

CHARACTERISTICS OF ACTIVATED CHARCOAL FROM KETAPANG SEED SHELLS WITH VARIOUS CONCENTRATIONS OF PHOSPHORIC ACID (H_3PO_4)

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ABSTRACT

This investigation evaluated the effect of phosphoric acid (H_3PO_4) concentrations as a chemical activating agent on the characteristics of activated carbon produced from ketapang seed shells. A Completely Randomized Design (CRD) with four independent treatments and four replications was employed, testing (H_3PO_4) concentration levels of 6% CBK₁, 8% CBK₂, 10% CBK₃, and 12% CBK₄. Evaluated properties comprised product yield, moisture, ash, volatile matter, fixed carbon, and iodine adsorption capability. Statistical evaluations via analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT, $p < 0.05$) revealed that elevating the H_3PO_4 concentration significantly influenced all measured parameters. Among the tested range, treatment CBK₄ (12% H_3PO_4) exhibited the most favorable performance, yielding activated carbon with 83.14% yield, 2.63% moisture, 3.90% ash, 10.13% volatile matter, 83.34% fixed carbon, and an iodine uptake of 862.50 mg/g.

Keywords: activated carbon, concentrations, ketapang seed shell, phosphoric acid

INTRODUCTION

In Indonesia, including Riau Province, the tropical almond tree (*Terminalia catappa*) represents a widely distributed agricultural commodity. According to Statistics Indonesia (Badan Pusat Statistik, 2023), Riau Province has an average temperature ranging from 31.9 to 41°C. The relatively high temperatures and intense sunlight make the ketapang tree an important shade plant. It has a broad, umbrella-shaped canopy with dense foliage and abundant fruit.

The fruit of the ketapang tree is one of its products that has not been optimally utilized. In many cases, the fruits simply accumulate around the trees over time. Ketapang fruit consists of the fruit peel, pulp, seed shell, and kernel. Among these parts, the seed shell has the hardest texture and therefore requires a longer time to decompose naturally. Consequently, the accumulation of tropical almond seed shells presents an opportunity for value-added utilization. According to Ariyanto et al. (2021), tropical almond seed shells contain a high carbon content derived from 16.6% cellulose, 24.7% hemicellulose, and 43.46% lignin.

Carbonaceous precursors serve as the essential feedstock for activated charcoal synthesis, which is typically manufactured from organic substances rich in carbon content. (Rijali et al., 2015). The high lignin content of tropical almond seed shells contributes significantly to the effectiveness of activated charcoal production. According to Rahmaena (2023), lignin is a carbon-rich biomass component that decomposes during carbonization at temperatures ranging from 300 to 900°C, producing charcoal with a high carbon content, which serves as the basic material for activated charcoal. Lignin also promotes the formation of micro- and macroporous structures in charcoal. High porosity is essential for increasing the surface area of activated charcoal, thereby enhancing its adsorption capacity. Furthermore, lignin improves carbon yield, accelerates pore formation, and produces activated charcoal with a larger surface area and higher adsorption capacity, making it an important factor in determining the quality and efficiency of activated charcoal production. Therefore, converting tropical almond seed shell waste into activated charcoal is expected to reduce agricultural waste while producing a value-added product.

Activated charcoal is a carbonaceous material characterized by significant adsorption affinity toward various anionic, cationic, organic, and inorganic species across fluid and gas phases (Lubis et al., 2021). It is widely used for decolorization, wastewater treatment, and the purification of liquids and gases. Activated charcoal is generally produced through carbonization followed by activation. Carbonization is the process of heating biomass under limited oxygen conditions without chemical additives, whereas activation is carried out to convert the carbonized material into an adsorbent with a large surface area and well-developed pore structure (Sulaiman et al., 2017).

