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Preparation and Characterization of Activated Carbon from Waste of Corn Cob (*Zea mays* L)

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Abstract:

The purpose of this study was to prepare and characterize activated carbon from waste corn cob (*Zea mays l*). The method used for preparation carbon from corn cob was pyrolysis with variations in the pyrolysis temperature 290 ^oC and 300 ^oC for 1 hour, this carbon was activated by chemical activation process with various activating reagent of HCl, $ZnCl_2$, and KOH. Then the optimum results will be varied concentration which is 2N, 4N, 6N, 8N, 10N. In the study, activated carbon was characterized based on actived carbon quality standards No. 06-3730-1995. The results of the research the best actived carbon was obtained from pyrolysis was 290 ^oC using a $ZnCl_2$ 4N activator solution and having water content of 2,07%, vapor content of 5,9%, ash content of 1,29% and bonded carbon content of 92,81%. Based on the results of the study, activated carbon of corn cobs conformed the carbon quality standards SNI No. 06-3730-1995.

Keywords **–Activated Carbon, Corn Cobs, Pyrolysis, SNI No. 06-3730-1995**

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I. INTRODUCTION

Indonesia is an agricultural country that has abundant biomass energy sources. One potential biomass energy source in Indonesia is agricultural waste such as straw, rice husk, and corn cobs [1]

Corn plants are multifunctional plants as well as the second important food crop after rice and wheat. Based on the order of the world's basic food ingredients, Corn ranks third after wheat and rice. Corn cobs are considered as a good proxy for the production of activated carbon, because corn cobs are mostly composed of lignin, cellulose, and hemicellulose so that they can potentially be activated carbon [2]. Corn cobs contain a bound component of 46.58% carbon, 5.87% hydrogen, 45.46% oxygen, 0.47% nitrogen, 1.40% ash, 0.01% sulfur, and 0,21% chlorine, so Corn cobs are widely used in various applications because the ash content is quite low [3] Rajalakshmi (2015) defines that corn cobs are the preferred raw material because they contain low amounts of minerals and produce carbon with high density, and have a small ash content , so that corn cobs can be used as activated carbon.

Activated carbon is a pore material made from several carbon-containing material cursors. The material is made by pyrolysis which undergoes a process of physical and chemical activation so that it can increase the pyrosity of carbon [4] and has the ability to absorb the anions, cations and molecules in the form of organic and inorganic compounds [5] Activated carbon is known as the most effective adsorbent and it useful for removing pollutants from polluted gases, this is caused by the nature of activated carbon which has a large surface area that can produce adsorption capacity and has good eating properties [6] in various applications due to low cost factors and easy to obtain such as energy sources [7] food processing, drugs, gas and absorption, cars, thermoelectric materials and can be used as catalysts. [8].

The quality requirements for activated carbon according to the Indonesian National Standard (SNI) 06-3730-1995 are as follows:

Requirements	Parameter
Vapor Content	Max 25 %
Water Content	Max 15 %
Ash content	Max 10 %
Bounded Carbon Content	Min 65 %
Absorption of iodine	Min 750 mg/g
Absorption of benzene	Min 25 %

Making activated carbon can be done through three stages, namely dehydration, carbonization and activation. Carbonization is a process of pyrolysis of carbon materials carried out at high temperatures without oxygen [9]. This combustion process causes decomposition of organic compounds from hemicellulose, cellulose, and lignin. The nature of the results of carbonization is determined by the conditions of the base material. Some parameters commonly used to determine the condition of carbonization are carbonization temperature and carbonization time which depends on the characteristics of activated carbon [10] while the activation process is an important process in making activated carbon, this process aims to enlarge the pore by breaking hydrocarbon bonds or oxidizing molecules surface molecules so that carbon experiences changes in physical and chemical properties. Various chemical activators have been used in making activated carbon from corn cobs, such as phosphoric acid (H_3PO_4), hydrogen peroxide (H_2O_2), nitric acid (HNO_3) [11] hydrochloric acid (HCl), sodium hydroxide (NaOH), trihydrogen phosphate (H_3PO_4), Zinc chloride ($ZnCl_2$) and Potassium hydroxide (KOH) [8].

