CHAPTER

3

MODIFIED BIOCHAR-BASED PINEAPPLE WASTE FOR CARBON DIOXIDE CAPTURE

Norazana Ibrahim, Noraina Ibrahim,
Aizuddin Suppe, and Vekes a/l Balasundram

3.1 INTRODUCTION

Global warming remains a persistent and critical environmental issue. The ongoing advancement of industrial operations has led to the continuous emission of carbon dioxide (CO_2), which is the primary greenhouse gas released into the atmosphere. Although CO_2 emissions have shown an annual increase, a temporary decline occurred in 2020 due to the impact of the COVID-19 pandemic (Quan et al., 2023). Industrial manufacturing has been identified as the leading source of these emissions (Shafawi et al., 2021). Hence, it is vital to take measures to slow the rising levels of atmospheric CO_2. In this regard, a variety of carbon capture and sequestration (CCS) technologies have been developed to help reduce CO_2 emissions (Gao et al., 2022).

Adsorption stands out as a highly efficient and cost-effective method for carbon capture and storage. Among the commonly used adsorbents are carbon-based materials, zeolites, and metal-organic frameworks (MOFs). However, zeolite performance in CO_2 adsorption is notably affected by environmental factors such as humidity, temperature, and pressure. Although MOFs can offer improved selectivity through metal-specific interactions, their complex and expensive synthesis procedures present barriers to large-scale application (Delgado-Marín et al., 2022). Moreover, MOFs are often sensitive to moisture, which can compromise their structural integrity during CO_2 adsorption. In contrast, carbon materials offer distinct advantages due to their broad availability, cost-effectiveness, and ease of preparation. Their inherently high surface area and well-developed porosity enhance CO_2 capture performance. Furthermore, carbon-based materials and biochar derived from biomass exhibit resistance to moisture, making them more robust candidates for CO_2 adsorption.

Biomass serves as a valuable raw material for producing carbon-based substances. It is widely available, renewable, and considered environmentally friendly due to its low pollution potential. The term biomass encompasses all organic matter derived from living organisms, including plant material, animal waste, and municipal organic residues. To date, substantial research has focused on transforming biomass into carbon-rich materials such as biochar.

Biochar is carbon-rich amorphous and aromatic material that may present various interesting properties such as high hydrophobicity, alkaline nature, good water and nutrient retention capacities, low thermal conductivity, high energy content, and high superficial porosity that enable interaction with external organic and inorganic compounds (Jeyasubramaniam et al., 2021). These properties are largely dependent on feedstock type and biochar production conditions. Although biochar is mostly recognized as valuable resource for soil fertilization and condition, this material also has significant potential to act as activated carbon for various application such as wastewater treatment and gas contaminant removal. In previous study by Mahmud et al. (2021) pineapple waste biomass (leaves and stem) was used to produce biochar and activated carbon which can be used in adsorption process of methylene blue dye. From the results, it has found that pineapple waste biomass showed its potential as sustainable adsorbent alternative for the removal of methylene blue from wastewater. In addition, Zhu et al.

(2019) has successfully proven that treating pineapple waste-derived porous carbons with alkali metal oxalates can enhance the performance of CO_2 adsorption. Based on the previous research, the production of biochar can exactly be used for adsorbing the contaminants not only for wastewater application, but also for gas contaminant removal.

Pyrolysis is a thermochemical process which converts biomass into bio-oil, biochar and gaseous product at 400–600°C in an oxygen-free environment (Dhyani & Bhaskar, 2018). It is a process that is presently considered as one of the alternatives within the utilization of agricultural or industrial waste due to the thermal conversion into biochar (solid), bio-oil (liquid), and fuel gas (CO, CO_2, H_2, CH_4, and other hydrocarbons) (Rodriguez et al., 2020). Different pyrolysis conditions, such as the types of feedstocks, pyrolysis temperature, heating rates as well as the type of pyrolysis reactor affect the physicochemical properties of biochar such as yield, specific surface area or its surface chemistry.

Biochar has a low capability for CO_2 adsorption, while the ability of modified biochar to adsorb CO_2 has been demonstrated in many studies (Dissanayake et al., 2020). To improve CO_2 capture performance, it is essential to increase porosity and incorporate basic functional groups on carbon-based adsorbents. The engineered biochar can be modified through impregnation of nanomaterial into the biochar. On the basis of nanomaterials used in biochar, they are categorized in three different types which are oxide or hydroxide biochar nanomaterial, magnetic biochar nanomaterial, and functional nanoparticles coated biochar. These composites are manufactured by different synthesis methods such as pre-treatment and post-treatment of biomass (Tan et al., 2016). The oxide or hydroxide nanomaterial can be introduced into biochar by targeting the element fortification via bio-accumulation, pre-treating the biomass using metal salt and post-pyrolysis insertion of nanometal oxide. Besides, biochar coated with functional nanoparticles such as graphene and its oxides, chitosan, carbon nanotubes and layered double hydroxides produce reasonable nanomaterial composites which in turn can effectively remove various contaminants. Meanwhile, biochar based