Electrolysis results in a comparison of metformin using aluminum, zinc, and iron (as the anode) as well as used carbon (as the cathode)

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Abstract. Metformin is an antidiabetic drug that can be obtained easily in pharmacies/on the market, because it is traded freely, so people can easily buy and consume it. Ferrous metal, aluminum metal, and zinc metals are metal quite easy to find and are often used by the public. Metformin and Ferrous metal, aluminum metal and zinc metals are metal are quite familiar in the community. This research aims to deconcentrate metformin which can be obtained easily in pharmacies/on the market by electrolysis method, using ferrous metal, aluminum metal, and zinc metals as an anode and carbon as the cathode. Electrolysis of metformin has been carried out using ferrous metal, aluminum metal, and zinc metal as an anode. The success of the electrolysis process was seen with a decrease in the sample COD index. In the case without the addition of electrolytes using ferrous metals, the COD index of the sample reduction was very low (9-17%). This research aims to increase the success of the electrolysis process, by adding various kinds of electrolytes, such as acetic acid (weak electrolytes), hydrochloric acid (strong electrolytes), sodium chloride and Fenton reagents. The addition of electrolytes can increase electrolysis yield significantly. The interaction between metformin during electrolysis is traced to the possibility of changes in the chromophore group (with UV-Visible spectra) and the functional group (with FTIR spectra) of the sample. From the research data obtained information that there is a decrease and shift in UV-Visible spectra and changes in functional groups after the electrolysis process occurs. The best electrolysis percentage is obtained, after adding NaCl solution and Fenton’s reagent in the range of 50-66%.

1. Introduction
Metformin is an oral anti-diabetes that belongs to the biguanide class. Metformin is the first choice drug for people with type 2 diabetes, especially for people who are overweight and obese as well as people with normal kidney function. In reducing high blood sugar levels, metformin works by
inhibiting the process of gluconeogenesis and glycogenolysis, slowing the absorption of glucose in the intestine, and increasing insulin sensitivity in the body [1]. The structure of the metformin molecule is as follows in figure 1.

![Metformin Hydrochloride](image)

**Figure 1** The structure of the metformin molecule

In the last few decades, many studies have reported environmental damage due to rapid industrial growth [2] report on the indifference of large industries to the environment, then inevitably environmental pollution is an inevitable necessity, which is marked by a decrease in water quality (in terms of physical and chemical properties). Reinforce the previous statement, namely about pharmaceutical industry liquid waste and industrial pesticide liquid waste is a group of hazardous compounds that can contaminate and cause poisoning if given in excessive doses [3]. This if left unchecked will be a bad sign for the environment in general and in particular human life. [2].

Liquid waste that contains a lot of organic compounds is very dangerous if it is dumped into the river before undergoing treatments. Liquid waste contains a lot of organic compounds such as fabric dyes (e.g., Reactive Black 5, Rhodamine B Reactive, Yellow 2 Reactive) [4], bisphenol and phenol compounds, insecticides (e.g., organochlorine, organophosphate, carbamate, pyrethrin/pyrethroid, and isopropylamine glysophate, paraquat dichloride, atrazine), [5], and fungicides (e.g. chlorophenol) [6] that can cause environmental pollution. Aerobic microorganisms in the water that function as decomposers of organic compounds can only carry out their functions if a sufficient amount of oxygen is present. If the existing oxygen is insufficient in amount, the oxidation of organic compounds becomes inhibited or can only reach the decaying stage. The more oxygen needed to oxidize organic compounds the less oxygen there will be in the body of the water. This can result in a massive loss of aquatic biota [7, 8, 9, 10, 11 and 12].