Based on the description, the active carbon from corn cobs was made with temperature variations in the carbonization process and using HCl, $ZnCl_2$, KOH activators and performed the best ratio of the concentration of the activator solution to the reagent activation.

II. RESEARCH METHODS

A. *Tools and materials*

In this study, the materials used for activated carbon was corn cobs, HCl, $ZnCl_2$, KOH activator solutions and distilled water. While the tools used ware porcelain crucible, furnace, filter paper, funnel, beaker, oven and analytical scales.

B. *Dehydrated Corn Cobs*

Corn cobs ware cleaned and cut into small sizes, then dried in the sun and heated at 105 ^{o}C to reduce water content so that good carbon was obtained.

C. *Carbonization and Activation of Corn Cob (Zea mays l.)*

At the carbonization stage, corn cobs were carried out by the pyrolysis process of 500 grams of corn cobs in the furnace at a temperature of 290 ^{0}C and 300 ^{0}C for 1 hour. Carbon from the pyrolysis was smoothed using mortar and pestle, then filtered using a 100 mesh sieve.

The activation phase was carried out by immersing 50 grams of carbon from the pyrolysis using different activator solutions (KOH, HCl, and $ZnCl_2$) each with a concentration of 4N as much as 100 ml for 24 hours. Then the carbon was filtered with Whatmann no. filter paper. 42 and washed using aquadeas to pH 7, oven at 105 ^{0}C for 1 hour, After obtaining a optimum activator mixture through testing (water content, ash content, vapor content and bounded carbon) then the concentration varied from 2N, 4N, 6N, 8N , 10N with the same procedure (Alfiany et al. 2013)

D. Characteristics of Active Carbon

The activated carbon obtained was tested with several parameters, namely :

1) Water Content Analysis

The activated carbon was weighed 1 gram and put in the dried porcelain exchange rate, then put into the oven at 110 °C for 1 hour, then the activated carbon was cooled in the desiccator and weighed. Water content can be calculated by the following equation:

$$\text{Water content} = \frac{a-b}{a} \times 100\%$$

Where:
a = initial activated charcoal weight (gram)
b = weight of activated charcoal after drying (gram)

2) Ash Content Analysis

One gram of activated carbon was put into porcelain crucible.Then it was tarnished in the furnace slowly after all the carbon was lost.The flame was enlarged at a temperature of 500 ^{0}C for 1,5 hours.When all the carbon has been reduced to ashes, cooled in a desiccator and then weight it until its fixed weigt is obtained

$$\text{Ash content} = \frac{\text{weight ash}}{\text{weight ash sample}} \times 100\%$$

3) Vapor Content Analysis

Activated carbon was heated to 310 °C in the furnace. After the temperature was reached, the carbon was left cold in the furnace without being associated with outside air. After the cold was put into the desiccator and weighed.

$$\text{Vapor Content} = \frac{a-b}{b} \times 100\%$$

Where:
a = initial activated carbon weight (gram)
b = activated charcoal weight after heating (gram)

4) Bounded Carbon Content

The bounded carbon content of activated carbon was obtained from the results of the reduction of the part lost at heating 310 ^{o}C (vapor content) and ash content.

$$\text{Bonded carbon} = 100\% - (A + B)$$

Where:
A = ash content (%)
B = vapour content (%)

III. RESULT AND DISCUSSION

A. Preparation of Activated Carbon from Corn Cobs

Activated carbon was carried out through two stages, namely the carbonization stage and the activation stage. The carbonization process was a combustion process that converts corn cobs into carbon through incomplete combustion by producing $C_{(s)}$, $CO_{(g)}$, and $H_2O_{(g)}$. the following was a reaction that occurs when carbonization takes place:

$$C_6H_{12}O_6 + O_2 \rightarrow 4C_{(s)} + 2CO_{(g)} + 6H_2O_{(g)}$$

The process of preparation of carbon was previously carried out by the process of dehydration, namely the drying of corn cobs using sunlight to reduce the water content to obtain good carbon, then corn cobs were carbonized at different temperature variations, namely temperature 290 ^{0}C, 300 ^{0}C for 1 hour. In the carbonization process there is shrinking of corn cobs because biomaterials contained in corn cobs such as hemicellulose, cellulose, and lignin are degraded to carbon by evaporating non-carbon material [14] After carbon is obtained, water content, steam content, ash content and bonded carbon from carbon corn cobs.

