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Conversion of Cellulose (Sugarcane Bagasse) to Sustainable Fuel Using Synthesized Zeolite-Y Catalyst

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ABSTRACT

Sustainable fuel is a fuel from renewable sources. The global community is turning attention to biofuel, biogas and biodiesel due to the increasing cost and adverse environmental effect of fossil fuel. In this research work zeolite -y catalyst was produced from local clay (kaolin clay) gotten from Alkaleri in Bauchi -State Nigeria and its catalytic activity was tested in the conversion of bagasse to ethanol. The kaolin was first beneficiated. 25g of the beneficiated kaolin was transformed to metakaolin and reacted with 7.5g of Sodium hydroxide, 34.1g of sodium silicate and 75ml of deionized water to form a gel at constant stirring (700rpm) at 27°C. The gel was aged for 3 days at room temperature, then crystallized in an oven at 100°C for 7hrs. The aged gel was filtered, washed with deionized water which reduced the pH to 7. It was then crystallized at 100°C for 12hrs. Physiochemical analysis was carried out to further confirm the nature of the synthesized zeolite. Finally, sustainable fuel (ethanol) was produced through dilute acid hydrolysis by the use of sugarcane bagasse. During fermentation one of the two samples was fermented with saccharomyces sareviaes together with the zeolite catalyst. The two samples were analyzed to confirm the catalytic activity of the zeolite catalyst.

Keywords: ethanol, sustainable fuel, kaolin, zeolite

INTRODUCTION

According to Christensen (et. al, 2008), biomass has in the past decade become an increasingly important resource for the production of transportation fuels and chemicals. This utilization is primarily based on biochemical transformations, such as fermentation to produce ethanol from sugars. Biomass conversion based on zeolite catalysis is an alternative approach which could find broad application, especially the conversion of lignocellulose to transportation fuels and sugars to chemicals (Zhang et al ,2018) This perspective describes recent developments in this area. Lignocellulose biomass is the most abundant bio- resource available and consists of three major components: cellulose, hemicellulose and lignin. Cellulose is a linear crystalline polymer composed of glucose units. Due to its high crystallinity, cellulose is very difficult to hydrolyze to glucose. Hemicellulose is different from cellulose since it is a branched amorphous polymer that is made of different pentose and hexose units. Due to the branching and its amorphous nature hemicellulose is easier to hydrolyze into monosaccharides than cellulose. Lignin is the largestnon- carbohydrate component of lignocellulose biomass (Yang,2019). It is an amorphous polymer of aromatic allylic alcohols that is very resilient towards hydrolysis and cannot be utilized by fermentation. Many strategies exist for the conversion of lignocellulose to fuels. Second generation bioethanol can be produced by pretreating lignocellulose to open it up for a subsequent enzymatic hydrolysis. This facilitates the release of monosaccharides which can be fermented into ethanol. This process enables non-edible lignocellulose to be used as a source for ethanol, although lignin remains unutilized. Gasification of lignocellulose is a different strategy which enables all the carbon containing species present in the lignocellulose to be utilized, including lignin. The lignocellulose is heated to temperatures in the range of 800–1000^{o} C in the presence of a small amount of oxygen. This facilitates the complete break-down into CO/CO2, H2 and H2O. The syngas thus produced can be converted into Fisher–Tropsch diesel or to methanol which can

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be used to produce gasoline using the MTG process (Bridgwater et., all 2000 & Lu *et a*l ,2022).

MATERIALS AND METHOD

Materials

The following materials and reagents were used for this research; Kaolin clay from Alkareli- Bauchi State, Sugarcane bagasse, from Kaduna Zinc Chloride, Sodium Silicate, Hydrochloride acid, sodium hydroxide and distilled water. The materials were sourced from school laboratory and open market.

The equipment used for the research includes weighing balance, magnetic stiller, oven, beakers, muffle furnace, measuring cylinder. Grinder, distillation column

Methodology

Clay Preparation

A sample of natural clay was collected from Alkareli, Bauchi State, Nigeria. The kaolin clay was cleaned to remove any impurities, such as organic matter, stones, or debris. This was achieved by washing the clay with water and allowing it to settle. The settled clay was collected and dried to remove excess moisture. Grinding the dried clay was done in a mortar to achieve a finer particle size of 0.24µ, which aids in subsequent processing

Beneficiation

400g of kaolin clay was dissolved in 150ml of deionized water to form a suspension which is decanted and the drifts at the bottom discarded. The solution is allowed to settle for 3hrs and then filtered. The process is repeated 3 times then dried at room temperature for 5days, grinded and sieved to a particle size of 0.046mm. The purpose of the beneficiation is to remove excess impurities in the clay which could hamper the zeolite extraction process

