

Morphological Evaluation of the Blended Microalgae-Activated Carbon (Mass Ratio 10:7) for Considering Its Impact on Thermal Conversion Processes

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Abstract. Morphology, including size, shape, and structure, plays a crucial role in determining heat and mass transfer within materials during thermal conversion processes. This study presents a concise overview of research conducted on the morphological evaluation of a blended composite consisting of microalgae and activated carbon, with a mass ratio of 10:7. To ensure homogeneity, the mixture was stirred simultaneously at 1200 rpm for 30 minutes. The blended microalgae-activated carbon composite was analyzed using scanning electron microscopy (SEM) to examine its surface structure and morphology. The SEM images revealed the presence of predominantly flake-shaped particles in the sample. The particle size distribution, determined from the SEM images, indicated that particles of approximately 30 μm in size were the most dominant. Considering the impact of this blended composite on thermal conversion processes, the findings suggest that the combination of both materials significantly enhances reactivity during thermal conversion.

1 Introduction

In an era marked by escalating energy demands that rise to nearly 700 QBtu by midcentury [1] and environmental concerns regarding the reducing carbon emissions toward net zero in 2050 [2], the investigation for sustainable and efficient sources of energy has become a paramount global priority. Among the plethora of renewable energy options, biomass holds immense promise due to its renewable nature and the potential to significantly reduce greenhouse gas emissions [3]. Within the realm of biomass, microalgae have emerged as a particularly promising feedstock owing to their rapid growth, high biomass yield, and capacity to thrive in diverse environmental conditions [4].

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Concurrently, activated carbon possesses a high surface area and porous structure. These characteristics provide an extensive and accessible surface for catalytic reactions to take place. When used as a catalyst in biomass thermal conversion processes, activated carbon can enhance the reactivity of the feedstock, promoting faster and more efficient conversion reactions [5]. Its use is expected to contribute to more efficient and cleaner methods of converting biomass into valuable energy products and chemicals, aligning with sustainable and eco-friendly energy production goals.

This study delves into the intricate interplay between microalgae and activated carbon, focusing on a specific mass ratio blend of 10:7 in order to comprehend its morphological characteristics and assess its impact on thermal conversion processes. Understanding the properties of this blended material is pivotal as it not only holds the potential to enhance the energy output of thermal conversion processes but also addresses concerns related to the efficient utilization of microalgae biomass for future energy feedstock.

The morphological evaluation of this microalgae-activated carbon blend is the cornerstone of this investigation. Through comprehensive analyses of its physical and structural properties, it is aimed to shed light on how this unique combination influences the thermal conversion processes. In this context, this paper presents an in-depth exploration of the morphological aspects of the microalgae-activated carbon blend. Doing so means embarks on a journey to unearth valuable insights that can revolutionize the field of biomass energy generation, paving the way for more sustainable and eco-friendly energy solutions.

2 Materials and Method

2.1 Materials

The dried AP powder was acquired from the Brackishwater Aquaculture Development Center (BADC) located in Situbondo, Indonesia. To achieve a consistent and even powder, the sample underwent sieving with a 60-mesh screen. A laboratory-scale AC featuring a grain size of 100 mesh was procured from Sigma-Aldrich Singapore. In accordance with prior research [6,7], the samples were combined in a mass ratio of 10SP/7AC through a mechanical stirring process at 1200 rpm for a duration of 30 minutes, resulting in a uniform final blended sample.

2.2 Method

The FEI Inspect S50 scanning electron microscope (SEM) was utilized to capture images of the specimen. Four different magnification levels (1000x, 5000x, 10,000x, and 20,000x) were employed, with subsequent particle size distribution and porosity analysis performed using two specific magnifications: 1000x and 20,000x.

3 Results and Discussions

Figure 1 presents the morphology of the sample at a magnification of 1000x, resulting from an SEM photograph. It was clearly observed that the blended sample had an irregular form. The elongated shapes and flaky-like form of the samples were strongly supposed originated from the activated carbon component, whereas the granule form was related to the microalgae. The particle size distribution (PSD) analyzed in Figure 1 is depicted in Figure 2. Figure 2 shows that the size of 30 μm was the most dominant ingredient in the sample, followed by 50, 110, and 70 μm , respectively.

Both characteristics, shapes, and sizes were considerable parameters that determined the thermal conversion process. Particle shape affects the heat transfer rate and the kinetics of chemical reactions during thermal conversion. Irregularly shaped particles may have greater surface areas and more complex surface geometries, leading to variations in heat transfer rates and reaction pathways compared to spherical particles. This can influence the overall combustion or gasification efficiency. Non-spherical particles may lead to variations in flow patterns, turbulence, and mixing, affecting temperature distribution and gas-solid interactions. This, in turn, impacts combustion completeness and emissions.

