Title: **Effects of charring temperature on physicochemical properties of wheat straw biochar**

Author: **Mardin Abdalqadir, Tannaz Pak, Sina Rezaei Gomari**

Environmental management through the effective utilisation of biowaste has attracted significant attention in recent years. The production of biochar and its use in agriculture can play a vital role in climate change mitigation and support improve the management and quality of forestry and agricultural waste. Biochar is the carbonaceous, porous material that can be obtained from the conversion of bio-based waste commonly via the pyrolysis process at elevated temperatures. Variation in pyrolytic temperature affects the yield and nutrient composition of biochar. The selection of optimum pyrolytic temperature is crucial before using it for agricultural and environmental purposes.

This study examines the effect of pyrolysis temperature on the physical and chemical characteristics of biochar (BC) derived from wheat straw. The feedstock sample was heated at 100 °C/min to different temperatures of 300, 400, 500, 600, 700 and 800 °C and held at that temperature for 15 min (residence time). The samples are then cooled back down to room temperature.

The produced biochar samples at different temperatures were characterised for their pore structures, chemical functionalities and mineral compositions to understand their physiochemical behaviour. We show that pyrolysis temperature plays a significant role in the formation of biochar microstructure. These biochar samples were utilised without any additional purifications/ treatments for their practical application as support materials for soil improvement and water treatment.

The results show that by increasing temperature, the biochar yield declines rapidly with the final yield of biochar of about 25% at 800 °C. This can be attributed to a greater biomass ‘s decomposition at elevated temperatures. Furthermore, our analysis shows that at the higher pyrolysis temperatures the functional groups alter more significantly indicated by the relative change in the degree of polarity [(O+N)/C and O/C] and aromaticity (H/C) ratios. The existence of some inorganic components such as crystalline SiO_2 and $CaCO_3$ have been also detected. A higher amount of alkaline metals is found in biochar that is produced at above 500 °C temperature (Mg, K and Ca). The SEM images demonstrated that as the temperature increased, the biochar particles became smaller and lost more of their original cell structures. However, BET Analysis showed that the surface area and micropore volume of biochar can be increased with charring temperature. The altered structure of biochar at elevated temperatures offers a large surface area, which is crucial in enhancing the soil arability, texture, and retention of nutrients and while also promoting the growth of beneficial microorganisms.

References

Alburquerque, J. A. *et al.* (2013) 'Enhanced wheat yield by biochar addition under different mineral fertilization levels', *Agronomy for Sustainable Development*, 33(3), pp. 475–484. doi: 10.1007/s13593-012-0128-3.

Atinafu, D. G. *et al.* (2021) 'Introduction of eicosane into biochar derived from softwood and wheat straw: Influence of porous structure and surface chemistry', *Chemical Engineering Journal*, 415(December 2020), p. 128887. doi: 10.1016/j.cej.2021.128887.

Bian, R. *et al.* (2018) 'Pyrolysis of contaminated wheat straw to stabilize toxic metals in biochar but recycle the extract for agricultural use', *Biomass and Bioenergy*, 118(August 2016), pp. 32–39. doi: 10.1016/j.biombioe.2018.08.003.

Cao, X., Sun, S. and Sun, R. (2017) 'Application of biochar-based catalysts in biomass upgrading: A review', *RSC Advances*, 7(77), pp. 48793–48805. doi: 10.1039/c7ra09307a.

Collins, S. R. *et al.* (2014) 'Variation in the chemical composition of wheat straw: The role of tissue ratio and composition', *Biotechnology for Biofuels*, 7(1), pp. 1–14. doi: 10.1186/s13068-014-0121-y.

Crombie, K. *et al.* (2013) 'The effect of pyrolysis conditions on biochar stability as determined by three methods', *GCB Bioenergy*, 5(2), pp. 122–131. doi: 10.1111/gcbb.12030.