The success of the electrochemical method is tremendous such as its function in degrading organic compounds were reported [13, 14]. Electrochemical methods are reported to be able to degrade organic compounds (such as Reactive Black 5 fabric dyes, Rhodamine B Reactive, Yellow 2 Reactive) which are soluble in water with very satisfactory results as reported by [13, 4]. Furthermore, it can degrade insecticides, herbicides, and fungicides. A previous study [7] demonstrated that insecticides (e.g. organochlorine, organophosphate, carbamate, pyrethrin/pyrethroid) could be degraded with very good results (around 87.6%). Herbicide compounds (e.g., isopropylamine glisophate, paraquat dichloride, atrazine) can also be reduced by an electrochemical method with almost perfect results (93.2%) [5, 6 and 7]. Studies in which electrodes were varied were able to increase the amendment of the electrolysis process. Bisphenol compounds dissolved in water were able to be reduced with excellent results using nanocomposite ZnFe2O4/TiO2 electrodes was reported [6, 7]. Variations of Fe3O4 composite electrodes synergized with the sono-electrolylhydrode system were also reported to be able to reduce atrazine well [15]. The latest research on electrochemistry utilized a boron-doped diamond (BDD) electrode that provided very significant results for the treatment of pollutants in wastewater [11 and 8]. Some of the advantages of the electrochemical method are that it is easy to do and quite inexpensive [15, 16].

The electrochemical method can be used as wastewater treatment. A lot of research has been done to treat wastewater in the pharmaceutical industry and liquid waste from the pesticide industry, one of which is by the electrolysis method. Electrolysis methods such as those conducted by [16] using
Graphite and composite electrodes as electrodes to remove organic pollutants in the water medium and desalination of water [15]. Even adsorbent materials derived from waste have also been reported [7, 5, 6] can be made active charcoal, can also be able to be applied as organic material adsorbents in a liquid medium. Electrocoagulation methods have also been tried to reduce components of organic waste. Carbon felt (CF) is also best used as an electrode in the electrochemical process using the Fenton reagent was reported [6, 7]. The use of carbon felt (CF) was further strengthened by (Dominguez et al., 2018) who reported the use of these electrodes to extract organochlorine pesticides in groundwater satisfactorily, at a minimal cost. Other electrocoagulation such as those conducted by [17, 18]. That magnetic fabrication of Co / BiFeO3 composites and continued processing of pharmaceutical waste by activation of peroxysulphate as a catalyst was reported [18]. In this study, cobalt-di-composite "doped" ferrite bismuth (Co / BiFeO3) was prepared by the sol-gel method. The results of Co / BiFeO3 were applied to eliminate tetracycline, the results obtained were that Co / BiFeO3 had fairly high efficiency, ie 81.09% of tetracyclines could be decomposed [18]. [11] emphasized the success of degrading organic waste (atrazine) by combining two methods, namely the combination/combination of electrolysis and ozonization which varies with the pH conditions on the liquid medium.

In this research, the processing of organic compounds (pharmaceutical materials) that are soluble in water (metformin). The electrodes used were aluminum, zinc, iron (as anodes) and carbon (as the cathode). The selection of aluminum, zinc and iron metals (as anodes) was designed to reduce iron and zinc solid wastes in the environment in addition to the properties of iron and zinc metals which are easily oxidized [1, 19]. Since aluminum, iron and zinc metal easily oxidize, they are expected to be able to be oxidized into Al3+, Fe3+, and Zn2+ cations. In theory, the cations combined with hydroxide ions from the solvent (water) decomposition reaction will form deposits of Zn(OH)2, Al(OH)3 and Fe(OH)3 that become adsorbents for metformin [1, 19]. Determination of the decrease in the concentration/level of metformin in through electrolysis was determined by measuring the COD value of the sample. Decrease in COD value in the sample indicates a decrease in metformin levels after undergoing the electrolysis process. COD determination was carried out using APHA (1995) method. The results of the maximum decomposition of metformin at room temperature were 9.1% (1 cm distance electrode, 20 minutes) for zinc and carbon as the electrodes, 16.9% (1 cm distance electrode, 20 minutes) for iron and carbon as the electrodes and 14.4% (1 cm distance electrode, 20 minutes) for aluminum and carbon as the electrodes. Moreover, the optimal percentages of the decomposition of metformin at adition electrolyte solution were 88.8% (1 cm distance electrode, 20 minutes) for iron (as anode) and carbon as the electrodes, 62.1% (1 cm distance electrode, 20 minutes) for zinc (as anode) and carbon as the electrodes and 76.4% (1 cm distance electrode, 20 minutes) for aluminum (as anode) and carbon as the electrodes. The optimal voltage was obtained at 4 Volts, 1 cm electrode distance and 7.5 mA/cm2 current density.