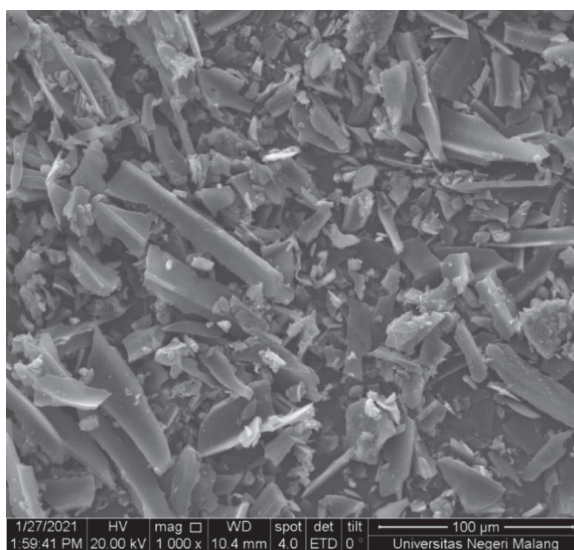


Fig. 1. SEM image of the blended sample at 1000x magnification.

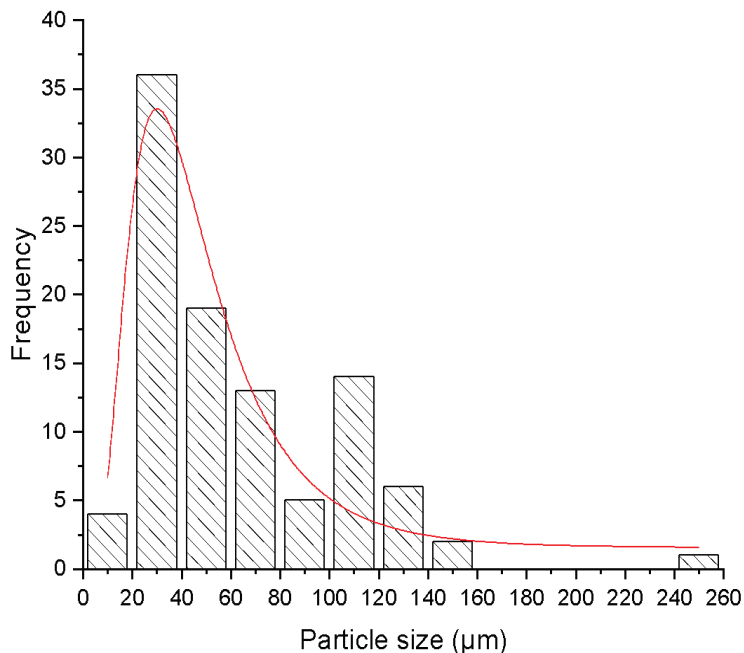


Fig. 2. PSD of the blended sample.

Flattened particles (a flaky-like form) have a natural tendency to cluster together, and as their size decreases, their packing density increases. These specific shapes and arrangements have a notable impact on heat and mass transfer processes during thermal conversion. In particular, denser formations tend to impede the transfer of heat to the inner regions and also restrict the release of volatile components.

The granular shape is characterized by the presence of relatively spacious gaps between particles, providing a larger available surface area for efficient heat transfer to the interior of the particle structure. This configuration also promotes the release of a greater quantity of volatile compounds through thermal cracking processes. As particle size decreases, the temperature differential between the particle's surface and its interior diminishes, leading to enhanced thermal efficiency in the processes. Details of heat transfer mode among two materials via numerous unique interfacial processes have been presented by Persson [8].

Particle sizes have a significant role in heat and mass transfer processes. As the particle size increases, the resistance to heat transfer decreases, resulting in enhanced heat and mass transfer rates. Consequently, the decomposition process occurs more rapidly, leading to the release of lighter volatile compounds and reduced char formation at the final temperature. Reduced particle size leads to an extension of the residence time for volatile matter released, primarily due to the increased surface area. The abundance of surface area in these particles, in turn, leads to a decelerated decomposition process and a higher production of char at the final temperature [9].

Moreover, particle size also strongly affects the thermal characteristics and kinetics of the materials during the thermal conversion process. The reduction in particle size results in a decrease in various factors, including the peak decomposition temperature, activation energy, thermal stability, and thermodynamic parameters of the material [10]. Additionally, as particle sizes increase, the average activation energy value also rises. The lower initial activation energy observed for smaller particles during the devolatilization process compared to larger particles suggests that the former undergo thermal conversion more readily than the latter, which begins at a significantly higher activation energy value [9].

4 Conclusion

This study has underscored the critical role of morphology, encompassing factors such as size, shape, and structure, in influencing the intricate dynamics of heat and mass transfer within materials undergoing thermal conversion processes. Specifically, this investigation centered on the morphological evaluation of a composite blend comprising microalgae and activated carbon, with a 10:7 mass ratio, representing an important stride in understanding its behavior during thermal conversion. The SEM analysis unveiled a predominant presence of flake-shaped particles within the composite. Furthermore, the determination of particle size distribution, gleaned from the SEM images, notably highlighted the prevalence of particles around 30 μm in size. Crucially, in contemplating the ramifications of this blended composite on thermal conversion processes, these findings illuminate a compelling narrative. It is evident that the amalgamation of microalgae and activated carbon, as reflected in these morphological observations, substantially heightens reactivity during thermal conversion. This outcome underscores the promising potential of this composite blend in enhancing the efficiency and effectiveness of thermal conversion processes, further contributing to the ongoing discourse on sustainable energy solutions.

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