

Characterization Of Charcoal Product Of Pyrolysis Of Human Hair Waste Activated With KOH Solution

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ABSTRACT

This research aims to characterize charcoal resulting from pyrolysis of human hair waste which is activated by KOH solutions using FTIR, XRD and SEM instruments. The human hair charcoal obtained from pyrolysis then goes into the particle size reduction process using a 60 and 100 mesh sieve. It is then activated using KOH and then the results of the activation are analyzed using FTIR, XRD instruments assisted by *software*. *Origin* and *Ms. Excel*, then SEM assisted by *Image-J software*. The ash content test results show that the amount of minerals and metals in human hair charcoal tends to increase. The results of the water content test show that the amount of water content in human hair charcoal tends to decrease. In analysis using FTIR it was identified showed the presence of various functional groups in human hair charcoal processed with KOH and Control Sample solutions. Mesh differences in processing give slight variations in peak intensity and position, but overall indicate the presence of O-H, CH, C=C, and CO groups. In the analysis using The solution gave the largest grain size in KOH mess 100, namely $D = 356.35764 \pm 11.18168$ nm.

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Introduction

One problem that is never discussed by the public is the problem of waste, for example domestic waste such as waste from household activities, business activities, restaurants and so on. And therefore, good waste management and processing is needed so that it does not have an impact on the community environment.

Human hair is a type of waste that is often underestimated as a result if it is allowed to accumulate, especially with current developments which have made salons or similar hair style places develop rapidly both in city centers and suburbs. Human hair waste is not easily digested by microorganisms in soil and water. The total part of human hair consists of 51% carbon, 21% oxygen, 17% nitrogen, 6% hydrogen, and 5% sulfur, as well as small amounts of minerals, 1% melanin and pheomelanin [17] [1]. In general, human hair fiber contains 50 – 60% keratin, 20 – 30% protein matrix, various pigments such as melanin, up

to 30% water, and lipids [15]. From the overall chemical content of human hair, almost all keratin and its derivatives are difficult to process by microorganisms in the soil.

Burning human hair in the open will produce smelly gas and can harm human health. According to Anjum in [3] provided data that workers processing haircut waste in India often experience respiratory infections and tuberculosis, due to inhaling the dust of burnt hair and the smell of rotting hair.

Managing human hair waste requires systematic thinking because of the importance of protecting the environment and human health, especially the potential for processing human hair waste so that it can be used for the benefit of humans and the environment or can be converted into waste products that are useful and have economic value. In the field of development of new materials and technologies there are several sociocultural and economic aspects associated with them, which often determine the adaptation of these uses

and technologies. Therefore, it is important to design and create appropriate technology to handle human hair waste starting from the potential use and technology as well as its impact on society and the environment.

The pyrolysis method is an alternative for processing urban solid waste and is thought to have good opportunities for development [9]. The working mechanism is simple and the pyrolysis process does not produce new waste that can pollute the environment, pyrolysis is one way to process solid waste, especially human hair waste [11]. Another advantage of pyrolysis is that solid waste will have products with a high ratio and high energy content. Pyrolysis techniques for processing solid waste, especially human hair waste, must be developed continuously in order to obtain a good and efficient working system. Pyrolysis itself is a reaction of the decomposition of substances at high temperatures in limited oxygen conditions, going through several stages starting from decomposition, gas formation, condensation and the final stage or termination. Pyrolysis of solid waste will produce products in the form of liquid, gas and the remainder in the form of solids or charcoal. About the kinetics of gas and liquid smoke resulting from catalytic pyrolysis of human haircut waste and their characterization [3].

KOH (potassium hydroxide) are often used in charcoal activation due to their unique chemical properties. KOH is a strong base that can help break down organic materials in human hair during pyrolysis, leading to the formation of a pore structure [12]. KOH were chosen as solutions in characterizing charcoal because they are chemical activators commonly used in the charcoal activation process.

KOH is a strong base. KOH can help break down organic materials in human hair during pyrolysis, leading to the formation of a pore structure. KOH can also react with carbon at high temperatures to form carbonate salts, which are then removed during the washing process, leaving pores in the charcoal.