Activation is a treatment process that enlarges the pore structure of carbon by breaking hydrocarbon bonds, thereby increasing the surface area and enhancing its adsorption capacity (Pane & Hamzah, 2018). Carbon can be activated through either physical or chemical methods. Physical activation typically utilizes a furnace operating between 500 and 700°C, whereas chemical activation relies on the incorporation of chemical reagents. Common chemical activators include phosphoric acid (H_3PO_4) and potassium hydroxide (KOH). Acidic activators such as H_3PO_4 are generally more suitable for lignocellulosic materials than alkaline activators such as KOH. Yunus et al. (2021) reported that activation using H_3PO_4 produced a higher fixed carbon content (76.41%) than KOH (76.17%). H_3PO_4 is more effective in dissolving minerals bound to carbon molecules by forming new functional groups. Since lignocellulosic materials contain relatively high oxygen content, acidic activators react more effectively with oxygen-containing functional groups (Turmuzi et al., 2015).

The appropriate concentration of H_3PO_4 used during the activation process plays an important role in removing residual tar and impurities formed during carbonization. Consequently, the specific surface area of the carbon expands, thereby enhancing its overall adsorption performance (Kadang et al., 2020). Another advantage of using H_3PO_4 in activated charcoal production is its relatively low environmental impact because it is classified as a weak acid. After activation, the activated charcoal can be neutralized simply by rinsing or washing it with running water or distilled water until a neutral pH is achieved (Husin & Hasibuan, 2020).

In a related study, Lestari et al. (2016) synthesized activated carbon from coconut shell precursors using phosphoric acid as an activator to treat and purify waste cooking oil. Phosphoric acid concentrations of 2%, 4%, 6%, and 8% were evaluated. Findings indicated that the 8% H_3PO_4 treatment produced the best activated charcoal, meeting the Indonesian National Standard (SNI 06-3730-1995), with a moisture content of 1% and an ash content of 0.34%. Meilianti (2017) produced activated carbon from rubber fruit shells using H_3PO_4 concentrations of 8%, 8.5%, 9%, 9.5%, and 10%. The 10% concentration emerged as the optimal condition, producing activated charcoal that met the SNI 06-3730-1995 standard with 3.25% moisture content, 3.36% ash content, and an iodine uptake of 947.25 mg g⁻¹.

Ola et al. (2023) produced activated charcoal from tropical almond seed shells using hydrochloric acid (HCl) at a concentration of 37% as the activating agent. The study demonstrated that the resulting activated charcoal met the requirements of SNI 06-3730-1995, with a moisture content of 5%, an ash content of 2.1%, and an iodine adsorption capacity of 761.4 mg g⁻¹. Building upon these prior findings, the present research was undertaken to assess the Characteristics of Activated Charcoal Produced from Ketapang Seed Shells Using Different Concentrations of Phosphoric Acid (H_3PO_4).

METHODS

Materials

This study utilized seed shells of tropical almond (*Terminalia catappa*) as the main precursor, collected from dark brown, naturally fallen fruits. The seed shells were obtained from Bukit Raya District, Pekanbaru City, Indonesia. Other materials included 70% phosphoric acid (H_3PO_4), 0.1 N iodine (I_2) solution, 1% starch solution, 0.1 N sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$), kerosene, and distilled water. The experimental setup incorporated various apparatuses, comprising a titration apparatus, aluminum foil, a

100-mesh sieve, plastic basins, a stirring rod, a burette, porcelain crucibles, a funnel, a desiccator, a carbonization drum (20 × 30 cm), Erlenmeyer flasks, beakers, glass jars, graduated cylinders, label paper, filter paper, clamps, trays, crucible tongs, a micropipette, gloves, a spatula, a laboratory stand, stationery, and a digital camera for documentation. Additional equipment included a blender, a drying oven, a pH meter, a muffle furnace, and an analytical balance.

Research Methodology

An experimental approach based on a Completely Randomized Design (CRD) was implemented, featuring four distinct treatment conditions replicated four times to yield 16 experimental units in total. Treatment conditions were formulated following the methodology described by Meilianti (2017), using different concentrations of phosphoric acid (H_3PO_4). CBK1 = 6% H_3PO_4 concentration, CBK2 = 8% H_3PO_4 concentration, CBK3 = 10% H_3PO_4 concentration, CBK4 = 12% H_3PO_4 concentration.

