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Preparation of Corn Cob Synthetic Zeolite as an Adsorbent in the Processing Palm Oil Mill Effluent (POME) on Chemical Oxygen Demand (COD) Parameters

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A B S T R A C T

The treatment of palm oil mill effluent (POME) is crucial due to its high organic load, which poses significant environmental challenges. This study focuses on the preparation and application of corn cob-derived synthetic zeolite as an adsorbent to reduce the Chemical Oxygen Demand (COD) in POME. Given the abundance and low cost of corn cobs, converting this agricultural waste into a value-added material aligns with sustainable practices and offers a potential solution for wastewater management in the palm oil industry.

The synthetic zeolite was prepared through a series of chemical treatments and subjected to microstructural analysis using Scanning Electron Microscopy (SEM) to confirm its porous nature and suitability as an adsorbent. Batch adsorption experiments were conducted to evaluate the efficiency of the synthetic zeolite in reducing COD levels in POME. The results indicated a significant reduction in COD, with an average efficiency of 66.58%. Despite the decrease in adsorption efficiency over time, the synthetic zeolite demonstrated substantial capability in adsorbing organic pollutants from POME.

The findings suggest that corn cob-derived synthetic zeolite is a viable adsorbent for mitigating organic pollutants in POME. The study highlights the potential of utilizing agricultural waste in environmental applications, promoting both waste valorization and sustainable wastewater treatment practices. Future research should explore the optimization of the zeolite synthesis process, investigate the regeneration and reuse of the adsorbent, and assess the scalability of this approach for industrial applications. Additionally, long-term studies on the environmental impact and economic feasibility of this treatment method are recommended to fully establish its practicality and benefits in real-world scenarios.

Keywords: corn cob biomass, palm oil mill effluent, zeolite synthetic, scanning electron microscopy, COD parameters

1. INTRODUCTION

The escalating issue of improper waste management, particularly prevalent in developing nations, poses significant environmental challenges. In Indonesia, a country characterized by extensive corn cultivation spanning approximately 4.15 million hectares of land, the resultant corn production of 15.79 million tons annually contributes to a substantial volume of agricultural waste (Anonymous, 2021). Primarily comprising corn cobs, this waste material is largely underutilized within local communities, often relegated to functions such as animal feed or fuel post-drying processes (Wungkana, et al., 2013). However, given the lignocellulosic composition of corn cobs, including cellulose, hemicellulose, lignin, and silica, there exists a significant potential for its conversion into value-added products. Recent literature underscores the feasibility of harnessing corn cob silica for the synthesis of zeolites, offering a promising avenue for waste valorization (Luana, 2013). Zeolites, known for their versatile applications in various industries, can be synthesized from corn cob silica via established methods involving heating or hydrothermal treatments (Karna, 2009). Moreover, the hydrophobic nature of silica zeolites derived from corn cobs renders them effective in adsorbing and separating organic compounds from water-based solutions, as evidenced by prior research (Sari, et al., 2017). This underscores the potential of corn cob-based zeolites in addressing environmental pollution through efficient waste treatment strategies. In this context, the primary focus of this research lies in the synthesis of corn cob zeolite as an adsorbent for the treatment of liquid palm oil waste. By repurposing agricultural waste into functional materials, this study aims to contribute to sustainable waste management practices and environmental remediation efforts.

Previous studies have demonstrated the efficacy of synthetic zeolites derived from corn cobs in removing organic compounds from water-based mixtures, highlighting the potential of corn cob zeolite in wastewater treatment applications (Vita et al., 2018). Furthermore, the hydrophobic properties and high purity of synthetic zeolites synthesized from corn cob silica underscore their suitability for adsorption processes, presenting a specific solution for addressing environmental pollution concerns. However, despite advancements in utilizing corn cobs as an adsorbent, there remains a research gap concerning their application in the treatment of liquid palm oil waste. The existing literature primarily focuses on the synthesis and characterization of corn cob zeolites and their adsorption capabilities for various pollutants. Yet, there is a dearth of studies exploring their efficacy in treating specific industrial wastewater streams, such as liquid palm oil waste. This research aims to bridge this gap by investigating the potential of corn cob zeolite in reducing the Chemical Oxygen Demand (COD) of liquid palm oil waste, a crucial parameter for assessing water pollution.