Determining the particle size of human hair charcoal resulting from pyrolysis will use a sieve with mesh 60 and 100. The use of mesh 60 and 100 in characterizing charcoal aims to obtain a charcoal particle size that is uniform

and in accordance with the needs of a particular application. During the pyrolysis process, human hair waste is converted into charcoal. To obtain activated charcoal with the desired properties, the charcoal particles need to be sieved. Mesh 60 has holes of a larger size than mesh 100, so the particles that pass through mesh 60 will be coarser. Charcoal with a larger particle size (passing mesh 60) tends to have lower moisture content and less ash content. This can increase the effectiveness of activated charcoal in certain applications, such as in water treatment, due to its greater surface area and higher porosity. In addition, charcoal with a larger particle size generally has a longer contact time in its application [14]. Mesh 100 has finer holes and is used to obtain smaller charcoal particles. These smaller particles may have certain properties that are useful in different applications, including a higher surface area relative to their volume that may be beneficial for surface chemical reactions or adsorption of certain materials.

Currently there is still a lack of knowledge about the characterization of charcoal resulting from pyrolysis of human hair waste. Looking at the character of charcoal resulting from pyrolysis which is activated with KOH solutions in this research will concentrate on how to characterize charcoal resulting from pyrolysis with activation of various solutions. Specifically, the charcoal resulting from pyrolysis is processed using SEM, XRD and FTIR analysis.

Materials and Methods

The materials used in this research were charcoal samples obtained from the results of the final stage of research by Anom & Lombok, 2023 in the kinetics of gas and liquid smoke resulting from catalytic pyrolysis of human haircut waste and their characterization, KOH solutions, as well as distilled water.

This research includes quantitative research that uses experimental methods to characterize charcoal resulting from pyrolysis of human hair waste which is activated with KOH solutions. The human hair charcoal obtained from pyrolysis then goes into the particle size reduction process using a 60 and 100 mesh sieve. It is then activated using KOH

and then the results of the activation are analyzed using FTIR, XRD instruments assisted by software. Origin and Ms. Excel, then SEM assisted by Image-J software .

Results and Discussion

Tabel 1. Human Hair Charcoal Characterization Results

Sample	Mass of Empty Cups	Cup + Sample	Furnace 1	Furnace 2	Average
KOH 100	26,0120	28,0120	26,7307	26, 1645	21.78 %
KOH 60	25,3836	27,3836	26,3938	26, 1645	44.78 %

Test results Ash content for the KOH solution is 21.78% for 100 mesh size and 44.78% for 60 mesh size. This indicates significant differences, which may be due to the influence of mesh size on combustion efficiency or the chemical composition of larger samples. For KOH, the difference in ash content between 100 mesh and 60 mesh is very significant, indicating that mesh size has a large influence on the combustion results and remaining ash content. Where according to Priprem *et al* , 2018 shows that chemical treatments such as KOH can affect the characteristics of ash from biological materials. For example, research on the use of eucalyptus ash to change the protein structure of hair shows that treatment with alkalis such as KOH can change the morphology and physical properties of hair, including its tensile strength. Additionally, research on the characterization of charcoal ash and wood ash in Africa found that the pH, electrical conductivity, and nutrient content of the ash can vary greatly depending on the material source and processing method [13] . Different ash content test results, as you found, can be caused by these variations.

Table 2. Human Hair Charcoal Water Level Test Results

Sample	Empty cup	Sample Cup	Warming up I	Warming up II	Average
KOH 100	52,4092	54,4092	54,4021	54,3980	0,56 %
KOH 60	39,7925	41,7925	41,7851	41,7801	0,62 %

Test results show that the water content in human hair charcoal tends to be low, ranging from 0.56% to 0.62%. This indicates that the water in the sample has been effectively evaporated during the heating process. KOH : Samples treated with potassium hydroxide show similar water content, around 0.56% to 0.62%. Where according to Gonjoo *et al* , 2023 shows that the water content in ash is very dependent on the processing method and heating conditions. For example, studies looking at charcoal ash from various biological materials suggest that heating temperature and duration greatly influence the remaining water content.