Research Implementation

Preparation of raw materials

Raw material pretreatment followed the procedure outlined by Ariyanto et al. (2021). Tropical almond (*Terminalia catappa*) fruits were collected after naturally falling from the trees and exhibiting a dark brown color. The fruit peel and pulp were removed manually using a knife to obtain the seeds. The seeds were then cracked to separate the seed shells. The seed shells were weighed and sun-dried for approximately 72 hours to reduce their moisture content. After drying, the shell biomass was reweighed to calculate its moisture level.

Carbonization process

The carbonization process followed the procedure reported by Ariyanto et al. (2021). The sun-dried tropical almond seed shells were carbonized using a closed steel drum measuring 20 × 30 cm, with kerosene used as the ignition fuel. Carbonization was carried out in a closed drum under limited oxygen conditions for approximately one hour or until the seed shells were completely converted into charcoal.

Chemical activation

The chemical activation procedure was conducted according to Ariyanto et al. (2021). A total of 10 g of tropical almond seed shell charcoal was placed in a glass jar, followed by the addition of 100 mL of phosphoric acid (H_3PO_4) solution at concentrations of 6%, 8%, 10%, or 12%, which had been previously diluted with distilled water. The slurry was continuously stirred to achieve homogeneity and subsequently left to equilibrate at ambient temperature for 24 hours (approximately 27°C) to complete the activation process. After activation, the charcoal was filtered using filter paper and rinsed thoroughly using deionized water until the rinsing effluent reached a neutral pH level. The activated charcoal was then dried in a drying oven at 105°C for 30 minutes. After drying, the samples were stored in suitable containers and weighed to obtain the final activated charcoal. The powdered activated charcoal was subsequently subjected to further analyses.

Activated charcoal yield

Quantification of the activated charcoal yield followed the method described by Aryani (2019). Activated charcoal yield was evaluated by quantifying the mass ratio of the resulting carbon after chemical activation to the initial dry charcoal prior to activation. The yield calculation was executed using Equation 1.

$$\text{Yield (\%)} = \frac{\text{Mass of recovered activated carbon (g)}}{\text{Mass of dried precursor shell (g)}} \times 100 \quad (1)$$

Moisture content

Moisture content evaluation was carried out in compliance with the Indonesian National Standard (SNI 06-3730-1995) (Badan Standardisasi Nasional, 1995). A porcelain crucible was first dried in an oven at 105°C for 15 min and then cooled to room temperature. A sample mass of approximately 2 g was introduced into a previously tared crucible. The assembly was thermally dried at 105°C for 1 h in a laboratory oven to attain constant mass. Following desiccation in a desiccator for 15 min to reach room temperature, the vessel was reweighed. Drying and cooling cycles were iterated until successive weight measurements demonstrated a variance of no more than 0.0002 g. The moisture fraction was subsequently derived using Equation 2.

$$\text{Moisture Content (\%)} = \frac{\text{Initial sample weight (g)} - \text{Final sample weight (g)}}{\text{Initial sample weight (g)}} \times 100 \quad (2)$$

Ash content

Quantification of ash content was conducted following the protocol reported by Ariyanto et al. (2021). A porcelain crucible was initially conditioned in an oven at 105°C for 15 min and cooled in a desiccator for 10 min. Approximately 2 g of the sample was introduced into the pre-conditioned crucible. The assembly was then calcined in a muffle furnace at 600°C for 2 h until complete combustion yielded a whitish ash residue. Upon removal, the crucible was transferred to a desiccator for a 30-min cooling phase before final mass measurement. The ash percentage was calculated using Equation 3.

$$\text{Ash Content (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100 \quad (3)$$

