mS, on the addition of 0.6 grams conductivity increased to 0.28 mS, and on the addition of 0.8 grams conductivity increased very high to 0.97 m S. So, it can be seen that the aquadest solution added with potato conductivity increased due to changes in resistance in a solution(Hamid et al., 2024). Where aquades has high resistance while aquades added with potato will cause the resistance value to decrease so that it increases the charge transfer value, so the greater the addition of potato will decrease the resistance value. So, when potato is added to the electrolyte it will increase the conductivity value of the electrolyte.

TEM characterization

TEM images and particle size distribution of Nano Carbon/Potato are presented in Figure 2 and Figure 3. The result is 160 nm after electroplating method with an average size of 100 nm. Thus, the nano carbon/potato and acetic acid carbon coating has been successfully coated on the particle surface(Hamid et al., 2023). The nano carbon/potato and acetic acid coating layer, which has oleophilic characteristics, is very important for particles to be easily dispersed and increase stability in the electrode manufacturing process by minimizing viscosity. Nano carbon/potato and acetic acid can also reduce particle agglomeration and clustering due to Van der Waals and magnetic forces between particles that affect particle sedimentation and viscosity (Hoffmann et al., 2020). This greatly affects the performance of the material as an electrode, the smaller the size of the material, the better the performance of the material because the faster the performance of the electrons in the electrode.