Gel formation

15g of metakaolin was mixed with 34.10g of Na_2SiO_3, 7.5g of NaOH,75ml of distilled water and stirred at room temperature for 7hrs at 700rpm to form a hydrogel. The gel was aged for 3 days at room temperature. The gel formation is the actual reaction process to the formation of the zeolite catalyst. The gel will need to be crystalized to form the catalyst seeds or particles

Crystallization

The aged hydrogel was transferred into a stainless autoclave and oven heated at 100°C for 7hrs.The crystallization process is so as to allow for the formation of the zeolite seeds or crystals

Filtration

The gel is filtered using filter paper to remove the excessive water. After crystallization, the excess water is now removed through filtration, also the unwanted materials is also filtered off through the process

Washing

The gel was washed with deionized water until its pH becomes 7. The washing process was done to further remove impurities from the zeolite crystals formed

Drying

The washed gel was oven dried for 8hrs at 100°C and grinded to a powdered form. The final dried solid product was characterized by XRD, SEM, XRF and BET. The drying process is to have a crystal that can be grinded and stored for a longer period.

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Bagasse

The sugarcane bagasse was sourced from kasuwan barci market in Kaduna and is generally composed of cellulose (33–36%), hemicellulose (28–30%), and lignin (17–24%).

: Pretreatment 500g of sugarcane bagasse is washed with tap water, rinsed with deionized water and dried at room temperature for 5 days. The pre-treatment process is to remove dirt and natural debris that come with the bagasse

Thermochemical process

Acid hydrolysis

12.5g of powdered sugarcane bagasse was transferred into a beaker. 9.8g of 0.2M dilute sulphuric acid of volume 250ml was added into the beaker. The mixture was transferred into a conical flask and allowed to completely soak in dilute sulphuric acid after they were properly homogenized with the help of a sterilized stirrer. The sample was then kept under room temperature of 27 °C for 24 hours. Aluminum foil was used to wrap the conical head prior to subjecting the sample at a constant temperature of 120°C for 30 mins. **Fermentation**

The pH of the sample (bagasse hydrolyzed with 0.2 sulphuric acid concentration) was brought to 5.5 using 1M of NaOH (Bai et al., 2020), 0.5g of yeast (Saccharomyces cerevisiae) was added into the 250 mL conical flask containing the production medium appropriately covered with the help of aluminum foil. The media was then stored in an incubator at a temperature of 35°C for 120 hours.

Table 2.1: Chemical composition of zeolite

Oxide	**Formula**	**Conc(wt%)**	**Mole%**
Silicon Oxide	SiO_2	55.371	66.116
Aluminum Oxide	Al_2O_3	35.262	24.812
Iron (iii) Oxide	Fe_2O_3	1.829	0.822
Titanium Oxide	TiO_2	4.383	3.937

The composition of zeolite was reported in percentage of oxide as shown in table 2.1, The concentration of silicon oxide and aluminum oxide were 55.371% and 35.262% were obtained as reported by Nwosibe et al 2019 and Wang et al ,2018

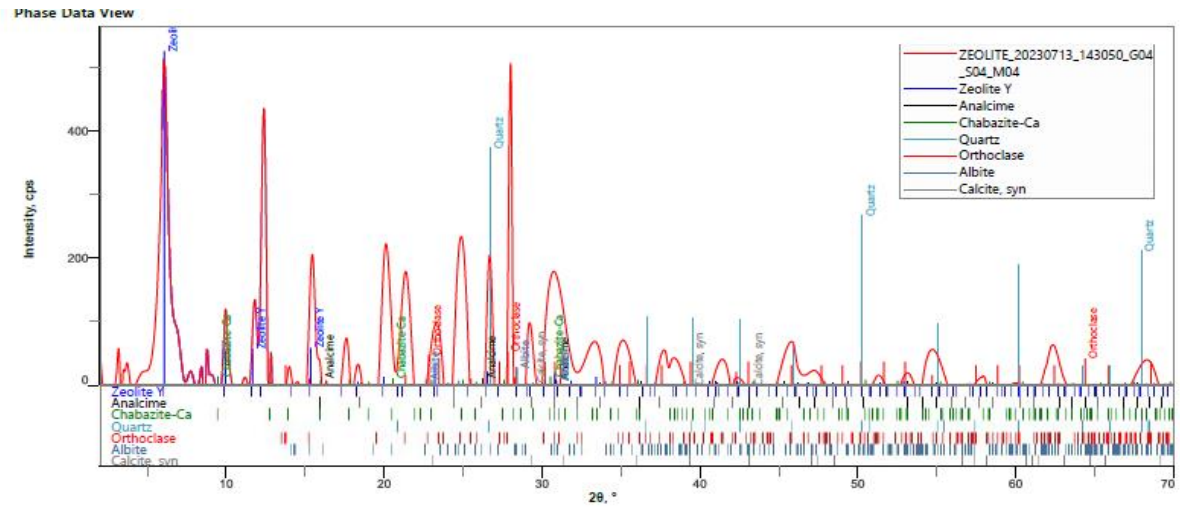

Figure 3.1: XRD pattern for synthesized zeolite.