B. Carbonization and Activation of Corn Cob

The carbonization process of corn cobs was carried out at 290 ^{0}C, 300 ^{0}C, 1 hour each. Then the water content, ash content, steam content and bound carbon to the corn cobs were tested. The test purpose to determine the quality of carbon produced based on the SNI standard No. 06-3730-1995.

a. ***Temperature variations***

1. Water content

Water content was carried out to determine the content of the remaining water content on carbon. Determination of water content on corn cobs carbon from the research results was presented through graph 3.1

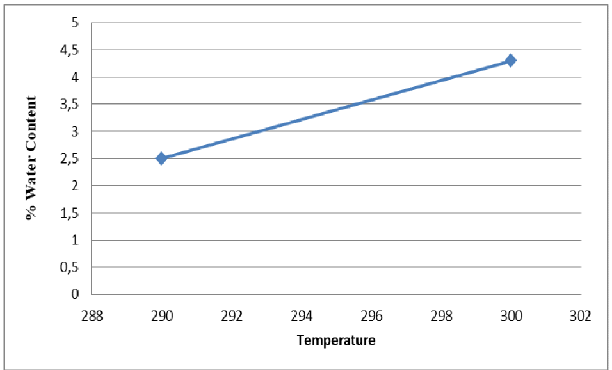


figure 3.1 water content with a temperature of 290 ^{0}C and 300 ^{0}C for 1 hour.

Based on graph 3.1 it can be explained that the carbonization process of corn cobs with a temperature of 290 ^{0}C was higher, namely around 2.5% and at a temperature of 300 ^{0}C the carbon water content of corn cobs produced was around 4.3%. The moisture content of various temperature activated carbon shows that the quality of activated carbon according to SNI 06-3730-1995 has met the standard of low of 15%.

2. Ash Content

Determination of ash content serves to determine the content of metal oxides contained in carbon. Where ash content was used as the remaining mineral which was still left behind from the carbonization process because corn cobs not only contain carbon and organic compounds but also contain some minerals. The results of determining the corn cob carbon results are presented in graph 3.2

Graph 3.2 shows that the ash content of carbon corn cobs at a temperature of 290 ^{0}C is 6.9% while the carbonization temperature of corn cobs 300 ^{0}C was greater at 10%. The graph explains that the greater the temperature in the carbonization process, the greater the ash content obtained. Increased ash content was due to the presence of non-carbon compounds that attach to the surface of charcoal [14]

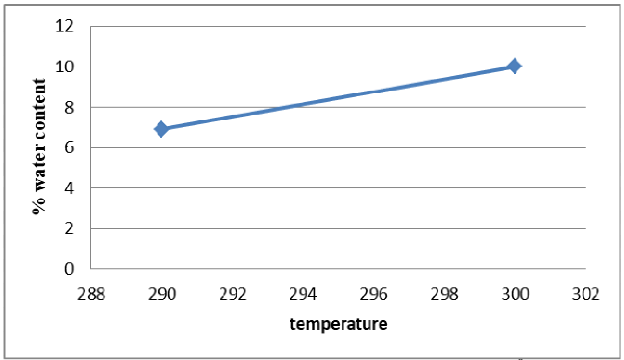


Figure 3.2 Ash Content with a temperature of 290 ^{0}C and 300 ^{0}C for 1 hour.