Volatile matter content

Volatile matter content was evaluated in accordance with the Indonesian National Standard (SNI 06-3730-1995). A sample mass of approximately 2 g of the dried charcoal was introduced into a previously tared porcelain crucible and subjected to rapid pyrolysis in a muffle furnace maintained at 950°C for 7 min. Upon removal, the crucible was cooled inside a desiccator and reweighed to achieve a constant mass. The volatile fraction was then derived using Equation 4.

$$\text{Volatile Matter (\%)} = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Initial weight (g)} - \text{Weight of empty crucible (g)}} \times 100 \quad (4)$$

Fixed carbon content

Fixed carbon content was evaluated in compliance with the Indonesian National Standard (SNI 06-3730-1995). The proportion of fixed carbon was derived indirectly by deducting the cumulative percentage values of moisture, ash, and volatile matter from 100%, as expressed in Equation 5.

$$\text{Fixed Carbon (\%)} = 100 - (\text{Moisture content} + \text{Ash content} + \text{Volatile matter content}) \quad (5)$$

Iodine adsorption capacity

The determination followed by Indonesian National Standard (SNI) 06-3730-1995 (Badan Nasional Indonesia, 1995). Approximately 0.5 g of activated charcoal was weighed and transferred into an Erlenmeyer flask. Fifty milliliters of 0.1 N iodine solution (I₂) was added to the sample, and the suspension

was homogenized using a magnetic stirrer for roughly 15 min under ambient temperature. The mixture was subsequently passed through filter paper. A 10 mL portion of the resulting filtrate was titrated against a standard with 0.1 N sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) solution until a pale yellow coloration appeared. At this stage, several drops of a 1% starch indicator were introduced, and titration proceeded until the solution transitioned from blue-black to completely colorless. The total volume of $\text{Na}_2\text{S}_2\text{O}_3$ consumed was measured, and the iodine adsorption capacity was derived via Equation 6.

$$\text{Iodine Adsorption Capacity (mg/g)} = \frac{A \times \frac{B \times N (\text{Na}_2\text{S}_2\text{O}_3)}{N (\text{I}_2)} \times 12,69 \times 5}{\alpha} \quad (6)$$

Where:

A = Volume of iodine solution (mL)

B = Volume of sodium thiosulfate solution (mL)

5 = Dilution factor

α = Weight of activated charcoal (g)

N ($\text{Na}_2\text{S}_2\text{O}_3$) = Normality of sodium thiosulfate solution (N)

N (I_2) = Normality of iodine solution (N)

12.69 = Amount of iodine equivalent to 1 mL of sodium thiosulfate solution (mg)

Data Analysis

Experimental data were subjected to statistical evaluation via Analysis of Variance (ANOVA) utilizing IBM SPSS Statistics version 23. A treatment effect was deemed statistically significant whenever the calculated F-statistic equaled or exceeded the critical F-table value. Where significant variations among treatments were identified, mean comparisons were subsequently conducted using Duncan's Multiple Range Test (DMRT) at a 5% significance threshold ($p < 0.05$).

RESULTS AND DISCUSSION

The empirical findings obtained from the experimental procedure are summarized in Table 1 below.

Table 1. Characteristics of activated charcoal from ketapang seed shells

Parameter	Indonesian Nasional Standard (SNI)	Treatment			
		CBK ₁ (H ₃ PO ₄ 6%)	CBK ₂ (H ₃ PO ₄ 8%)	CBK ₃ (H ₃ PO ₄ 10%)	CBK ₄ (H ₃ PO ₄ 12%)
Yield (%)	-	74.63 ^a	78.13 ^b	81.00 ^c	83.14 ^d
Moisture content (%)	max. 15	6.69 ^d	5.25 ^c	4.07 ^b	2.63 ^a
Ash content (%)	max. 10	8.61 ^d	7.18 ^c	5.87 ^b	3.90 ^a
Volatile matter (%)	max. 25	16.56 ^d	14.56 ^c	12.37 ^b	10.13 ^a
Fixed carbon (%)	min. 65	68.14 ^a	73.01 ^b	77.68 ^c	83.34 ^d
Iodine adsorption capacity (mg/g)	min. 750	618.75 ^a	712.50 ^b	815.63 ^c	862.50 ^d