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RESULTS AND DISCUSSION

From figure 3.1, the peak crystallinity at 2θ is obtained at 6.09°, 12.35°, 20.04°and 30. 90°.These trends obtained follows similar trends as reported by Salami et al, 2018.

Table 3.2: BET for the synthesized zeolite.

Data	**Value**
Surface Area	650.162$m^{2/}$g
Pore Volume	0.320cc/g
Pore Diameter	2.105

From table 3.2, the synthesized zeolite has a surface area of 650.162m^2/g, and a pore volume 0.320cc/g and a pore diameter 2.105 was reported by Wang et al, 2019 and Alhillo *et al* 2015, having similar trends.

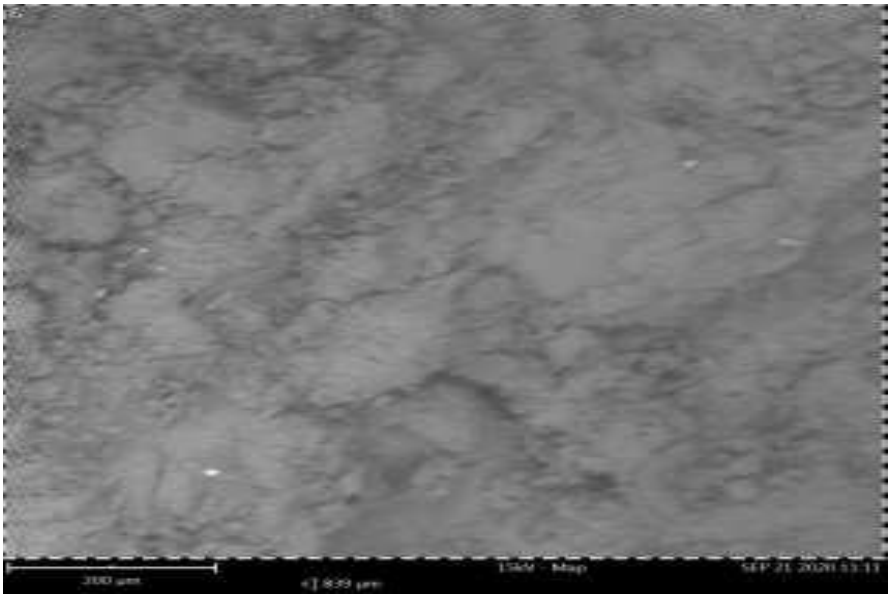

Figure 3.2: SEM image of synthesized zeolite

Element Number	**Element Symbol**	**Element Name**	**Atomic Conc.**	**Weight Conc.**
14	Si	Silicon	78.85	72.49
13	Al	Aluminum	11.04	10.73
26	Fe	Iron	3.01	2.70
22	Ti	Titanium	1.02	1.13
19	K	Potassium	1.23	1.09
20	Ca	Calcium	2.15	2.73
39	Y	Yttrium	0.87	2.45
47	Ag	Silver	0.72	2.45
41	Nb	Niobium	0.57	1.69
16	S	Sulfur	0.01	0.92

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15	P	Phosphorus	0.87	0.86
17	Cl	Chlorine	0.68	0.76
12	Mg	Magnesium	1.29	1.20
11	Na	Sodium	1.25	1.40

3.1: Burgases conversion to fuel was achieved by *dilute* acid hydrolysis by the use of sugarcane bagasse. During fermentation one of the two samples was fermented with saccharomyces sareviaes together with the zeolite catalyst. The two samples were analyzed to confirm the catalytic activity of the zeolite catalyst (Li et al ,2018)

CONCLUSION AND RECOMMENDATIONS

Conclusion

From the research work carried out it was concluded that:

Kaolin was sourced from Alkaleri in Bauchi State and characterized, its characterization shows high concentration of silicon oxide (SiO2) and aluminum oxide (Al2O3).

Zeolite-Y was synthesized from kaolin and subjected to chemical analysis. XRF result shows high aluminum and silicon concentration with small traces of impurities of iron, calcium, vanadium. XRD result shows crystalline peak of 2 θ = 7°, 16°, 22°, 28°, and 31°. SEM shows distribution of pore spaces similar to what is obtained in literature.

Sustainable fuel was produced by the catalytic activity of the synthesized zeolite using dilute acid hydrolysis and compared favorably with the market standard.

Recommendations

We hereby put forward the following recommendation

Other arrays of protocols for synthesis of zeolite should be developed, used and compared with the result of this work.

Quantitative and qualitative analysis of the residue obtained after distilling of the fermented liquor should be carried out.

Other routes for the conversion of bagasse to ethanol should be developed using zeolite as a catalyst.

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