2. Research method

2.1. Equipment and materials

2.1.1. Equipment. The equipment used is a set of titration devices (Erlenmeyer, burette, and static), glasswares, electrochemical waste treatment reactor, adaptors, zinc and ferrous metals (anodes) and carbon (cathode).

2.1.2. Materials. The materials used were an artificial liquid waste (aspirin/mefenamic acid dissolved in water), Na2SO4, NaOH, H2SO4, K2Cr2O7, HgSO4, Ag2SO4, Ferro ammonium sulfate, ferroin indicator, Whatman 40 paper, and distilled water

2.2. Instrument design
The electrolysis reactor consisted of an adaptor, Zinc (Zn) or Iron (Fe) metal (as the anode) placed parallel to the carbon plate (cathode), with varying distances of 0.5; 1; 1.5; 2; 2.5; 3; 3.5 and 4 cm. The setup was then mounted on a 1000 mL glass container and connected to a DC current source.

Figure 2. Electrolytic reactor diagram

2.3. Effects of voltage, electrode distance, pH, and time on decreasing COD value.
The sample, 500 ppm mefenamic acid dissolved in 500 mL water, was put into the reactor. HCl and NaOH were added into the solution to regulate acidic and alkaline atmospheres of the solution. In this study the pH of the solution, voltage, electrode distance and electrolysis time were varied. Al and carbon electrodes were immersed in the reactor with a distance of 1 cm. The solution was electrolyzed at a time variation of 0 to 100 minutes with an interval of 10 minutes at a voltage of 4 V and a current density of 7.5 mA/cm². COD values are determined before and after electrolysis. The same procedure was performed for voltage variations of 2, 4, 6, 8, 10 and 12 Volt, electrode distance of 0.5; 1; 1.5; 2; 2.5; 3; and 3.5 cm, and variations in pH 1, 3, 5, 7, 9, 11, 13. The same procedure was also carried out for Zn and carbon electrodes Fe and carbon electrodes.

2.4. COD Analysis (APHA, 1995)
COD determination was carried out using the iodometric titration method. As much as 5 mL distilled water as the blank solution and 5 mL of sample were put into Erlenmeyer 250 mL. They were added with 2.5 mL K2Cr2O7 - HgSO4 and 5 mL H2SO4 - Ag2SO4. The solutions were covered and heated for 2 hours in an oven at 150°C. They were then cooled and the lids were rinsed with 2 mL of distilled water. 1 mL of concentrated H2SO4 and 3 drops of ferroin indicator were added. Titration was done with ferrous ammonium sulfate standard solution of 0.025 N until the equivalence point (colored red-brown) was reached. Determination of COD levels is calculated by the following formula:

\[
\text{COD Concentration (ppm)} = \frac{(A - B) \times N \times 8000}{\text{mL sample}}
\]

Descriptions:
A = Volume (mL) of titrant for blank solution
B = Volume (mL) of titrant for sample solution
N = Solution normality of Fe(NH4)2SO4

3. Results and discussions

3.1. Effect of voltage on the percentage of electrolysis
In this study the varying voltages applied were 0.5; 1; 1.5; 2; 2.5; 3; 3.5; 4 and 5 volt. The effect of voltage is necessary to be investigated in the electrolysis process because of the relation with a total cost.

To study the effect of voltage during the electrolysis process of treatment of water containing metformin, electrolysis was carried out with varying voltages of 1 to 7 volts and current densities of 7.5 mA/cm². Electrolysis was carried out for 20 minutes at the neutral condition and electrode distance of 1 cm at room temperature. The electrolysis of metformin was measured before and after the process. Previous researchers reported that an increase in voltage will, in general, accelerate and increase electrolysis ratios until an optimum point is reached.