The resulting data used is the wavelength and transmission produced by each sample, while the transmittance shows a linear correlation with variations in the composition of the sample. FTIR measurements using (Shimadzu, IRPrestige-21) work in a scan range of 4000-340 cm⁻¹ .

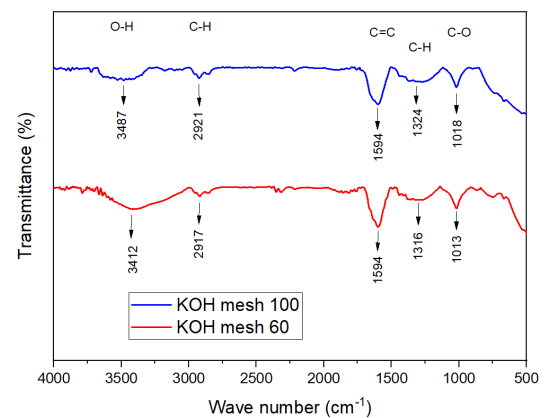


Figure 1. FTIR Spectrum of Human Hair Charcoal with KOH mess 60 and 100 Solutions

The spectrogram identified in the FTIR spectrum shows various chemical bonds and functional groups in human hair charcoal samples processed with KOH solution.

In general, the peak intensity for each functional group on mesh 60 tends to be higher compared to mesh 100, indicating that the use of a larger mesh (mesh 60) may result in more functional groups being detected or perhaps more functional groups being available. There

is a slight difference in peak position between mesh 60 and mesh 100, but this difference is not significant and is still within the acceptable range for functional group identification. Where research shows that activation with KOH can produce activated charcoal with a high surface area and developed pore structure. For example, in research on bamboo charcoal, increasing the KOH ratio increased the specific surface area and micropore volume [18].

Table 3. FTIR Spectrogram Analysis of Human Hair Charcoal with KOH mess 60 and 100 Solutions

Group	Size	Wavelength	Information
OH group (hydroxyl)	Mesh 100	3487 cm^{-1}	This peak indicates the presence of a hydroxyl group (-OH) which is usually found in water or alcohol molecules.
	Mesh 60	3412 cm^{-1}	
CH group (alkanes and aromatics)	Mesh 100	2921 cm^{-1}	This peak indicates the presence of CH bonds which are usually found in aliphatic or aromatic hydrocarbon chains.
	Mesh 60	2917 cm^{-1}	
C=C group (aromatic or alkene)	Mesh 100	1594 cm^{-1}	This peak indicates the presence of a carbon-carbon double bond (C=C) which is commonly found in aromatic or alkene structures.
	Mesh 60	1594 cm^{-1}	
CH group (bending)	Mesh 100	1324 cm^{-1}	This peak indicates the bending vibration of the CH bond which is generally found in hydrocarbon compounds.
	Mesh 60	1316 cm^{-1}	
CO group (alcohol, ester, or ether)	Mesh 100	1018 cm^{-1}	This peak indicates the presence of CO bonds which are usually found in alcohols, esters or ethers.
	Mesh 60	1013 cm^{-1}	

The spectrogram identified in the FTIR spectrum shows various chemical bonds and functional groups in the human hair charcoal sample processed with the Control Sample.

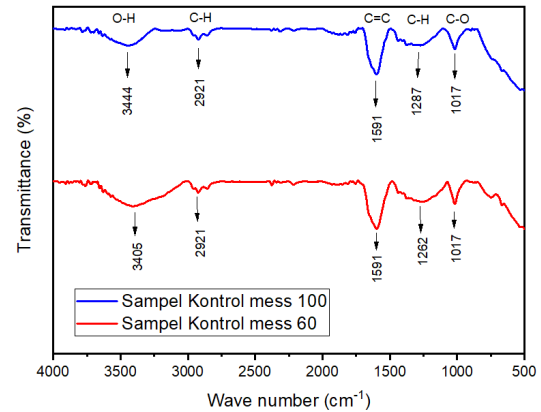


Figure 2. FTIR Spectrum of Human Hair Charcoal with 60 and 100 mess Control Samples

