# Converting Agricultural Wastes to Biochar: From Good Agricultural Waste Management Practice to High-Potential Use of Biochar as Heterogeneous Catalyst

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The agricultural waste-derived biochar is highly appreciated due to its characteristics that may provide materialfor the use of agricultural, environmental, and industrial applications. In this study, ten agricultural wastes and crop residues, including wood (WB), rice husk (RHB), corncob (CB), pinecone (PCB), longan shell (LSB), water caltrop shell (WCSB), white popinac (WPB), bamboo (BB), sugarcane bagasse (SBB), and coconut fiber (CFB), were collected and converted to biochars which aimed to reduce the agricultural waste volume and towards the use of the products as agricultural, industrial, and environmental applications.

The feedstock was dried in the drier (Binder, Germany) at 105$^0$C for 24h before carbonized at 550$^0$C for 4h in the muffle furnace (Grand Hand Instrument, Taiwan) to generate the biochars. The obtained biochars were dried at 105$^0$C for 24h before grinding into 0.6 mm particle. Various measurements were conducted to characterize these ten kinds of biochar, including elemental contents (C, H, O, N, S), elemental ash compositions (Na, K, Mg, Ca, P), specific surface area, Secondary Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDS), thermogravimetric analysis (TGA), X-Ray diffraction (XRD), X-Ray photoelectron Spectroscopy (XPS), Fourier Transform Infrared (FTIR).

Table 1. The properties of biochars produced at 550$^0$C for 4h

| Biochar | Biochar yield, % | Ash content, % | Elemental content, % | | | | | Atomic ratio | | Surface area, $m^2.g^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | H | O | N | S | H/C | O/C | |
| WB | 27.7 | 8.90 | 83.76 | 2.76 | 6.59 | 1.37 | 0.11 | 0.40 | 0.059 | 295 |
| RHB | 30.9 | 39.75 | 49.92 | 1.71 | 4.66 | 0.69 | 0.21 | 0.41 | 0.070 | 217 |
| CB | 24.1 | 11.24 | 78.45 | 2.70 | 7.36 | 2.25 | 0.15 | 0.41 | 0.070 | 180 |
| PCB | 31.0 | 6.26 | 81.28 | 2.66 | 7.00 | 1.04 | 0.11 | 0.39 | 0.065 | 371 |
| LSB | 33.9 | 16.07 | 77.45 | 2.46 | 9.56 | 1.72 | 0.10 | 0.38 | 0.093 | 142 |
| WCSB | 34.6 | 13.46 | 78.92 | 2.51 | 9.61 | 1.53 | 0.11 | 0.38 | 0.091 | 227 |
| WPB | 24.9 | 7.60 | 83.99 | 2.70 | 10.47 | 1.14 | 1.50 | 0.39 | 0.093 | 232 |
| BB | 25.8 | 10.89 | 79.46 | 4.09 | 8.11 | 0.98 | 1.0 | 0.33 | 0.077 | 244 |
| SBB | 22.2 | 13.14 | 71.47 | 2.37 | 7.45 | 1.48 | 0.88 | 0.40 | 0.078 | 290 |
| CFB | 35.2 | 11.07 | 83.33 | 2.48 | 6.89 | 1.11 | 0.2 | 0.36 | 0.062 | 204 |

The biochars' mass yield (Table 1) ranged from 22 to 35%. Most biochars' surface areas were ≥ 150 $m^2$/g which meets the requirement of European Biochar Certificate (Version 4.8). The biochars were mesoporous material and pore volume ranged between 0.098 and 0.199 $cm^3$/g, indicating good water-holding capacity, positive impact on soil hydrology, and a potential habitat for microorganic soil communities. Also, all O/C ratios < 0.1 and most H/C ratios < 0.4 referred to the biochar stability (Hassan et al., 2020), would increase the reusability of biochar (e.g., as applying as biochar-based catalysts) and higher contents of Na, K, Mg, Ca, and P due to their plant-derived feedstock, so they are suitable for the soil amendment and improvement of soil carbon sequestration (Schimmelpfennig and Glaser, 2012; Spokas et al., 2012). All the biochars tested were alkaline which is an agreement with previous studies (Jindo *et al.*, 2014; Zornoza *et al.*, 2016), indicating that the biochar as soil amendment would remediate not only acidic soil but also stabilize the trace contaminant mobilization in an acidic environment.

Solid carbonaceous materials, like biochar, have surface oxygenated functional groups, which immerse in aqueous medium will represent as hydroxyl groups and behave as Bronsted acid sites as following:

$$\underline{S}OH_2^+ \rightleftharpoons SOH + H^+, K_{a_1}^{int} \quad (1)$$

$$\underline{S}OH \rightleftharpoons SO^- + H^+, K_{a_2}^{int} \quad (2)$$

Surface acidity is important to the understanding of the mechanism of adsorption reaction of adsorbents as well as catalytic performances of heterogeneous catalysts. Gouy-Chapman theory of electrical double layer was used to calculate the surface acidity of activated carbon by Corapcioglu and Huang (1987). Zeta potentials of each kind of biochars (Figure 1) were measured at the pH varied from 3 to 9, and used to determine the surface acidity. The surface acidity results were comparable to other carbonaceous materials (Corapcioglu and Huang, 1987; Fan et al., 2019). The investigation on surface acidity of biochars suggested that the biochars are promising catalysts in environmental remediation or precursors for industrial applications.

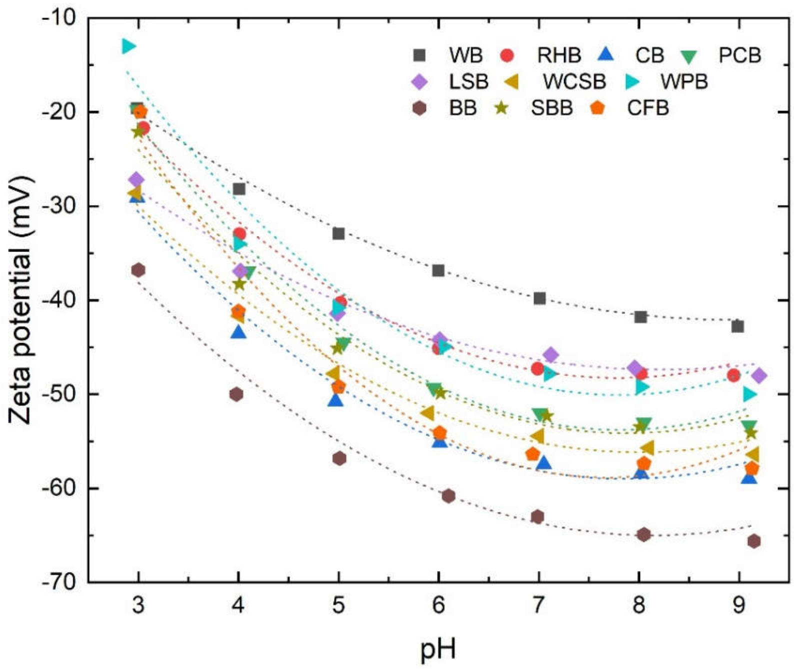


Figure 1. Zeta potential of biochar – experimental conditions:
[biochar] = 10g/L, [$NaClO_4$] = 0.01 M, room temperature

Converting agricultural waste to biochar reduces the volume and weight of solids, and creates a product with many essential properties that can be used as a soil amendment. Surface acidity of biochars can be effectively characterized by determining the zeta potential variation in the pH sequences. The surface acidity results showed their potential application as heterogeneous catalysts and catalyst supports.

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