At 2 volts, the electrolysis obtained an optimal yield for metformin using Iron (as anode) and carbon electrodes (redeem process 17.8%), at 2 volts the electrolysis obtained an optimal yield for metformin using aluminum (as anode) and carbon electrodes (redeem process 14.2%) and at 2.5 volts the electrolysis obtained an optimal yield for metformin using Zinc (as anode) and carbon electrodes (redeem process 11.6%).

The result of the observation of varying voltages with the percentage of electrolysis (without electrolyte solution) using Zinc (as the anode) carbon electrodes, using Aluminum (as the anode) carbon electrodes and using Iron (as the anode) and carbon electrodes are shown in Figure 3.

![Figure 3. The relationship between variations in voltages with the percentage of electrolysis (without electrolyte solution) using Zinc (as the anode) carbon electrodes, using Aluminum (as the anode) carbon electrodes and using Iron (as the anode) and carbon electrodes](image)

If the voltage is less than 2 Volts (using Aluminum (as anode) carbon electrodes and using Iron (as the anode) and carbon electrodes), and 2.5 volts (using Zinc (as the anode) carbon electrodes) then the energy available for the electrolysis process is not enough. Conversely, if the voltage is raised above the optimum voltage (2 volts) it will result in a decrease in metformin electrolysis ratio as voltage increase above the optimal condition open the possibility for re-decomposition to occur to organic compounds already deposited by Fe(OH)₃ and Al(OH)₃ flocs from the electrolysis process. The same reason at using Zinc (as the anode) carbon electrodes, if the voltage is raised above the optimum voltage (2.5 volts) it will result in a decrease in metformin electrolysis ratio as voltage increase above the optimal condition open the possibility for re-decomposition to occur to organic compounds already deposited by Zn(OH)₂ flocs from the electrolysis process (principle of shifting equilibrium of chemical reaction/Le Chatelier's principle). Thus, if the voltage from an electrolysis process were to be reduced or increased, it would be counterproductive and reduce electrolysis yield.

3.2. Effect of electrodes distance on the percentage of electrolysis

In this study the varying electrodes distances applied were 0.5: 1; 1.5; 2; 2.5; 3; and 3.5 cm. The effect of distance of the electrodes is necessary to be investigated since the electrolysis process is largely
determined by the effectiveness of the electrodes (Al, Fe, and Zn as anode and carbon as the cathode). The results of the observation of distance without the electrolite solution are shown in Figure 4.

**Figure 4.** The relationship between variations in electrode distance with the percentage of electrolysis (without electrolyte solution) using Zinc (as anode) carbon electrodes, using Aluminum (as the anode) carbon electrodes and using Iron (as the anode) and carbon electrodes.

Based on the results of the study, the electrode distance affects the decrease in COD value, wherein the maximum percentage of electrolysis was obtained with electrode distance of 1 cm. The percentage of electrolysis obtained was 16.9% (iron metal as the anode), 14.4% (aluminum as the anode) and 9.1% (zinc metal as the anode). At the optimum electrode distance, an oxidation reaction from either of the anodes (iron, aluminum and zinc) would occur followed by the maximum formation of hydroxide salts which were Fe(OH)₃, Al(OH)₃ and Zn(OH)₂ salts. According to the law of attractions/electrostatics $F = \frac{Q_1Q_2}{R^2}$, where $Q_1$ and $Q_2$ are coloumb charges of A and B and R is the distance between the two particles.

During the electrolysis process at the anode, due to the effect of the solution and voltage atmosphere given, the Fe, Al and Zn metals would oxidize into their cations. The presence of hydroxide ions from the reduction of water and base would then cause the production of deposits of Fe(OH)₃, Al(OH)₃ and Zn(OH)₂. The reactions that occurred are as follows [1, 19]:

Oxidation-reduction reactions in iron metal as the anode.

