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POTENTIAL OF BAMBOO POWDER AS AN ADSORBENT TO REGENERATE USED COOKING OIL

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ABSTRAK

Penelitian ini mengevaluasi efektivitas bubuk bambu yang diolah menjadi karbon aktif untuk meregenerasi minyak jelantah menggunakan tiga metode: tanpa perlakuan panas tinggi, aktivasi konvensional, dan aktivasi *furnace.* Aktivasi dengan KOH meningkatkan porositas dan luas permukaan. Parameter utama yang dianalisis meliputi kadar air, asam lemak bebas (FFA), dan bilangan peroksida (PV). Hasil penelitian menunjukkan bahwa arang aktif metode *furnace* memiliki kinerja terbaik, menghasilkan kadar air 0,05%, memenuhi SNI 7709:2019 (< 0,1 %). Sebaliknya metode konvensional dan serbuk bambu menghasilkan kadar air masing-masing sebesar 0,12% dan 0,66%. Kandungan FFA terendah sebesar 0,23 % juga terdapat pada arang aktif tungku memenuhi SNI 01-3741 2002 (<0,3%). Selain itu, bilangan peroksida yang dihasilkan arang aktif dengan metode *furnace* adalah 6,3 mek O_2/kg, lebih baik dibandingkan metode konvensional (9,7 mek O_2/kg) dan bubuk bambu (13,3 mek O_2/kg), keduanya memenuhi SNI No. 01-3741-2013 (< mek 10 O_2/kg). Kinerja arang aktif dengan metode *furnace* unggul disebabkan oleh porositasnya yang optimal, peningkatan kandungan karbon aktif, sifat hidrofobik, dan kemampuan interaksi dengan pengotor. Oleh karena itu, arang bambu yang diaktifkan dengan metode furnace menunjukkan potensi sebagai adsorben yang efektif untuk meregenerasi minyak jelantah.

ABSTRACT

This research evaluates the effectiveness of bamboo powder processed into activated carbon for regenerating used cooking oil using three methods: no high heat treatment, conventional activation, and furnace activation. The activation with KOH enhances porosity and surface area. Key parameters analyzed included water content, free fatty acids (FFA), and peroxide value (PV). The results indicated that furnace-activated charcoal performed best, yielding an oil content of 0.05%, which is compliant with SNI 7709:2019 (<0.1%). In contrast, conventional and bamboo powder methods produced water contents of 0.12% and 0.66%, respectively. The lowest FFA content of 0.23% was found in the furnace-activated charcoal, which meets the SNI 01-3741-2002 standard (<0.3%). Additionally, the peroxide value was 6.3 meq O_2/kg, which is lower than the conventional method (9.7 meq O_2/kg) and bamboo powder (13.3 meq O_2/kg), both of which meet SNI No. 01-3741-2013 (<10 meq O_2/kg). The furnace-activated charcoal's superior performance is attributed to its optimal porosity, increased active carbon content, hydrophobic properties, and interaction capabilities with impurities. Thus, furnace-activated bamboo charcoal shows promise as an effective adsorbent for regenerating used cooking oil.

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INTRODUCTION

Indonesia is the country with the highest consumption of palm oil for cooking worldwide, followed by India and China. This high consumption of palm oil may indicate a preference for fried foods over other types of food. The increased use of cooking oil can increase the amount of used cooking oil (UCO) produced (Agro Perspektiva, 2024).

The increase in the use of cooking oil and used cooking oil is not balanced with public awareness of the importance of food and environmental health. Food made with used cooking oil is dangerous to health because it contains substances that can cause degenerative diseases such as cancer, stroke, and other dangerous diseases. In addition, public awareness of environmental protection remains minimal, resulting in the careless disposal of used cooking oil waste, which pollutes the environment (Rahayu et al., 2020).

Used cooking oil is waste from cooking oil that has been repeatedly used for frying (Waluyo et al., 2020). Degradation reactions that occur during the frying process cause the cooking oil to deteriorate (Nasrun et al., 2017). Used cooking oil must be processed to improve its quality and reduce its adverse health effects. The use of adsorbents is one method of processing used cooking oil to restore its clarity and maintain its quality.