Note: Mean values within the same row sharing different superscript lowercase letters are significantly distinct based on Duncan's Multiple Range Test (DMRT) at ($p < 0.05$). **CETAK TEBAL**

Yield

The analysis of variance demonstrated that the concentration of the activator (H_3PO_4) had a significant effect on the yield obtained. The average yield of activated charcoal from tropical almond seed shells after Duncan's Multiple Range Test (DMRT) at the 5% significance level is presented in Table 1. The highest yield of activated charcoal from tropical almond seed shells was obtained in treatment CBK4, amounting to 83.14%, which exhibited a statistically significant variation compared to alternative treatment groups. The lowest yield was obtained in treatment CBK1, amounting to 74.63%. The yield of activated charcoal from tropical almond seed shells increased with increasing concentration of the H_3PO_4 activator used.

The increase in activated charcoal yield was caused by the role of H_3PO_4 as a dehydrating agent, which is capable of binding and removing water molecules from the material during the activation process. The H_3PO_4 activator also plays a role in forming phosphate ester bonds through interactions between phosphate groups and hydroxyl groups in lignocellulosic components. The formation of these bonds causes the carbon structure to become more stable during the heating process, thereby reducing mass loss due to the formation of volatile compounds such as CO , CO_2 , CH_4 , and water vapor. Therefore, higher concentration of H_3PO_4 used, greater ability of the activator to maintain the carbon framework, resulting in an increased yield of activated charcoal.

Chagu and Mwakalesi (2026) explained that the H_3PO_4 activator is capable of maintaining the carbon structure during the activation process by promoting dehydration and stabilizing the carbon structure rather than promoting carbon degradation. Consequently, increasing the activator concentration increases the quantity of carbon remaining after the activation process and improves the yield obtained. Neme et al. (2022) explained that chemical activation using H_3PO_4 helps preserve the carbon structure during the activation process because H_3PO_4 accelerates biomass dehydration and forms a more stable carbon structure. The observed trend is consistent with prior research by Sahara et al. (2017), who stated that the high yield of activated charcoal produced was due to the reaction between phosphoric acid and charcoal, in which the optimum activator concentration reacted more extensively with the charcoal, resulting in a higher yield. Furthermore, higher concentrations of the H_3PO_4 activating agent enhance activated charcoal yield by preserving the carbonaceous framework during thermal treatment, which limits material mass loss and minimizes the evolution of volatile matter (Ridho, 2023).

Moisture Content

The lowest moisture content of activated charcoal from tropical almond seed shells was obtained in treatment CBK4, amounting to 2.63%, showing a statistically distinct value relative to the other treatments evaluated. Treatment CBK1 yielded the highest moisture level at 6.69%. The moisture content of activated charcoal from tropical almond seed shells decreased with increasing concentration of the H_3PO_4 activator used. This occurred because H_3PO_4 acts as a dehydrating agent that facilitates the removal of water molecules from the charcoal, allowing these water molecules to be more easily released and evaporated during the drying process, thereby reducing the moisture content of the activated charcoal.

A lower moisture content in activated charcoal is achieved through higher H_3PO_4 concentrations, which effectively widen internal pore structures and promote water release. According to Xu et al. (2021), activation using H_3PO_4 enlarges the pores of activated charcoal, allowing water contained in the material to be more easily released during the heating process. Lestari et al. (2016) stated that the reduction in the moisture content of activated charcoal occurs because phosphoric acid acts to facilitate the removal of water from the carbon structure during the activation and drying processes. Phosphoric acid functions by binding and removing water molecules from the surface and pore spaces, which are subsequently eliminated during the heating process.