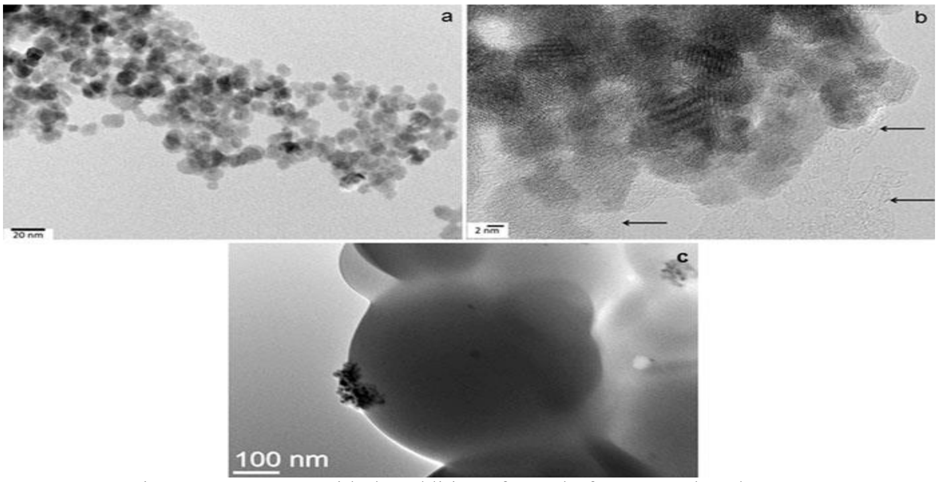

Fig. 2. TEM Image with the addition of 15 ml of Nano Carbon / Potato

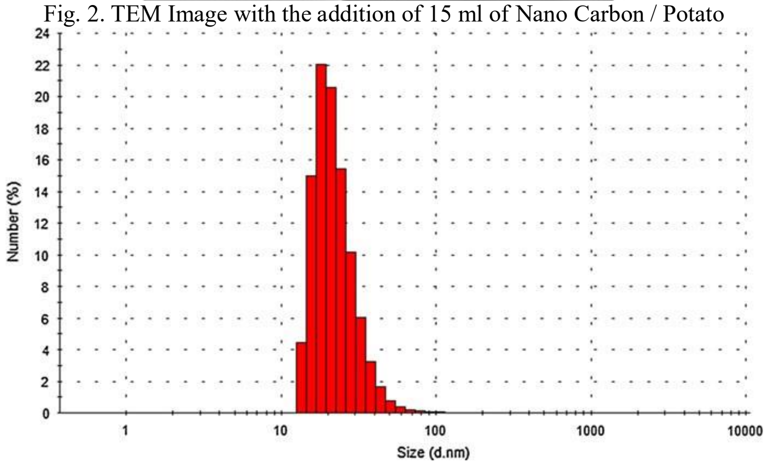

Fig. 3. Particle’s size distribution Nano Carbon/ Potato

FTIR Characterization

The IR spectrum of shows the presence of an absorption band with a sharp intensity at the wave number 3202 cm^{-1} as an absorption band from the asymmetric -NH group. The 3000-3500 cm-^{1} absorption band is the stretching vibration of the cluster NH and OH. The absorption band at the wave number 2072 cm-^{1} with medium intensity is the absorption band from the C-H group. The absorption band at wave number 1562 cm-^{1} with moderate intensity is the bending vibration of the NH amide group. Absorption bands at wave numbers 1380 and 1315 cm-^{1} with sharp intensity as secondary OH bands. FTIR shows a wavelength of 3282.48 cm due to the width of potato absorption and overlapping with the C-H-O group. Can be used as a supercapacitor electrode because it has a C double bond functional group with a sharp peak and a C-H-O functional group(Dayana et al., 2024). The group is cationic, which means it can produce an optimal electric charge. FTIR test shows that Potatoes/CNDs can be used as a supercapacitor electrode composition.

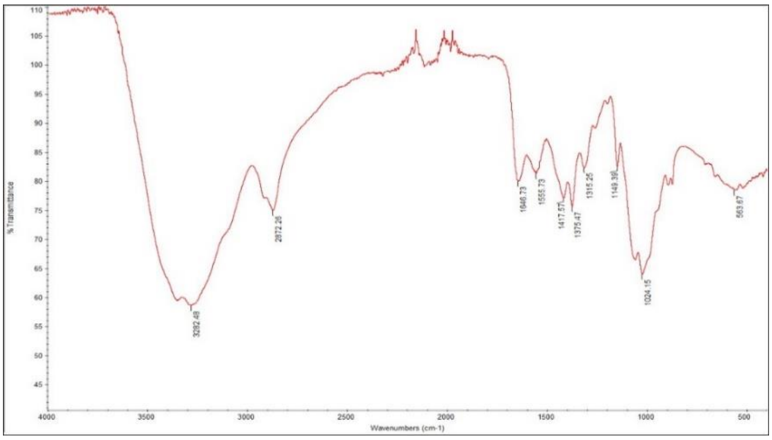

Fig. 4. FTIR Image with the addition of 15 ml of Nano Carbon / Potato

AAS characterization

The effective Carbon-potato formula was determined based on the adsorption capacity of Cu(II) metal which was analysed using AAS (Dayana et al., 2024). Power analysis results Table 1. Adsorption study of carbon-potato on Cu (II) metal.

Table 4 - Carbon-Potato adsorption study on Cu (II) metal

Adsorbent	C_i (mg/L)	C_e (mg/L)	Q_e (mg/g)
1:1	8	6,2833	0,1717
1:3	8	5,6412	0,2359
1:5	8	5,4029	0,2597
1:10	8	4,3402	0,3660

Table 4 shows that increasing the amount of carbon in the composite will increase the adsorption ability of on Cu (II) metal and the Carbon-Potato composite formulation which provides the greatest adsorption capacity is at a ratio of 1:10 (w/v), with an adsorption capacity against Cu (II) metal of 0.3660 mg/g or 2.3037 x 10-4 mol/g. The addition of active carbon composition to potato composites can cause a decrease in the crystalline properties of potato. Reducing the crystal properties can increase the adsorption capacity of the adsorbent against heavy metals(William et al., 2022),(Hermanto et al., 2024). The adsorption capacity of modified potatoes can occur at optimum pH conditions. According, the adsorption capacity of modified potatoes on metals occurs in the pH range 4.5- 5.5. In an acidic environment (pH < 4) protonation of the amine group (-NH2) on the adsorbent to become NH3+ can occur, thereby reducing the number of active sites on the surface of the modified potato adsorbent to adsorb metal ions H+ ions in solution can compete with metal ions for the active site (-NH2) thereby reducing the number of metal ions adsorbed. This makes the reaction between anions and cations in the manufacture of electrodes from potato nano carbon process faster because the inhibiting elements (toxic) have been reduced by this absorption.

Result of Electrode Potato

Analysis of potatoes to be made as electrodes with two positive and negative pieces showed better dispersion stability(Dayana et al., 2024);(Rianna et al., 2024);(Hamid et al., 2024). The electrodes are made as shown in figure 5.a and have been tested using a smartphone as shown in figure 5.b. The acid in the potato forms a chemical reaction with zinc and copper and when electrons flow from one material to another energy is released.