Anode: $\text{Fe (s)} \rightarrow \text{Fe}^{2+} (aq) + 2 e$ \hspace{1cm} $E_0 = 0.44 \text{Volt}$

$\text{Fe}^{2+} (aq) + 2 \text{OH}^- (aq) \rightarrow \text{Fe(OH)}_2 (s)$

$2\text{H}_2\text{O}(aq) \rightarrow \text{O}_2 (g) + 4 \text{H}^+ (aq) + 4 e$

$\text{Fe (s)} + 2 \text{H}_2\text{O} + 2 \text{OH}^- \rightarrow \text{Fe(OH)}_2 (s) + \text{O}_2 (g) + 4 \text{H}^+ (aq) + 6 e$

Cathode: $6 \text{H}_2\text{O} (aq) + 6 e \rightarrow 3 \text{H}_2 (aq) + 6 \text{OH}^- (aq) E_0 = -0.83 \text{Volt}$

$\text{Fe (s)} + 8 \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_2 (s) + \text{O}_2 (g) + 3 \text{H}_2 (aq) E_0 = -0.39 \text{Volt}$

Oxidation reduction reactions in Aluminum metal as anode.

Anode: $\text{Al} \rightarrow \text{Al}^{3+} + 3 e$ \hspace{1cm} $E_0 = 1.662 \text{Volt}$

$3 \text{H}_2\text{O} + 3e \rightarrow 1.5 \text{H}_2 + 3 \text{OH}^-$ \hspace{1cm} $E_0 = -0.83 \text{Volt}$

$\text{Al} + 3 \text{H}_2\text{O} \rightarrow \text{Al}^{3+} + 1.5 \text{H}_2 + 3 \text{OH}^- \hspace{1cm} E_0 = 0.832 \text{Volt}$

$\text{Al}^{3+} + 3 \text{OH}^- \rightarrow \text{Al(OH)}_3$

Oxidation reduction reactions in zinc metal as anode.

$\text{Zn} \rightarrow \text{Zn}^{2+} + 2 e$ \hspace{1cm} $E_0 = 0.76 \text{Volt}$

$2 \text{H}_2\text{O} + 2e \rightarrow \text{H}_2 + 2 \text{OH}^- \hspace{1cm} E_0 = -0.83 \text{Volt}$

Anode: $\text{Zn} + 2 \text{H}_2\text{O} \rightarrow \text{Zn}^{2+} + \text{H}_2 + 2 \text{OH}^- \hspace{1cm} E_0 = -0.07 \text{Volt}$
The presence of oxygen dissolved in water caused ferro hydroxide deposits to oxidize to ferric hydroxide that also settles in the solution [1, 19]. The reaction is as follows:

Anode: 4 Fe(s) $\rightarrow$ 4 Fe$^{2+}$ (aq) + 8 e$^-$
4 Fe$^{2+}$ (aq) + 10 H$_2$O(aq) + O$_2$(g) $\rightarrow$ 4 Fe(OH)$_3$(s) + 8 H$^+$ (aq)

Cathode: 8 H$^+$ + 8 e$^-$$\rightarrow$ 4 H$_2$
4 Fe(s) + 10 H$_2$O(aq) + O$_2$(g) $\rightarrow$ 4 Fe(OH)$_3$(s) + 4 H$_2$

Based on the data obtained from the experiment, iron (Fe) anode was able to obtain greater electrolysis results in electrolyzing mefenamic acid than zinc (Zn) anode. This is due to the Ksp value of Fe(OH)$_3$ of 3.1 x 10$^{-36}$ that is smaller than Ksp value of Al(OH)$_3$(2x10$^{-31}$), that is smaller than Ksp value of Zn(OH)$_2$ which is 3.1 x 10$^{-17}$ [1, 19]. Thus, the formation of Fe(OH)$_3$ salt floc is easier than Al(OH)$_3$ and Zn(OH)$_2$ salt. The floc formed from these hydroxide salts would later become the floc core thought to be able to readily adsorb metformin the sample.