3. vapor content

vapor content serves to find out the amount of substance or compound still after the carbonization process. Determination of vapor content on corn cobs carbon from the research results was presented through graph 3.3

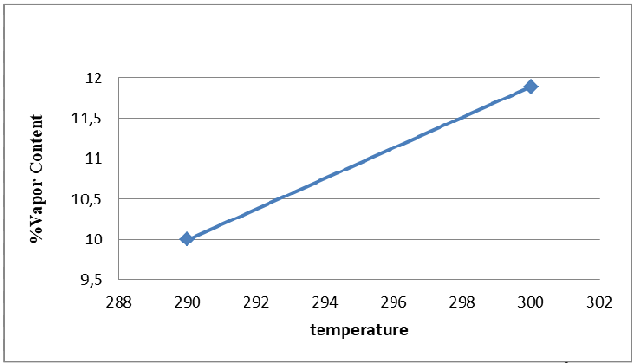
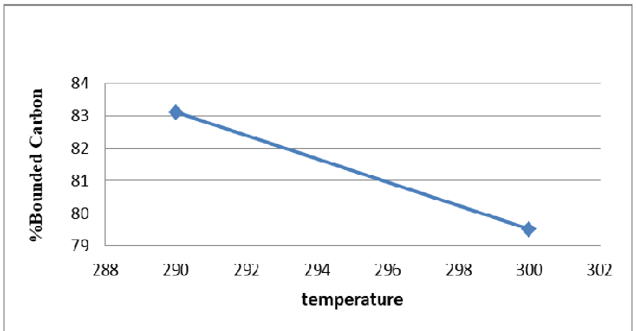


figure 3.3 Vapor Content with a temperature of 290 ^{0}C and 300 ^{0}C for 1 hour.

Graph 3.3 shows that corn cobs carbon at carbonization temperature of 290 ^{0}C has a vapor content of 10% while carbonization of corn cobs at 300 ^{0}C has a vapor content of 11.89%. The graph explains that the higher the carbonization temperature, the more volatile substances that evaporate.

4. bounded carbon

bounded carbon content purpose to determine the carbon content after the carbonization process. Determination of bound carbon content on carbon corn cobs from the results of the study is presented through graph 3.4



Gambar 3.4 bonded carbon with a temperature of 290 ^{0}C and 300 ^{0}C for 1 hour.

Graph 3.4 shows that carbon bound by corn cobs at carbonization temperature of 290 ^{0}C is greater than in the carbonization process of 300 ^{0}C corn cobs. based on the results of research on carbon from corn cobs from various temperature variants that have met SNI No. 06-3730-1995. So that it can be collapsed from the graph, the higher the carbonization temperature, the lower the carbon content produced, the less due to the amount of volatile substances that evaporate.

b. Variation of reagents

The activation phase was carried out by immersing 50 grams of carbon from the pyrolysis using different activator solutions (KOH, HCl, and $ZnCl_2$) each with a concentration of 4N as much as 100 ml for 24 hours. Then the carbon is filtered using Whatmann no. filter paper. 42 and washed using aquadeas to pH 7, oven at 105 ^{0}C for 1 hour, After obtaining optimum activator mixture through testing moisture content, ash content, vapor content and bounded carbon (Alfiany et al. 2013)

Figure 3.5 shows the variation of carbon cobs activating reagents using an acid (HCl), alkaline (KOH) activator solution, and salt ($ZnCl_2$), there are 4 tests carried out to determine the quality of the carbon, namely moisture content, steam content, ash content, and bound carbon content. In Figure 3.5 shows the carbon corn cobs in the HCl activating reagent have water, ash, steam and bonded levels of 2.87%, 0.79%, 9.03% and 90.18%. And activating using KOH activator solution has water, ash, vapor and bonded content, namely 6.4%, 17.5%, 20% and 60.8%. The activating reagent of the ZnCl2 activator solution gives more optimal results because it has a water content of 2.081%, ash content of 1.29%, the lowest vapor content of 5.96 and the highest carbon bound content of 92.75%. Based on the table above, it can be concluded that the activated carbon produced has standards SNI 06-3730-1995 except for carbon activation using a KOH activator solution at ash content of 17.5%.