Table 4. FTIR Spectrogram Analysis of Human Hair Charcoal with Control Samples of 60 and 100 mess

Group	Size	Wavelength	Information
OH group (hydroxyl)	Mesh 100	3444 cm^{-1}	This peak indicates the presence of a hydroxyl group (-OH) which is usually found in water or alcohol molecules.
	Mesh 60	3405 cm^{-1}	
CH group (alkanes and aromatics)	Mesh 100	2921 cm^{-1}	Both spectra show a peak at around 2921 cm^{-1} . This peak indicates the presence of CH bonds which are usually found in aliphatic or aromatic hydrocarbon chains.
	Mesh 60	2921 cm^{-1}	
C=C group (aromatic or alkene)	Mesh 100	1591 cm^{-1}	Both spectra show a peak at around 1591 cm^{-1} . This peak indicates the presence of a carbon-carbon double bond (C=C) which is commonly found in aromatic or alkene structures.
	Mesh 60	1591 cm^{-1}	
CH group (bending)	Mesh 100	1287 cm^{-1}	This peak indicates the bending vibration of the CH bond which is generally found in hydrocarbon compounds.
	Mesh 60	1262 cm^{-1}	
CO group (alcohol, ester, or ether)	Mesh 100	1017 cm^{-1}	Both spectra show a peak at around 1017 cm^{-1} . This peak indicates the presence of CO bonds which are usually found in alcohols, esters or ethers.
	Mesh 60	1017 cm^{-1}	

XRD is an instrument that can be used to estimate the atomic arrangement and distance

between atoms in a crystal and the degree of crystallinity in a solid. XRD measurements using Shimadzu Maxima XRD-7000 then using Origin and Ms software. Excel to obtain volume fractions

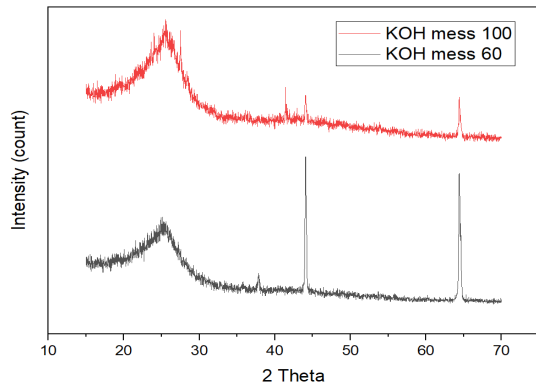


Figure 3. XRD diffraction pattern of Human Hair Charcoal with KOH mess 60 and 100 Solutions

The difference in XRD spectra between KOH mesh 60 and 100 could be due to different particle sizes affecting the X-ray diffraction. In KOH mesh 60, the diffraction peaks tend to be at a higher angle of 2 theta compared to KOH mesh 100, which indicates higher crystallinity. The smaller full width at half maximum (FWHM) at KOH mesh 60 (peaks 1 and 2) indicates larger particles or more ordered crystals. The relative intensity of the main peak in KOH mesh 60 is higher than that in KOH mesh 100, indicating that the sample with KOH mesh 60 has a more ordered structure or better crystalline. KOH mesh 100 has a larger FWHM in the second peak, indicating the presence of a smaller crystal size or more crystal defects compared to KOH mesh 60. Research on the characterization of activated carbon activated with KOH from biomass materials, such as olive stones, has been carried out and showed significant results. In this study, activated carbon was produced via hydrothermal carbonization of olive stone at 220°C, followed by chemical activation using KOH. The results show that activated carbon activated with KOH has a BET surface area of 2122 m²/g, which indicates a significant increase in porosity and

adsorption capacity compared to unactivated hydrocarbons (Diaz *et al* , 2022).