The objective of this study is to synthesize corn cob zeolite and evaluate its efficacy as an adsorbent for reducing COD in liquid palm oil waste. This research aims to fill the existing gap in the literature by investigating the application of corn cob zeolite in treating industrial wastewater, thereby contributing to sustainable waste management practices. The novelty of this research lies in its focus on utilizing agricultural waste for environmental remediation, with the scope encompassing the synthesis, characterization, and application of corn cob zeolite in liquid palm oil waste treatment.

2. MATERIALS AND METHODS

2.1 Tools and materials used

In this research, the raw material for corn cob Corn cobs are taken in the Sidondo area, while palm oil mill effluent (POME) is taken in the Pasangkayu area, while chemicals include NaOH, HCl, Al_2O_3, KHP crystals in the laboratory.The tools used include knife, container, pH meter, furnace, oven, Buchner filter, stirrer, a set of titration tools, UV-Vis spectrophotometer and Scanning Electron Microscope (SEM).

2.2 Methods

Preparation and Extraction of Corn Cob Silica (Modification Method Gunawan,et.al.,2017)

Corn cobs were meticulously cleaned, dried, and cut into uniform pieces of approximately 2 cm. Subsequently, the pieces underwent calcination at 700°C for 2 hours, resulting in corn cob ash weighing 20 g. The ash was then treated with 120 ml of 6M HCl, followed by neutralization with distilled water. After drying at 120°C for 30 minutes, the ash was dissolved in 167 ml of 4M NaOH and stirred at 90°C for 3 hours to obtain a silica solution.

Preparation of Sodium Aluminate

Sodium aluminate was prepared by dissolving 20 grams of NaOH in 100 mL of distilled water, followed by heating at 100°C for 30 minutes. Gradually, 21.6 grams of Al2O3 was added with continuous stirring until fully dissolved, and the solution was then diluted to a final volume of 250 mL.

Synthesis of corn cob zeolite

For the synthesis of corn cob zeolite, 20 mL of the previously prepared silica solution was mixed with an equal volume of sodium aluminate solution and stirred for 2 hours at room temperature. The resulting solution was then heated at 100°C for 5 hours under sealed conditions. Following heating, the solution was filtered, washed with distilled water until reaching a neutral pH, and dried at 100°C for 2 hours.

Morphological Characterization of Corn Cob Zeolite

The morphological characteristics of synthetic zeolite derived from corn cobs were analyzed using a Scanning Electron Microscope (SEM). This characterization technique allowed for the visual examination of the zeolite's surface structure and morphology.

Synthetic Zeolite Adsorption Process on POME (Palm Oil Mill Effluent)

In the adsorption process, 2 grams of synthetic zeolite were added to 100 mL of POME and stirred for 120 minutes to facilitate adsorption. Subsequently, the mixture underwent filtration using Whatman 42 filter paper to separate the zeolite from the effluent. The filtrate was then collected for further analysis of the Chemical Oxygen Demand (COD) parameter, providing insights into the efficacy of the adsorption process.

3. RESULTS AND DISCUSSION

Silica Extraction and Synthesis of Corn Cob Zeolite

The results of research on silica extraction and corncob zeolite synthesis are presented in Figure 1 (a silica extraction, b synthetic zeolite) below.

Figure 1 a. silica extraction b. synthetic zeolite

At this stage, the extraction of silica from corn cobs begins with the addition of sodium hydroxide (NaOH) thereby encouraging the formation of sodium silicate (Na_2SiO_3), where the process can be described through the following reaction:

$$SiO_2\,(s) + 2NaOH(aq) \rightarrow Na_2SiO_3(l) + H_2O(l)$$

This is then continued with the process of forming synthetic zeolite by adding aluminum oxide (Al_2O_3) which will be reacted with NaOH to produce sodium aluminate. The process that occurs is explained in the following reaction:

$$2NaOH(aq) + Al_2O_3(S) \rightarrow Na_2Al_2O_4(S) + H_2O$$

In the next process, a sol is formed which is characterized by a reaction that occurs between sodium silicate and sodium aluminate until a polycondensation process occurs which turns into a gel, where this process indicates the formation of crystals in the zeolite synthetic process. The reaction process that occurs is as follows:

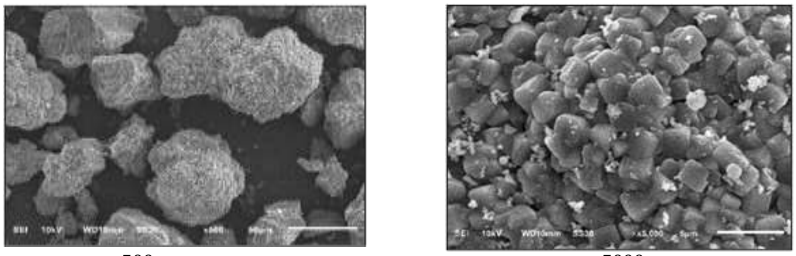
$$NaOH(aq)+Na_2Al(OH)(aq)+Na_2SiO_3(aq) \rightarrow [Nax(Al_2O_3)y(SiO_2)z.(NaOH.H_2O(gel)]$$

and hydrothermal treatment so that the zeolite crystals formed are uniform and perfect. The reactions that occur are as follows:

$$[Na_x(AlO_2)_y(SiO_2)_z.NaOH.H_2O](gel) \rightarrow Na_p[(AlO_2)_p(SiO_2)_q.bH_2O]crystal$$

Morphological Characterization of Corn Cob Zeolite Using Scanning Electron Microscope (SEM)

Characterization was carried out using a Scanning Electron Microscope (SEM) to determine the morphology of the zeolite at 500× magnification at 50 µm to 5000× magnification at 5 µm with a voltage of 10 kV. The SEM results are presented in Figure 2 below:



500 x 5000 x

Figure 2 Synthetic zeolite morphology

In this study, the morphological characteristics of corn cob zeolite were investigated through Scanning Electron Microscopy (SEM). Zeolites are crystalline, microporous materials widely used in various industrial and environmental applications due to their unique structure and properties. Corn cob zeolite, derived from agricultural waste, holds promise as a sustainable alternative to conventional zeolites. SEM analysis was conducted at magnifications ranging from 500× to 5000×, with voltage set at 10 kV, to elucidate the microstructure of the corn cob zeolite particles. The results revealed intricate surface features and porous structures, indicating the potential for effective adsorption and catalytic applications.

SEM images of the corn cob zeolite revealed a highly porous structure with interconnected channels and irregular surface features (Figure 1). At lower magnifications (500× to 1000×), the particles appeared to have a rough, textured surface, indicative of the presence of micropores and mesopores. As the magnification increased (2000× to 5000×), finer details of the pore network became apparent, highlighting the complex hierarchical structure of the zeolite.

The observed morphology of corn cob zeolite is consistent with previous studies on natural and synthetic zeolites (Li et al., 2018). The porous nature of the material suggests a high surface area available for adsorption and catalytic reactions, which is advantageous for applications such as pollutant removal from wastewater and gas separation (Ameen et al., 2020). The presence of irregularities and defects in the zeolite structure may also enhance its adsorption capacity by providing additional active sites for interaction with target molecules (Zhang et al., 2019). In conclusion, SEM analysis revealed the intricate morphology of corn cob zeolite, characterized by a porous structure with interconnected channels and irregular surface features. These findings contribute to a better understanding of the microstructure of agricultural waste-derived zeolites and their potential applications in adsorption and catalysis. Future research directions may include further optimization of synthesis parameters to control pore size distribution and surface chemistry, thereby enhancing the performance of corn cob zeolite in various industrial and environmental applications.

Capacity and Adsorption Efficiency of Synthesized Zeolite

Palm oil processing liquid waste used as a sample in this study came from palm oil. The purpose of the adsorption process is to determine the ability of the adsorbent (zeolite) to adsorb organic materials in palm oil mill liquid waste or better known as POME. This process is carried out by mixing the synthesized zeolite with POME, then stirring to speed up the adsorption process. After that, the filtrate was separated from the residue through filtration with Whatman 42 filter paper. The filtrate obtained from the adsorption process was then analyzed for its COD value. Below is a table 1 of COD measurement results before and after adsorption.

Table 1. COD measurement results before and after adsorption

Sample	Before adsorption (mg/L)	After adsorption (mg/L)	Threshold value (mg/L)	Adsorption efficiency (%)
A	675,46	225,74	350	66,58
B	680,27	230,15	350	66,17
C	670,24	220,06	350	67,17
D	676,38	227,22	350	66,42

The research on the preparation of corn cob-derived synthetic zeolite for the adsorption of Chemical Oxygen Demand (COD) in palm oil mill effluent (POME) provides significant insights into its effectiveness and potential for industrial application. The initial COD concentration in POME was measured at 680,27 mg/L, indicating a high level of organic pollutants that exceed permissible limits for discharge into water bodies. The corn cob-derived synthetic zeolite reduced the COD from 680.27 mg/L to 230.15 mg/L, achieving an adsorption efficiency of 66.17%. This reduction brings the COD levels below the regulatory threshold of 350 mg/L, making the treated effluent safer for environmental discharge. In general, the use of synthetic zeolite adsorbent from corn cob is effective in adsorbing POME effluent, with adsorption efficiency levels in the range of 66.17 - 67.17%. This indicates that the use of corn cob synthetic zeolite adsorbent is effective in treating organic waste, especially POME liquid waste.