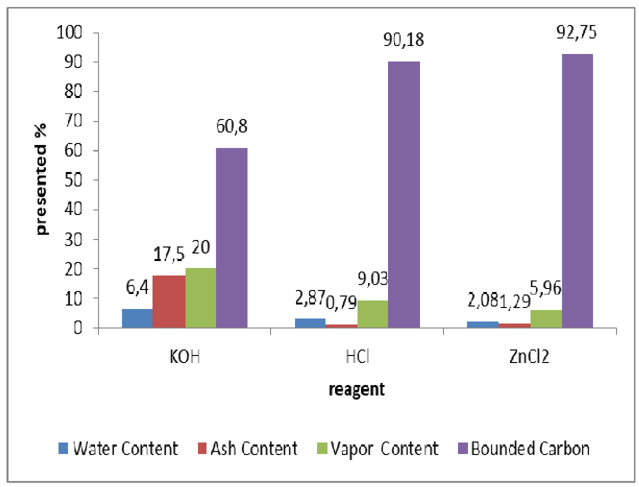


Figure 3.5 variation of activated carbon reagents from the research using acid (HCl), alkaline (KOH) and salt (ZnCl2) activator solutions.

c. Variation of concentration

Obtained by optimum activator through (water content, ash content, vapor content and bounded carbon) namely $ZnCl_2$, the concentration varies from 2N, 4N, 6N, 8N, 10N

1. Water Content

Water content of a variety of reagents activating corn cobs of activated carbon was carried out to determine the content of the remaining water content in activated carbon after going through the activation process using a concentration variation activato. Determination of water content on corn cobs activated carbon from the results of research with variations in concentration is presented through graph 3.6

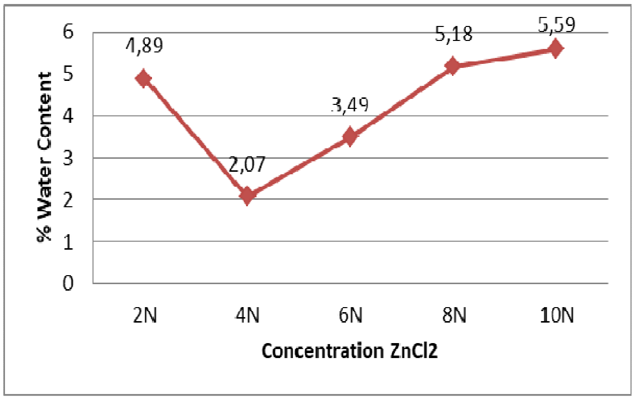


Figure 3.6 graph of water content of activated carbon with $ZnCl_2$ activator solution concentration of 2N, 4N, 6N, 8N, 10N

Graph 3.6 shows that the water content of cob corn which is activated using a $ZnCl_2$ activator solution with concentrations of 2N, 4N, 6N, 8N, and 10N shows that with a concentration of 4N it produces a lower water content of 2.07%. Water content of corn cobs activated carbon tends to experience loss along with the increase in concentration. The water content of corn cobs produced meets SNI carbon quality standards. 06-3730-1995 because the water content is not more than 15%.

2. Ash Content

Ash content purpose to determine the content of metal oxides which are still present in corn cobs activated carbon after activation. Where ash content was used as the remaining mineral which is still left behind from the carbonization process because corn cobs not only contain carbon and organic compounds but also contain some minerals. The results of the determination of corn cob carbon results of the study are presented in graph 3.7

Graph 3.7 shows that the ash content of cob was activated using a $ZnCl_2$ activator solution with concentrations of 2N, 4N, 6N, 8N, and 10N indicating that at 4N the concentration produces a lower water content of 1.29% compared to the concentration of 2N, 6N, 8N, and 10N. The graph shows that the greater the concentration of $ZnCl_2$, the greater the ash content obtained. This is because the greater the concentration of $ZnCl_2$ used to soak the corn cobs, the greater the mineral left in the activated carbon. The quality standard for activated carbon was a maximum of 10%, so the cobs corn activated carbon of the research results meet the standard SNI No. 06-3730. -1995.

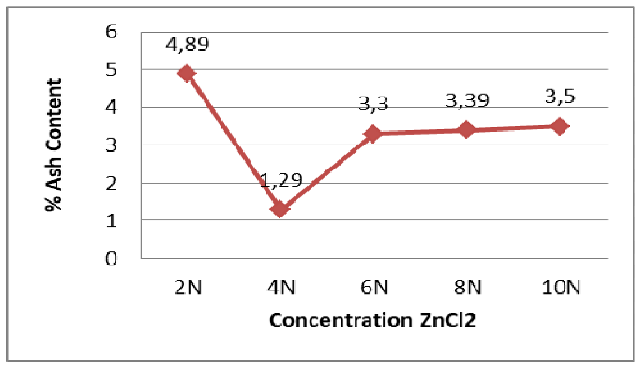


Figure 3.7 graph of ash content of activated carbon with ZnCl2 activator solution concentration of 2N, 4N, 6N, 8N, 10N