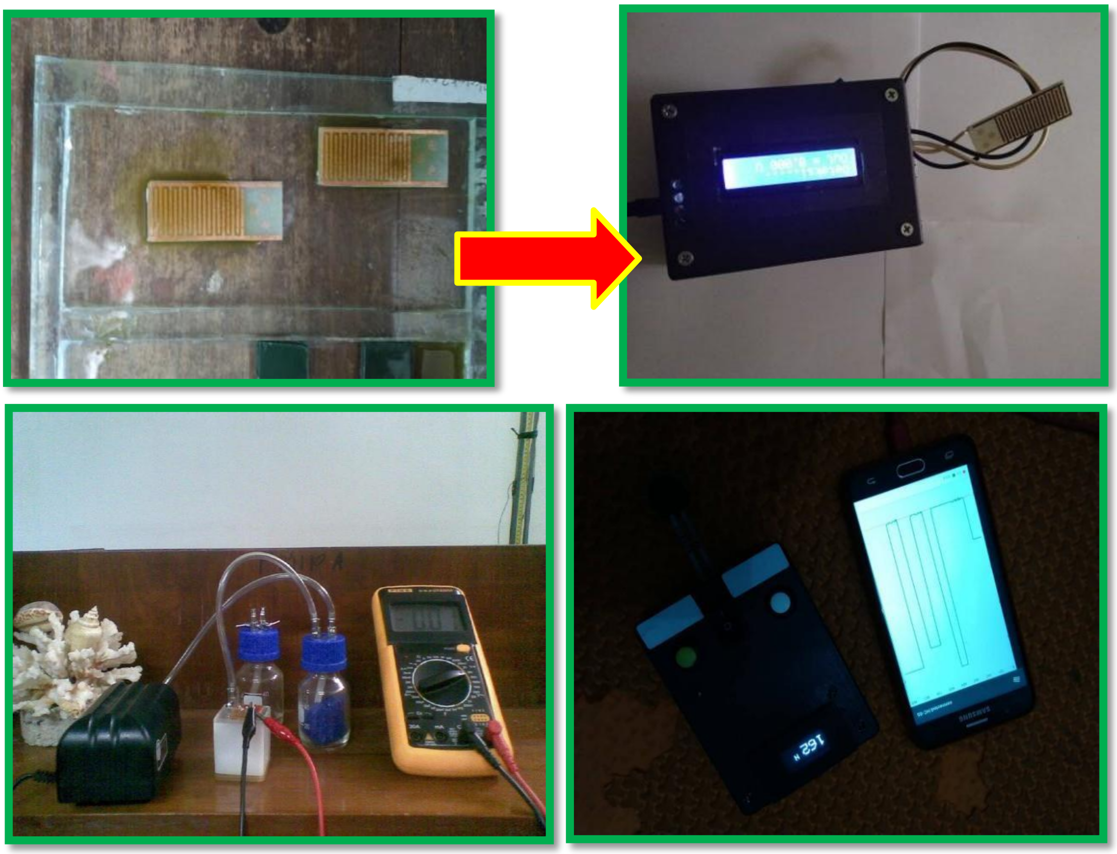

Fig. 5. Result of Electrode Potato

Table 5 - The result of material synthesis using the electroplating method.

Material	Maximum concentration (g/L)	Results	Reference
Ni–ZnO	15	0.55 µm/min	(Sajjadnejad et al., 2017)
Ni-W/ZrO_2	5	12.80 µA/cm	(Beltowska-Lehman et al., 2018)
rGO/AgNWs	3	90 % Degradation	(Singh and Dhaliwal, 2022)
Nickel ferrites	–	129.87 mg g^{-1}	(Verma and Balomajumder, 2020)
Potatoes/CNDs	0,8	0,97 m s	(This Study)

5. Conclusion

This research was conducted in the laboratory by giving marinas treatment to potatoes and measured repeatedly and testing was carried out to determine the extent of the carbon content so that potatoes are very good to be used as electrodes with electroplating method. The results obtained were 0.8 grams of potatoes with a very high conductivity increase to 0.97 m S. The result TEM 160 nm after treatment an average size of 100 nm successfully coated on the surface of the particles. FTIR shows a wavelength of 3282.48 cm due to the width of potato absorption and overlapping with the C-H-O group. AAS shows the adsorption capacity of modified potato on metals occurs in the pH range 4.5-5.5. Analysis of potatoes to be made as electodes with two positive and negative pieces showed better dispersion stability. The electrodes are made and have been tested using a smartphone. The acid in the potato forms a chemical reaction with zinc and copper and when electrons flow from one material to another energy is released.

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