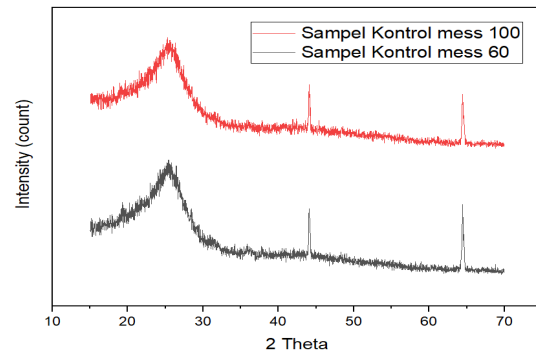


Figure 4. XRD diffraction pattern of Human Hair Charcoal with 60 and 100 mess Control Samples

Comparison of the XRD spectra between the 60 and 100 mesh control samples shows several significant differences that can provide information about the structure and crystallinity properties of the samples. In the 60 mesh control sample, the FWHM at the second peak (2.84000°) indicates the presence of a smaller crystal size or the presence of crystal strain. In the 100 mesh control sample, the FWHM at the first peak (3.84000°) is even larger, indicating a smaller crystal size or more crystal defects compared with the 60 mesh. The relative intensities of the main peaks in both meshes indicate that the 100 mesh control sample has a lower relative intensity at the third peak (64.4050°) compared to the other peaks. This may indicate differences in crystalline phase or crystal size distribution. The difference in FWHM between mesh 60 and 100 shows that the smaller mesh (100) tends to produce particles with smaller crystal sizes or more crystal defects, which can affect the mechanical and chemical properties of the material. The presence of a peak at 2 Theta 64.4050° on mesh 100 that is absent on mesh 60 may indicate a different crystal phase or a changed crystal orientation due to differences in particle size.

Figure 5 shows a morphological image of a human hair charcoal sample using a KOH

solution of mesh 60 (a) and mesh 100 (b). It appears that the sample consists of grains with a size of 100 μm . The granules are irregularly shaped and of unequal size. By using Image-J software, the particle size distribution was obtained as shown in Figure 6.

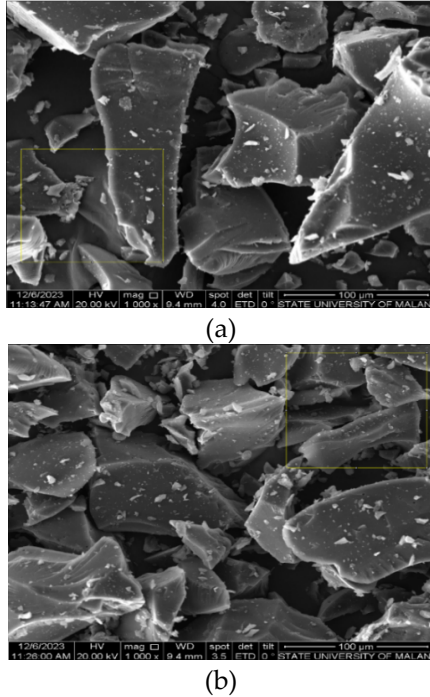


Figure 5. SEM characterization results of Human Hair Charcoal with KOH solution mesh 60 (a) and mesh 100 (b)

By using the Gauss curve approach, data were obtained as shown in Table 5. It was found that the center of symmetry value of the curve as a representation of the average grain size, $D = 149.77071 \pm 5.63339$ nm for mesh 60 (c) and $D = 356.35764 \pm 11.18168$ nm for mesh 100 (d). Previous research shows that activation using KOH can significantly increase the surface area of activated charcoal. Double activation (before and after pyrolysis) produces activated charcoal with a higher iodine number and surface area compared to single activation. SEM analysis revealed significant changes in the morphology of the pores after KOH activation [10].

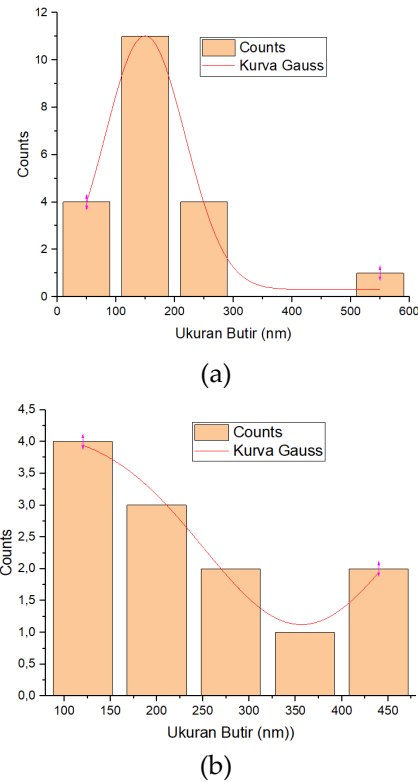


Figure 6. Grain size distribution of SEM images from Figure 5. The curves in the image were obtained with the Gauss mesh 60 (a) and mesh 100 (b) approaches.