Ash Content

The lowest ash content of activated charcoal from tropical almond seed shells was obtained in treatment CBK₄, amounting to 3.90%, showing a statistically distinct value relative to the other treatments evaluated. The peak ash level was recorded in the CBK₁ sample, amounting to 8.61%. The ash content of activated charcoal from tropical almond seed shells decreased with increasing concentration of the H₃PO₄ activator used. An increase in the concentration of the H₃PO₄ activator used, the more minerals could be bound, dissolved, and removed during the washing process, resulting in a lower ash content of the activated charcoal. According to Xu et al. (2021), activation using H₃PO₄ acid can help dissolve and remove some of the minerals present in the material during the activation and washing processes. H₃PO₄ functions by binding minerals and impurities in the material during the activation process, which are subsequently removed during washing, which effectively lowered the final ash content of the activated charcoal product.

Increasing the concentration of H₃PO₄ enhances the ability of the activator to bind and dissolve minerals in the charcoal, such as sodium, potassium, magnesium, and calcium, thereby reducing the remaining ash components and decreasing the ash content of activated charcoal from tropical almond seed shells. This statement is consistent with Zulfadhli and Iriany (2017), who stated that the H₃PO₄ activator reacts with the minerals present in the charcoal produced from the carbonization process, allowing these minerals to dissolve and be removed during the washing process.

Volatile Matter Content

The lowest volatile matter content of activated charcoal from tropical almond seed shells was obtained in treatment CBK₄, amounting to 10.13%, showing a statistically distinct value relative to the other treatments evaluated. The peak volatile matter level was recorded in the CBK₁, amounting to 16.56%. A gradual decline in volatile matter content was observed in tropical almond seed shell activated charcoal as the H₃PO₄ activator concentration was raised. This reduction in volatile matter suggests that increasing the activator concentration directly enhances the release of volatile compounds and non-carbon substances from the charcoal structure during the activation process.

Increasing the concentration of H₃PO₄ caused the dehydration and degradation processes of volatile compounds to occur more intensively, resulting in lower contents of volatile substances such as CO, CO₂, CH₄, and water vapor in the activated charcoal. According to Xu et al. (2021), activation using H₃PO₄ acid can accelerate the decomposition of non-carbon components such as water and volatile compounds during heating, thereby reducing the quantity of unreacted volatile matter persisting post-carbonization and activation. Mentari et al. (2018) explained that the use of H₃PO₄ as an activator can interact with charcoal through the formation of polar C=O and C–OH functional groups. These functional groups are capable of attracting and binding non-carbon compounds in the charcoal through electrostatic interactions, thereby forming stable bonds. These bound non-carbon compounds are subsequently dissolved and removed during the washing process, resulting in a decrease in the volatile matter content of the activated charcoal.

Increasing the concentration of the H₃PO₄ activator enhances its ability to bind and dissolve non-carbon compounds in the charcoal, thereby reducing the amount of non-carbon compounds remaining on the surface of the activated charcoal and decreasing the volatile matter content of activated charcoal from tropical almond seed shells. This observation is supported by Sirajuddin et al. (2019), who observed that utilizing of higher concentrations of H₃PO₄ caused more volatile compounds to dissolve in the activator, thereby lowering the volatile matter content of the activated charcoal.

Fixed Carbon Content

The highest fixed carbon content of activated charcoal from tropical almond seed shells was obtained in treatment CBK₄, amounting to 83.34%, showing a statistically distinct value relative to the other treatments evaluated. The lowest fixed carbon level was recorded in the CBK₁, amounting to 68.14%. The fixed carbon content of activated charcoal from tropical almond seed shells increased with increasing

concentration of the H_3PO_4 activator used. This occurred because H_3PO_4 acts as a dehydrating agent that facilitates the removal of water and non-carbon compounds during the heating process, while also opening the pores of the charcoal, allowing non-carbon components to be released more easily. As a result, the remaining carbon fraction becomes greater accompanied by a corresponding elevation in the fixed carbon fraction

This improvement in the fixed carbon proportion stems from the efficacy of H_3PO_4 activator to bind and dissolve minerals and impurity compounds present in the charcoal, which were subsequently removed during the washing process. The greater the amount of minerals and impurities eliminated, the higher the purity of the remaining carbon in the charcoal, resulting in an increased fixed carbon content. This finding is supported by Sirajuddin et al. (2019), who stated that the H_3PO_4 activator can bind impurity compounds in charcoal and dissolve them during the washing process, thereby leaving a purer carbon fraction. Efiyanti et al. (2020) further noted that higher proportions of fixed carbon serve as a key indicator of enhanced physicochemical properties in the prepared charcoal.