Adsorption is considered an efficient and economical method due to its affordability, regenerative nature, and relatively simple process. Bamboo has long been recognized as a natural material with great potential as an adsorbent, as it contains cellulose ranging from 42.4% to 53.6% and lignin ranging from 19.8% to 26.6%. Previous research has shown that bamboo can function as an adsorbent for various pollutants, including heavy metals such as lead (Pb). Research by Ajeng & Wesen indicates that aquatic bamboo plants can adsorb 76% of lead (Pb) (Ajeng & Wesen, 2013). Meanwhile, research by Widayanto et al. shows that activated bamboo charcoal has a higher constant value, namely 0.001305 (Widayatno et al., 2017).

Although bamboo has been widely used as an adsorbent for various pollutants, research on its use as an adsorbent for used cooking oil remains very limited. Therefore, the purpose of this study is to examine the potential of bamboo as an oil adsorbent, considering its abundant availability, low production costs, and sustainable nature.

METHODS

Materials

The materials used in this research were bamboo, used cooking oil, aluminum foil, filter paper, distilled water, KOH, ethanol, NaOH, $H_2C_2O_4$, PP indicator, chloroform, acetic acid (CH_3COOH), saturated KI, 10% KI, $Na_2S_2O_3$, starch, and n-hexane.

Tools

The tools used in this research are knives, choppers, analytical balances, cans, porcelain dishes, ovens, furnaces, petri dishes, spatulas, stirring rods, beakers, spray bottles, measuring flasks, funnels, hot plates, clamps and stands, burettes, Erlenmeyer flasks, dropper pipettes, volumetric pipettes, UV-VIS spectrophotometry..

Research Procedures

Bamboo Preparation

The bamboo is first cleaned, shaved, and ground using a chopper to form a powder. The bamboo powder is divided into three treatment variations. The first variation is untreated bamboo powder. The second variation is bamboo powder charcoaled using a conventional method, manually fired at an uncontrolled temperature. The third variation involves bamboo powder that is oven-dried at 105°C to reduce its moisture content, followed by a 1-hour firing in a furnace at 400°C.

Adsorbent Activation

All three bamboo treatment variations were activated using KOH for 4 hours. After the activation process, the adsorbent was filtered using filter paper. Next, the adsorbent was neutralized with distilled water until the pH reached a neutral level, and then it was filtered again. Finally, the adsorbent was oven-dried for 3 hours at 105°C to remove moisture.

Adsorption of Used Cooking Oil

Five grams of each adsorbent was placed in an Erlenmeyer flask. Next, 100 mL of filtered used cooking oil was added. The mixture was heated for 30 minutes while stirring. After the heating process was complete, the mixture was filtered to separate the oil from the adsorbent. The adsorbed oil was transferred to a reagent bottle for analysis.

Water Content Analysis

For 30 minutes, the porcelain cup was heated in an oven at 105°C. After that, the porcelain cup was cooled in a desiccator for 15 minutes, then weighed to determine its initial weight. Next, 2 grams of each oil was placed in the porcelain cup and weighed again. Next, it was heated in an oven at 105°C for 4 hours. After that, it was cooled in a desiccator for 15 minutes, then weighed again to determine the final weight. The following formula can be used to calculate the water content.

$$\%\,Water\ content = \frac{initial\ sample\ weight - constant\ weight}{early\ west\ sample} \times 100\% \quad \text{(Eq. 1)}$$

Analysis FFA (*Free Fatty Acid*)

Five grams of each oil were placed in an Erlenmeyer flask, then 50 mL of ethanol was added and heated until the mixture was homogeneous. After that, the PP indicator was added and titrated with 0.1 N NaOH until a pink color was formed. The following formula can be used to calculate the FFA (Free Fatty Acid) content.

$$\%FFA = \frac{V_{NaOH} \times N_{NaOH} \times BE_{Oil}}{sample\ weight \times 1000} \times 100\% \quad \text{(Eq. 2)}$$

Description:
N NaOH = volume of NaOH used during titration (mL)
N NaOH = Normality of NaOH (N)
BE oil = molecular weight of oil (256), sample weight (g)

Analysis PV (*Peroxide Value*)

Three grams of each oil was placed in an Erlenmeyer flask, then 15 mL of acetate-chloroform was added in a 3:2 ratio. The mixture was stirred, then 0.5 mL of saturated KI solution was added, covered, and allowed to stand for 2 minutes. After that, 15 mL of distilled water was added and titrated until a pale yellow color was formed. A few drops of starch were added, then titrated again until the blue color disappeared. The following formula can be used to calculate the PV (Peroxide Value) content.