Table 5. Data from Gaussian analysis in Figure 10 mesh 60 (a) and mesh 100 (b)

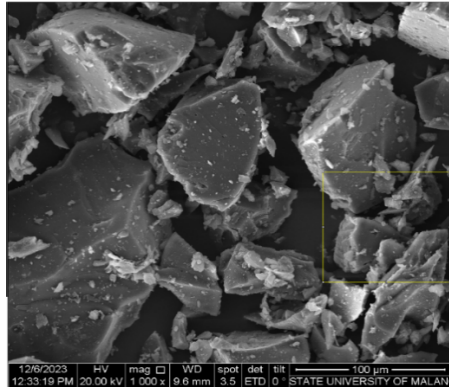
Prameter	Mark	Std error
Y0	0.30259	0.37622
Xc	149.77071	5.63339
w	136.47256	9.76479
A	1832.85029	173.17143
Sigma	68.23628	4.88239
FWHM	160.68416	11,49716
Heigh	10,71573	0.72242

(a)		
Parameter	Nilai	Std error
Y0	4,19967	0.53409
Xc	356,35765	11,18167
w	212,16118	48,75703
A	-818,00735	289,09929
Sigma	106.08059	24,37852
FWHM	249,8007	57,40702
Heigh	-3.07632	0.50302

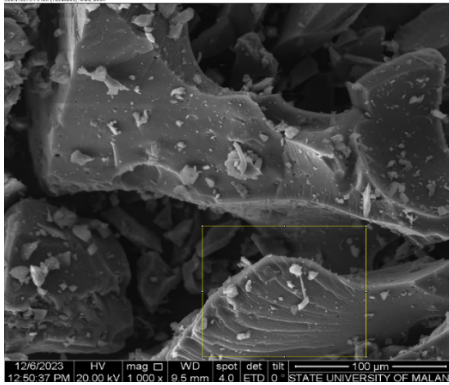
(b)		
Parameter	Nilai	Std error
Y0	4,19967	0.53409
Xc	356,35765	11,18167
w	212,16118	48,75703
A	-818,00735	289,09929
Sigma	106.08059	24,37852
FWHM	249,8007	57,40702
Heigh	-3.07632	0.50302

Figure 7 shows a morphological image of a human hair charcoal sample using a KOH solution of mesh 60 (a) and mesh 100 (b). It appears that the sample consists of grains with

a size of 100 μm . The granules are irregularly shaped and of unequal size. By using Image-J software, the particle size distribution was obtained as shown in Figure 8.



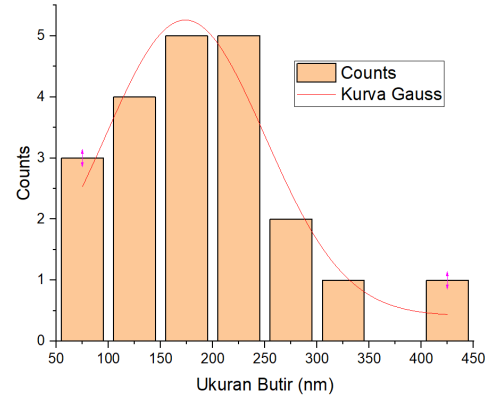
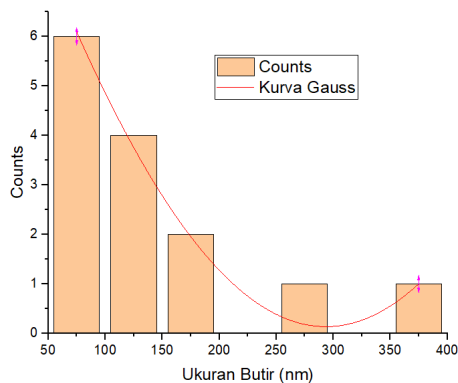
(a)