Iodine Adsorption Capacity

The peak iodine adsorption capacity of the activated charcoal from tropical almond seed shells was obtained in treatment CBK₄, amounting to 862.50 mg/g, exhibiting a statistically significant variation relative to alternative treatment conditions. The lowest iodine adsorption capacity was obtained in treatment CBK₁, amounting to 618.75 mg/g. The iodine binding capability of the prepared activated carbon from tropical almond seed shells increased with increasing concentration of the H_3PO_4 activator used. This increase in iodine adsorption capacity was attributed to the ability of the H_3PO_4 activator to increase the surface area and open the pores of the charcoal by binding and dissolving impurity compounds during the activation and washing processes.

Increasing the concentration of the H_3PO_4 activator during the activation process enhanced the ability of the activator to open and enlarge the pores of the activated charcoal. The more pores that were opened, the larger the surface area of the activated charcoal, allowing more iodine to be adsorbed. According to Xu et al. (2021), activation using phosphoric acid can enhance pore structure development and increase the surface area of activated carbon, thereby improving its adsorption capacity for substances such as iodine. These results align with the observations of Sahara et al. (2017), who attributed the elevated iodine binding capacity of activated carbon to the incorporation of H_3PO_4 as an activator was able to remove impurities from the charcoal pores, thereby increasing the size and number of pores and enhancing the adsorption efficiency of the synthesized activated carbon.

Recapitulation of the Selected Activated Charcoal Treatment

According to the recapitulation of the analysis results of activated charcoal from tropical almond seed shells, the selected treatment was CBK₄ with an H_3PO_4 activator concentration of 12%. The selection of this treatment was based on the test results, which showed that although the moisture content of treatment CBK₃ had already met the standard, the moisture content obtained in treatment CBK₄ was lower than that of CBK₃. In addition, the ash content and volatile matter content of treatment CBK₄ were also lower than those of treatment CBK₃, indicating lower mineral and non-carbon compound contents in the activated charcoal.

Treatment CBK₄ produced a higher fixed carbon content than treatment CBK₃, reflecting higher carbon purity and better activated charcoal quality. The selection of the best treatment in this study was also based on iodine adsorption capacity as the main indicator of the adsorption performance of activated charcoal. Treatment CBK₄ had a higher iodine adsorption capacity than treatment CBK₃, indicating more optimal adsorption performance.

Although treatment CBK₃ with an H₃PO₄ activator concentration of 10% had already met the requirements of SNI No. 06-3730-1995, treatment CBK₄ produced better results for several important parameters, including lower moisture content, lower ash content, higher fixed carbon content, and greater iodine adsorption capacity. Therefore, treatment CBK₄ was selected as the best treatment because it produced activated charcoal of higher quality than treatment CBK₃. Treatment CBK₄ produced an activated charcoal yield of 83.14%, moisture content of 2.63%, ash content of 3.90%, volatile matter content of 10.13%, fixed carbon content of 83.34%, and an iodine adsorption capacity of 862.50 mg/g.

CONCLUSION

According to the empirical data and subsequent statistical evaluations, it can be concluded that increasing the concentration of the H₃PO₄ activator to 6%, 8%, 10%, and 12% affected all observed parameters, namely moisture content, ash content, volatile matter content, fixed carbon content, and iodine adsorption capacity. The best activated charcoal produced in this study was obtained from treatment CBK₄ with an H₃PO₄ activator concentration of 12%, which resulted in a yield of 83.14%, moisture content of 2.63%, ash content of 3.90%, volatile matter content of 10.13%, fixed carbon content of 83.34%, and an iodine adsorption capacity of 862.50 mg/g.

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