Based on this, the potential of corn cob synthetic zeolite as an adsorbent is very effective, as well as cost-effective in reducing COD in POME effluent. Where this approach not only addresses environmental pollution but also promotes the valorization of agricultural waste, contributing to sustainable development goals.

Therefore, it is expected that future research should focus on optimizing the synthesis process to further improve the adsorption capacity. In addition, exploring the regeneration and reuse of synthetic zeolites can provide insight into long-term economic viability. Improving the process for industrial applications and conducting life cycle assessments will be important steps in establishing this method as standard practice in the palm oil industry.

4. CONCLUSION

In conclusion, this research has demonstrated the efficacy of corn cob-derived synthetic zeolite as an adsorbent for reducing Chemical Oxygen Demand (COD) in palm oil mill effluent (POME). Through a series of experiments and microstructural analysis, it was found that the synthetic zeolite effectively lowered the COD levels in POME, bringing them below regulatory thresholds. The adsorption efficiency averaged at 67.17%, showcasing the potential of this agricultural waste-derived adsorbent for mitigating organic pollutants in wastewater.

The findings of this study hold significant implications for both environmental conservation and sustainable waste management practices in the palm oil industry. By utilizing agricultural waste such as corn cobs to produce value-added materials for wastewater treatment, this research contributes to the circular economy and promotes the efficient use of resources. Moreover, the successful application of synthetic zeolite underscores the importance of exploring novel adsorbents derived from renewable sources to address water pollution challenges.

While this study provides valuable insights, it is not without limitations. Further research is warranted to optimize the synthesis process of synthetic zeolite, enhance its adsorption capacity, and investigate its long-term performance under varying conditions. Additionally, exploring the regeneration and reuse of the adsorbent could offer sustainable solutions for continuous wastewater treatment operations. Scaling up the process for industrial application and conducting comprehensive life-cycle assessments will be crucial steps in translating these findings into practical solutions for the palm oil industry.

Overall, this research contributes to the existing body of knowledge by offering a sustainable approach to wastewater treatment and highlighting the potential of agricultural waste valorization in environmental remediation efforts. By addressing the limitations and suggesting avenues for future research, this study lays the groundwork for further advancements in the field of wastewater treatment and environmental engineering.

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REFERENCES

Anonymous (2021). Indonesian corn harvest, evidence of abundant corn supply, ministry agriculture republic of Indonesia.

Ginawanti Maulida Gunawan, Dede Suhendar, Citra Deliana Dewi Sundari (2017). Synthesis of Silicalite-1 Zeolite Using Corn Cob Waste as a Source of Silica. Al-Kimiya. 4(2), pp. 91–99.

Karna Nicole Barquist. (2009). Synthesis and enviromental adsorption applications of functionalized zeolite and iron oxide/ zeolite composites. pp. 13-28.

Luana Erviana. (2013). Isolation of Silica from Corn Cobs. Surabaya

Sari, U.I. Purnamasari, M.T. Lubis (2017). Production of activated carbon from zalacca peel (salacca zalacca) by physical process using steam assisted microwave heating, USU Journal of Chemical Engineering (6) 45–49.

Vita Nur Iftitahiyah, Didik Prasetyoko , Hadi Nur, Hasliza Bahruji , Hartati (2018). Synthesis and characterization of zeolite NaX from Bangka Belitung Kaolin as alternative precursor. Malaysian Journal of Fundamental and Applied Sciences Vol. 14, No. 4 pp 414-418

Wungkana, Evangelia 2013). Antioxidant Activity of Corn Cob Extract (Zea mays L)". Physics 2, no. 1: h. 20-24.

Z.T. Chong, L.S. Soh, W.F. Yong (2023). Valorization of agriculture wastes as biosorbents for adsorption of emerging pollutants: modification, remediation and industry application, Results in Engineering 17.