The reactions that occurred are as follows [1, 19]:

Zn$^{2+}$ + 2 OH$^-$ $\rightarrow$ Zn(OH)$_2$  Ksp Zn(OH)$_2$ = 3.1 x 10$^{-17}$
Al$^{3+}$ + 3 OH$^-$ $\rightarrow$ Al(OH)$_3$  Ksp Al(OH)$_3$ = 2.0 x 10$^{-31}$
Fe$^{3+}$ + 3 OH$^-$ $\rightarrow$ Fe(OH)$_3$  Ksp Fe(OH)$_3$ = 3.1 x 10$^{-36}$

The zinc hydroxide, aluminum hydroxide and ferric hydroxide deposits formed would become the floc core of the solution and would attract residues present in the solution, resulting in larger floc deposits. According to [1, 19, 20] the formation of larger the floc deposits is due to the electrostatic interaction between Zn (OH)$_2$, Al(OH)$_3$ and Fe(OH)$_3$ floc core with other particles in the solution [1, 19]. This reason is also suspected as the reason why Fe anode is more effective than the Al and the Zn anode in electrolyzing metformin in the same solution, the same electrode distance, and temperature conditions [19, 20].

The adsorption mechanism of the hydroxide salts towards metformin in the water medium can be written as follows [19]:

L…H + (OH)OFe $\rightarrow$ L…OFe + H$_2$O
L…H + (OH)OAl $\rightarrow$ L…OAl + H$_2$O
L…H + (OH)OZn $\rightarrow$ L…OZn + H$_2$O

3.3. Effect of electrolysis duration on the percentage of electrolysis at room temperature
To study the effect of duration on electrochemical treatment of water containing mefenamic acid, the electrolysis was carried out at a voltage of 2 volts (Iron as anode and carbon as cathode, Aluminum as anode and carbon as cathode) 2.5 volts (Zink as anode and carbon as cathode) and a current density of 7.5 A/cm$^2$. Electrolysis was carried out for durations of 10, 20, 30, 40, 50, 60, 70, 80 and 90 minutes at the neutral solution and electrode distance of 1 cm at room temperature. The metformin was measured before and after the electrolysis process. The researcher hypothesizes that time has a concrete dominant influence on metformin electrolysis reactions. At room temperature, the time needed for metformin electrolysis to reach optimum yield is only 20 minutes. The results of the observation can be seen in Figure 5.
Figure 5. The relationship between duration and percentage of electrolysis results for zinc and carbon electrodes, aluminum and carbon electrodes as well as iron and carbon electrodes at room temperature.

Based on figure 5 this owes to the fact that when time is raised the reduction and oxidation (redox) reactions become more effective. The faster the oxidation-reduction reaction, the greater the amount of coagulated organic compounds. Greater increase in the amount of coagulated organic compounds conforms with a more significant decrease in COD value or an increase in the percentage of metformin electrolysis. This is by the basis of Arrhenius’s theory [19] which states that temperature is one of the factors that can affect the speed of the electrolysis process and holds for the synergistic effect of temperature and time on the electrolysis process of an organic compound [15, 4].

3.4. Effect of electrolyte solution on the percentage of electrolysis

In this study the varying electrodes distances applied were 0.5; 1; 1.5; 2; 2.5; 3; and 3.5 cm. The effect of distance of the electrodes is necessary to be investigated since the electrolysis process is largely determined by the effectiveness of the electrodes (Al, Fe, and Zn as anode and carbon as the cathode). The results of the observation of distance without electrolyte solution are shown in Figure 6.

Figure 6. The relationship between variations in an electrolyte solution with the percentage of electrolysis (without electrolyte solution) using Zinc (as anode) carbon electrodes, using Aluminum (as the anode) carbon electrodes and using Iron (as the anode) and carbon electrodes.