3. Vapor Content

Vapor content on corn cobs carbon from the research results is presented through graph 3.8

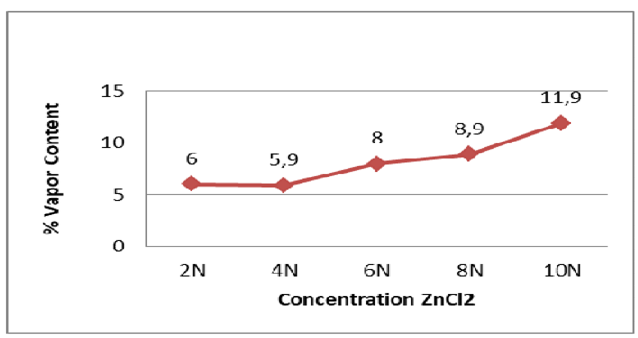


Figure 3.8 graph of vapor content of activated carbon with ZnCl2 activator solution concentration of 2N, 4N, 6N, 8N, 10N

Graph 3.8 shows that the steam content of the cob corn activated using a $ZnCl_2$ activator solution with concentrations of 2N, 4N, 6N, 8N, and 10N shows that with a concentration of 4N it produces a lower water content of 5.9%. The highest levels of volatile substances are produced by activated carbon with a concentration of 10N, while the lowest vapor content is produced by activated carbon with a concentration of 4N. High volatile substances can reduce the ability of activated carbon to absorb gases or solutions. From the results of the study it can be stated that the vapor content of corn cobs produced meets carbon quality standards SNI 06-3730-1995 because the vapor content is not more than 25%.

4. Bounded Carbon

The bound carbon content to the corn cobs actived carbon from the research results was presented through graph 3.9

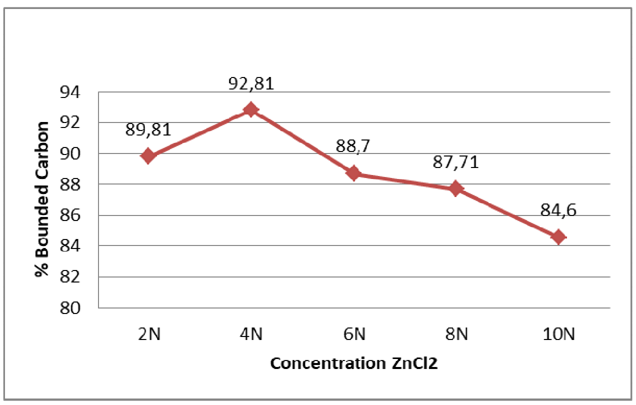


Figure 3.9 Graph of the Bounded carbon content of activated carbon with a ZnCl2 activator solution concentration of 2N, 4N, 6N, 8N, 10N

Graph 3.9 shows that the carbon content of bound cobs corn which are activated using a ZnCl2 activator solution with concentrations of 2N, 4N, 6N, 8N, and 10N shows that the concentration of 4N produces a higher carbon content of 92.81%. Most of the bound carbon content produced meets the activated carbon quality standards based on SNI No. 06-3730-1995 which is a minimum of 65%. The lowest bound carbon value is produced by a concentration of 10N. In addition, the high and low levels of the bound kabon are also affected by the content of cellulose and lignin which can be converted into carbon atoms. However, the carbon content of activated carbon was lowered due to the length of activation [15]

CONCLUSION

The most effective condition in making activated carbon from corncob (*Zea mays* L) was at a carbonization temperature of 290 °C for 1 hour using a 4N $ZnCl_2$ activator with 24 hour immersion. Activated carbon from corncob fulfills the quality requirements of activated carbon according to SNI No. 06-3730-1995 using activator $ZnCl_2$ 4N with the following : water content 2,07%, vapor content 5,9 %, ash content 1,29 % and bounded carbon 92,81 %.

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