$$PV = \frac{N_{Na_2S_2O_3} \times V_0 - V_{1\ Na_2S_2O_3} \times 1000}{sample\ weight} \quad \text{(Eq. 3)}$$

Description:
N $Na_2S_2O_3$ = normality of $Na_2S_2O_3$ (N)
V_0 $Na_2S_2O_3$ = volume of $Na_2S_2O_3$ used during blank titration (mL)
V_1 $Na_2S_2O_3$ = volume of $Na_2S_2O_3$ used during sample titration (mL),

Clarity Test

The three adsorbed oil samples were diluted using n-hexane. The samples were then placed in a cuvette. The oil absorbance was then measured at a wavelength of 360 nm using pure oil as a blank.

RESULT AND DISCUSSION

The potential of bamboo stem powder as an adsorbent for regenerating used cooking oil is based on the ability of activated carbon from bamboo to adsorb impurities contained in used cooking oil. The primary objective of this study was to evaluate the effectiveness of bamboo powder in three different treatment variations for adsorbing impurities in used cooking oil.

Adsorbent activation using KOH aims to release dirt that covers the carbon pores, thereby increasing the pore size and surface area of the bamboo powder (Dewi et al., 2021). The activation process increases the activated carbon content in bamboo charcoal, which is hydrophobic and tends to attract non-polar compounds and cellulose content with hydroxyl groups (-OH) that can interact with impurities, such as FFA and peroxide compounds. This process is designed to produce optimal bamboo powder as an adsorbent for heavy metals and organic compounds in used cooking oil. One of the physical characteristics that is very important in determining the quality of activated carbon as an adsorbent is its surface area. Bamboo carbon has a surface area of around 10-50 m^2/g. If bamboo carbon is chemically activated (at a temperature of 105°C for 3 hours) using KOH, the activated carbon produced typically has a surface area of around 500-1500 m^2/g or more (Evbuomwan et al., 2013).

During the adsorption stage, the used cooking oil with furnace-processed activated bamboo charcoal appeared clearer compared to activated bamboo charcoal from traditional charcoal processing and activated bamboo powder. This is due to the furnace process producing activated charcoal with a greater number of pores and a larger surface area, making it more effective in absorbing impurities, color compounds, and dissolved substances. Traditionally processed activated charcoal has fewer pores due to the lower temperature and shorter duration of the process, resulting in a lower adsorption capacity; however, it can still reduce oil turbidity. Meanwhile, activated bamboo powder without high heat treatment had the lowest adsorption capacity because its pore structure was not optimal, resulting in the lowest oil clarity. This is because the pores are not well formed, reducing the powder's ability to interact with impurities in used cooking oil (Nasrun et al., 2017).

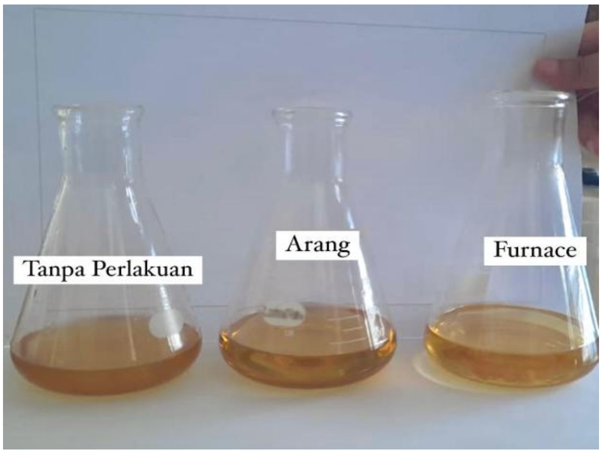

Figure 1. Adsorption results with three different treatment variations

Table 1. Analysis of the Quality of Adsorption Oil

Variations of bamboo adsorbents	Adsorption Oil Quality Analysis		
	Water content	FFA	PV
Active bamboo powder	0,66 %	0,87 %	13,3 meq O_2/ kg
Activated charcoal from conventional methods	0,12 %	0,30 %	9,67 meq O_2/ kg
Furnace-made activated charcoal	0,05 %	0,23 %	6,3 meq O_2/ kg