(b)

Figure 7. SEM characterization results of Human Hair Charcoal with Control Samples mesh 60 (a) and mesh 100 (b)

By using the Gauss curve approach, data were obtained as shown in Table 8. It was found that the center of symmetry value of the curve as a representation of the average grain size, $D = 293.56584 \pm 19.26444$ nm for mesh 60 (a) and $D = 173.65619 \pm 9.54422$ nm for mesh 100 (b).



(b)

Figure 8. Grain size distribution SEM image Figure 7. Curves in the image obtained with the Gauss mesh 60 (c) and mesh 100 (d) approaches

Table 8. Data from Gaussian analysis in Figure 8 mesh 60 (a) and mesh 100 (b)

Parameter	Mark	Std error
Y0	58.39339	509.02464
Xc	293.56584	19.26444
w	941.8583	4361.19283
A	-68767,25496	918901,98118
Sigma	470.92915	2180,59641
FWHM	1108,95341	5134,91215
Heigh	-58,2554	508,74891

(a)

Parameter	Value	Std error
Y0	0.41807	0.53442
Xc	173,65619	9,54422
w	153,19401	28,61323
A	929,453	227,07527
Sigma	76,597	14,30662
FWHM	180,37216	33,68951
Heigh	4.8409	0.66677

(b)

Conclusion

Based on the results of the research conducted, several conclusions can be drawn:

- From table 1, it can be seen that the sample with mesh 60 treated with KOH showed the highest ash content (44.78%). Samples with 100 mesh treated with KOH and H_2SO_4 tend to show lower ash content than samples with 60 mesh. Based on the results of table 2, the water content in human hair charcoal shows very low values (0.56% to 0.62%). This shows that

the heating process carried out was sufficient to evaporate most of the water in the sample.

- This FTIR spectrum shows the presence of various functional groups in human hair charcoal processed with KOH and Control Sample solutions. Mesh differences in processing give slight variations in peak intensity and position, but overall indicate the presence of OH, CH, C=C, and CO groups.
- XRD patterns of human hair charcoal treated with different sized meshes show significant differences in the resulting structures, with smaller meshes producing more intense and more crystalline peaks.
- on human hair charcoal resulting from pyrolysis activated by KOH solutions gave the largest grain size in KOH mess 100, namely $D = 356.35764 \pm 11.18168$ nm