3.5. Analysis structure metformin

3.5.1. UV-Visible Spectra Analysis. UV-Visible Spectra is a representation of covalent unsaturated groups present in a material that causes the chromophore character of the material. The wavenumbers
of metformin before electrolysis appeared around the 250 nm wavelength region. The existence of a combination of several groups of -NH chromo for contained in metformin, resulting in an electronic transition from σ to σ ∗ and also the electronic transition from ℓσ to ℓσ ∗ which causes wavelengths in the region around 250 nm. The metformin structure is as follows:

![Metformin Hydrochloride](image)

**Figure 7.** The structural formula of metformin hydrochloride [22]

UV-Visible spectra are representations of chromophore groups (covalent unsaturated groups) that exist in a material. This can explain the chromophore group component which is a constituent group of the material. So UV-Visible Spectra usually can be used for both qualitative and quantitative analyses. The spectra results obtained are presented in figure 8 as follows:

![UV-Visible spectra](image)

**Figure 8.** UV-Visible spectra of Metformin before electrolysis (Metformin tablet), after electrolysis with Iron anode, after electrolysis with Aluminum anode and after electrolysis with Zink anode.

Base on data UV – Visible spectra, there is a shift in uptake in metformin before and after electrolysis. This indicates a change in functional groups that occur during the electrolysis process. The absorption range that explains the presence of the chromophore group (amine groups) is in table 1 as follows:

| Wavenumber (cm⁻¹) | Absorbance | Characteristic Spectra          |
|-------------------|------------|---------------------------------|
| 246               | Sharp      | Amina group (σ to σ ∗)         |
| 205               | Weak       | Amina group (ℓσ to ℓσ ∗)       |

**Table 1.** Analysis UV-Visible spectra of Metformin before electrolysis (Metformin tablet), after electrolysis with Iron anode, after electrolysis with Aluminum anode and after electrolysis with Zink anode. Electrolysis without electrolyte solution and with an added electrolyte solution.

3.5.2. **FTIR Spectra Analysis.** FTIR spectra is a representation of characteristic spectra present in a material, which explains the functional groups in the material. The wavenumbers of metformin before electrolysis appeared around the 1670 cm⁻¹ wavelength region indicating the functional group of
carboxylic compounds (RCOOH), in the area around 1700 cm$^{-1}$ wavelength indicating the functional group of carbonyl compounds (RC=O), 3393 cm$^{-1}$ region indicating the functional group of Amina N-H stretching, 1080 cm$^{-1}$ region indicating the functional group of sulfoxide and 1544 cm$^{-1}$ region indicating the functional group of C=C [23].

**Figure 9.** FTIR spectra of Metformin before electrolysis (Metformin tablet), after electrolysis with Iron anode, after electrolysis with Aluminum anode and after electrolysis with Zink anode

Base on data FTIR spectra, there is a shift in uptake in metformin before and after electrolysis. This indicates a change in functional groups that occur during the electrolysis process. The absorption range that explains the presence of amine groups, N-aromatic groups, C = O groups, amide groups, and sulfoxide groups is in table 2 as follows:

**Table 2** Analysis FTIR spectra of Metformin before electrolysis (Metformin tablet), after electrolysis with Iron anode, after electrolysis with Aluminum anode and after electrolysis with Zink anode

| Wavenumber (cm$^{-1}$) | Absorbance | Characteristic Spectra                  |
|------------------------|------------|----------------------------------------|
| 3393                   | Medium     | Vibration Amina N-H stretching         |
| 2931                   | Weak       | Vibration N-aromatic stretching        |
| 1710                   | Medium     | Vibration C=O stretching               |
| 1670                   | Medium     | Vibration amide (C-N) stretching       |
| 1544                   | Medium     | Vibration C=C stretching               |
| 1080                   | Medium     | Vibration sulfoxide stretching         |

4. Conclusion

The electrolysis process Metformin occurs optimally at a distance of 1 cm (in iron, aluminum, and zinc as an anode and carbon as an anode) and processing time of 20 minutes. The voltage used in the electrolysis process of Metformin is optimal at 2 volts (in iron and aluminum as an anode and carbon as an anode) and 2.5 volts (zinc as an anode and carbon as an anode). The addition of electrolyte solutions (especially the Fenton reagent) can increase the yield of the Metformin electrolysis process. Structural changes were occurred in Metformin, but have not broken down into simple molecules.

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