Chapter 9
# Electrochemical Performance of Biomass-Derived AC and CNTs-Based Supercapacitors

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## ABSTRACT

*This study investigates the electrochemical performance of activated carbon (AC) derived from two biomass sources, rice husk (RH) and walnut shell (WS), utilizing two activation methods: chemical activation with potassium hydroxide (KOH) and physical activation with carbon dioxide (CO2). The aim is to evaluate the potential of these bio-derived carbon materials in energy storage applications, particularly for supercapacitors. The electrochemical behavior of the activated carbon electrodes was assessed using cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD) techniques, along with electrochemical impedance spectroscopy (EIS), to evaluate the specific capacitance, energy density, charge transfer resistance, and ion diffusion properties.*

## 1. INTRODUCTION

Activated carbons (ACs) are vital materials with diverse applications in fields such as catalysis, water purification, and carbon dioxide capture, due to their high specific surface area, adjustable porous structure, and the presence or absence of functional groups (Zhao et al., 2023). The primary sources for producing ACs include coal, wood, and biomass, with biomass being the most economically advanta-

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geous option due to its cost-effectiveness and absence of harmful contaminants (Lee et al., 2023). The production of high-quality, eco-friendly, and economically viable ACs for use in energy storage and other applications depends on selecting the appropriate activation method (Atamanov et al., 2018), reagent, temperature, and time (Ilyin et al., 2023).

Chemical activation using potassium hydroxide (KOH) is the most common and effective method for producing ACs from biomass (Hermawan et al., 2023). However, KOH presents significant environmental and safety risks, as it is a strong alkali that can cause serious health hazards during handling. Its high cost, along with the environmental impact of its production and disposal, further complicates the process. These drawbacks highlight the need for alternative activation methods (Alharbi et al., 2022).

Physical activation using carbon dioxide ($CO_2$) offers a safer, cheaper, and more economical alternative. However, this method has some disadvantages, including a lower specific surface area and a narrower range of pore sizes compared to chemical activation. This is due to the relatively low reactivity of $CO_2$ in comparison to KOH. Consequently, there is a need to identify cost-effective and readily available biomass with suitable chemical composition and structural properties for efficient activation with $CO_2$ (Goel et al., 2021).

The pore formation mechanism also differs between activation methods. In chemical activation, pores form through the interaction of chemical reagents with disorganized carbon and inorganic structures, whereas $CO_2$ activation enlarges pore diameters through physical expansion driven by chemical reactions between the activation gas and active carbon atoms. Understanding the influence of these activation methods on the final physical and chemical properties of ACs is crucial for optimizing their performance in various applications (Okayama et al., 2010).

## 2. ENERGY STORAGE AND CARBON MATERIALS

Energy storage is critical for technological progress, especially as industries and transportation continue to rely heavily on fossil fuels. As a result, research focuses on developing environmentally friendly, efficient energy storage systems. Batteries, fuel cells, and electrochemical capacitors (ECs) are the most common energy storage devices. While batteries and fuel cells store energy through redox reactions, ECs store energy via ion adsorption or fast surface reactions, offering the advantage of long lifespans (Kim et al., 2005).

ECs utilize powdered active materials to form porous structures that facilitate electrochemical reactions. To enhance conductivity and structural integrity, conductive carbon materials and polymer binders are added. However, despite these additions, EC electrodes often have low conductivity, necessitating the use of metal current collectors to ensure efficient electron transport and mechanical support. To maximize energy storage in ECs, efforts are focused on using active materials that store more energy while minimizing the amount of inactive components, such as binders and conductive additives (Iijima et al., 1991).

Activated carbons (ACs), derived from plant-based materials such as apricot stones and rice husks, are commonly used in ECs. Their porosity and surface area, which are crucial for storing electrical charge through ion adsorption, are influenced by the activation conditions. These ACs provide a high surface area that improves the electrode's performance at the electrode-electrolyte interface.