Reference

- [1] Akhmadi, Z., & Suharno, S. (2017). EFFECTIVENESS OF HAIR WASTE IN REDUCING OIL LEVELS IN WORKSHOP WASTEWATER. Pontianak Ministry of Health Polytechnic, 3 (1), 17-17.
- [2] Amirudin M., Elida Novita, Tasliman. (2020). Variation Analysis of Sulfuric Acid Concentration as Activation of Active Charcoal Made from Tobacco Stems (*Nicotiana tabacum*). Faculty of Agricultural Technology, University of Jember, 3 (2): 99-108.
- [3] Anom, ID K., & Lombok, J Z. (2022). Reaction Kinetics in the Pyrolysis of Human Hair Waste . , 5(1), 186-192.
- [4] Beibei Xu, Min Chang, Chengguo Fu, Jiale Han, Yahui Wang, Yipeng Feng and Zhiping Zhang. (2024). Effect of Preparation Process on the Physicochemical Properties of Activated Carbon Prepared from Corn Stalks. School of Mechanical and Electrical Engineering, Henan Institute of Science and Technology, Xinxiang 453003, China.
- [5] Diaz E., Ines Sanchis , Charles J. Coronella and Angel F. Mohedano. (2022). Activated Carbons from Hydrothermal Carbonization and Chemical Activation of Olive Stones: Application in Sulfamethoxazole. Adsorption. Chemical Engineering Department, Faculty of Sciences, Universidad Autonoma de Madrid, 28049 Madrid, Spain.
- [6] Evangelin C.D, Sai Venkat Naren and M. Dharmendirakumar. (2012). Comparison of the Surface Features of the Three Chemically Modified Silk Cotton Hull Activated Carbons. Department of Applied Science and Technology, A.C.Technology, Anna University, Chennai - 600 025, India. Vol. 28, No. (4): Pg. 1761-1768.
- [7] Giraldo L, Diana Paola Vargas and Juan Carlos Moreno-Piraján. (2020). Study of CO₂ Adsorption on Chemically Modified Activated Carbon With Nitric Acid and Ammonium Aqueous. Departamento de Química, Facultad de Ciencias, Universidad Nacional de Colombia, Bogotá, Colombia.
- [8] Gonjoo Richika, Shveta Sharma, Ashish Kumar and MM Are`Mou Daouda. (2023). Activated Carbon: Fundamentals, Classification, and Properties. Department of Chemistry, School of Chemical Engineering and Physical Sciences, Lovely Professional University, Punjab, India.
- [9] Himawanto, D A., Indarto, I., Saptoadi, H., & Rohmat, T A. (2011). CHARACTERISTICS AND GLOBAL KINETIC APPROACH TO SLOW PYROLYSIS OF SELECTED CITY WASTE. Diponegoro University, 13 (3), 140-140.
- [10] Jamilatun Siti, Martomo Setyawan, Siti Salamah, Dwi Astri Ayu Purnama, Riska Utami Melani Putri. (2015). MANUFACTURING ACTIVATED CHARCOAL FROM COCONUT SHELLS WITH ACTIVATION BEFORE AND AFTER PYROLYSIS. Faculty of Industrial Technology, Ahmad Dahlan University. 2460 – 8416.
- [11] Maafa, I M. (2021). Pyrolysis of Polystyrene Waste: A Review. Multidisciplinary Digital Publishing Institute, 13(2), 225-225.
- [12] Mistar, E M., Alfatah, T., & Supardan, M D. (2020). Synthesis and characterization of activated carbon from *Bambusa vulgaris striata* using two-step KOH activation.
- [13] Neina Dora, Sibylle Faust and Rainer Georg Joergensen. (2020). Characterization of charcoal and wood ash for use in African peri-urban agriculture. Soil Biology and

- Plant Nutrition, University of Kassel, Nordbahnhofstr. 1a, 37213 Witzenhausen, Germany.
- [14] Nurhayati, N., Dewi, NY S., Azhari, A., Wardi, H K., Huzair, A., Maesaroh, H., & Ghazali, M. (2023). INTRODUCTION OF PURIFICATION TECHNOLOGY TO IMPROVE THE QUALITY OF COCONUT COOKING OIL IN THE HOUSEHOLD INDUSTRY . , 7(3), 2622-2622.
- [15] Novita, S A., Santosa, S., Nofialdi, N., Andasuryani, A., & Fudholi, A. (2021). Review Article: Operational Parameters of Biomass Pyrolysis . , 4(1), 53-67.
- [16] Priprem Aroonsri, Yao-Chang Lee , Wanwisa Limphirat , Suppachai Tiyaworanant, Kedsarin Saodaeng, Jiranan Chotitumnavee , Nuttanunth Kowtragoon. (2018). Eucalyptus ash alters secondary protein conformation of human grey hair and facilitates anthocyanin dyeing. Department of Pharmacology, Faculty of Dentistry, Mahidol University, Bangkok, Thailand.
- [17] Qian, W., Sun, F., Xu, Y., Qiu, L., Liu, C., Wang, S., & Yan, F. (2014). Human hair-derived carbon flakes for electrochemical supercapacitors. Royal Society of Chemistry, 7(1), 379-386.
- [18] Weigang Zhao, Lu Lou, Hongyan Wang, and Mizi Fan. (2017). Synthesis of Bamboo-Based Activated Carbons with Super-High Spesific Surface Area of Hydrogen Storage. Collage of Material Engenering, Fujian Agriculture and Forestry University. 12 (1), 1246-126