The hygroscopic properties of the resulting activated carbon are determined by measuring its water content. Water content is the primary factor determining the extent of oil deterioration, as its presence accelerates the hydrolysis process, which initiates oil decomposition. The greater the amount of water contained in the oil, the higher the rate of hydrolysis. The presence of water in oil typically leads to the formation of FFA and glycerol (Fathanah & Lubis, 2022). The use of bamboo powder as an adsorbent in reducing water content depends on three treatment variations applied to the bamboo powder. SNI 7709:2019 stipulates that the maximum water content in cooking oil is 0.1%. Test results showed that furnace-processed bamboo activated carbon met SNI requirements, with a water content of 0.05%. Meanwhile, used cooking oil refined with activated bamboo powder was not effective enough in absorbing water, as indicated by its still quite high water content, namely 0.66%. Conventionally processed bamboo activated carbon produced oil with a lower water content of 0.12% but did not meet SNI standards. The absorption of water content from furnace-activated carbon is enhanced because the pores produced have a wider surface area, which can increase the adsorption capacity of the activated carbon (Dewi et al., 2019).

Free fatty acids (FFA) are straight-chain carboxylic acids with 12 to 20 carbon atoms, which are divided into saturated and unsaturated fatty acids. The FFA content in cooking oil reflects its quality; good oil has more unsaturated fatty acids than saturated. The higher the FFA number, the lower the quality of the oil (Levia & Mhubaligh, 2023). The results of determining the Free Fatty Acid (FFA) content of used cooking oil depend on the treatment variation. Based on the SNI 01-3741-2002 standard, the FFA content permitted by the government is 0.3%. The test results obtained the FFA content of the active bamboo powder variation of 0.87%, while the variation of activated charcoal processed using the conventional method was 0.30%. These results indicate that activated charcoal with the conventional method provides better adsorption than activated bamboo powder. The FFA content in furnace-activated charcoal of 0.23% has met the SNI standard. The FFA content in furnace-activated charcoal is better than that of activated bamboo powder and activated charcoal processed using conventional methods, because the furnace-activated charcoal adsorbent has a large surface area, so that it can accelerate the adsorption rate and increase the number of particles that can be absorbed (Hasriani et al., 2023).

The peroxide value is a measure of the degree of damage to an oil or fat due to oxidation. The higher the peroxide value, the more peroxide compounds are formed, which are the cause of the rancid aroma in oil or fat. SNI Standard No. 01 3741-2013 sets the maximum limit for the peroxide value for a particular food ingredient at 10 meq O_2/kg. Based on the results of the peroxide value test, activated bamboo powder does not meet the SNI standard. The peroxide value of activated charcoal processed using the conventional method of 9.7 meq O_2/kg already meets the SNI standard. However, the results of the peroxide value of activated charcoal from the furnace showed better results at 6.3 meq O2/kg, due to its large surface area, which can accelerate the adsorption rate and increase the number of particles that can be absorbed (Hasriani et al., 2023).

Oil and fat contain dyes that can absorb light from the spectrum. This color plays a role in determining the quality of oil and fat. This is the basis for determining the properties of oil using a UV-Vis spectrophotometer. This tool measures oil clarity using a wavelength of 360 nm, with absorbance indicating the level of turbidity (Leong et al., 2018). Based on the measurement results, the adsorbance value of pure oil as a blank was 0.448. Meanwhile, the adsorption results with bamboo powder had the highest adsorbance value of 0.883, which showed that it was less effective in reducing oil turbidity compared to activated charcoal. In oil adsorption results, the bamboo activated charcoal processed using conventional methods decreased to 0.275. The adsorption results with bamboo activated charcoal in the furnace had an adsorbance value of 0.122. Of the three types of adsorbents, bamboo activated charcoal in the furnace was the most effective in reducing the turbidity of used cooking oil.

CONCLUSION

Bamboo powder processed into activated charcoal through the furnace method exhibits the best effectiveness in regenerating used cooking oil compared to conventional methods or those without high-heat treatment. This is shown by the ability of furnace-activated charcoal to meet SNI standards for water content (0.05%), free fatty acid content (0.23%), and peroxide value (6.3 meq O_2/kg). The furnace method produces more optimal activated charcoal because the temperature and duration of the process increase the surface area and porosity, making it more effective in absorbing dirt, color compounds, and dissolved substances. Thus, furnace-activated charcoal from bamboo powder has excellent potential as an adsorbent for efficiently regenerating used cooking oil in an environmentally friendly manner.

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