Du, W. *et al.* (2019) 'Designing synthesis of porous biomass carbon from wheat straw and the functionalizing application in flexible, all-solid-state supercapacitors', *Journal of Alloys and Compounds*, 797, pp. 1031–1040. doi: 10.1016/j.jallcom.2019.05.207.

Elnour, A. Y. *et al.* (2019) 'Effect of pyrolysis temperature on biochar microstructural evolution, physicochemical characteristics, and its influence on biochar/polypropylene composites', *Applied Sciences (Switzerland)*, 9(6), pp. 7–9. doi: 10.3390/app9061149.

Medyńska-Juraszek, A. *et al.* (2020) 'Wheat straw biochar as a specific sorbent of cobalt in soil', *Materials*, 13(11), pp. 1–15. doi: 10.3390/MA13112462.

Mohanty, P. *et al.* (2013) 'Evaluation of the physiochemical development of biochars obtained from pyrolysis of wheat straw, timothy grass and pinewood: Effects of heating rate', *Journal of Analytical and Applied Pyrolysis*, 104, pp. 485–493. doi: 10.1016/j.jaap.2013.05.022.

Muhammad, N. *et al.* (2017) 'Impact of wheat straw biochar on yield of rice and some properties of Psammaquent and Plinthudult', *Journal of Soil Science and Plant Nutrition*, 17(3), pp. 808–823. doi: 10.4067/S0718-95162017000300019.

Naeem, M. A. *et al.* (2014) 'Yield and nutrient composition of biochar produced from different feedstocks at varying pyrolytic temperatures', *Pakistan Journal of Agricultural Sciences*, 51(1), pp. 75–82.

Naeem, M. A. *et al.* (2017) 'Effect of wheat and rice straw biochar produced at different temperatures on maize growth and nutrient dynamics of a calcareous soil', *Archives of Agronomy and Soil Science*, 63(14), pp. 2048–2061. doi: 10.1080/03650340.2017.1325468.

O'Toole, A. *et al.* (2013) 'Characterization, Stability, and Plant Effects of Kiln-Produced Wheat Straw Biochar', *Journal of Environmental Quality*, 42(2), pp. 429–436. doi: 10.2134/jeq2012.0163.

Peng, X. *et al.* (2011) 'Temperature- and duration-dependent rice straw-derived biochar: Characteristics and its effects on soil properties of an Ultisol in southern China', *Soil and Tillage*

Research, 112(2), pp. 159–166. doi: 10.1016/j.still.2011.01.002.

Peterson, S. C. and Jackson, M. A. (2014) 'Simplifying pyrolysis: Using gasification to produce corn stover and wheat straw biochar for sorptive and horticultural media', *Industrial Crops and Products*, 53, pp. 228–235. doi: 10.1016/j.indcrop.2013.12.028.

Qian, T. T. *et al.* (2019) 'Screening of wheat straw biochars for the remediation of soils polluted with Zn (II) and Cd (II)', *Journal of Hazardous Materials*, 362(August 2018), pp. 311–317. doi: 10.1016/j.jhazmat.2018.09.034.

Sain, M. and Panthapulakkal, S. (2006) 'Bioprocess preparation of wheat straw fibers and their characterization', *Industrial Crops and Products*, 23(1), pp. 1–8. doi: 10.1016/j.indcrop.2005.01.006.

Saleem Khan, T. and Mubeen, U. (2012) 'Wheat Straw: A Pragmatic Overview', *Current Research Journal of Biological Sciences*, 4(6), pp. 673–675.

Shen, Z. *et al.* (2017) 'Characteristics and mechanisms of nickel adsorption on biochars produced from wheat straw pellets and rice husk', *Environmental Science and Pollution Research*, 24(14), pp. 12809–12819. doi: 10.1007/s11356-017-8847-2.

Di Stasi, C. *et al.* (2019) 'Physically activated wheat straw-derived biochar for biomass pyrolysis vapors upgrading with high resistance against coke deactivation', *Fuel*, 255(April), p. 115807. doi: 10.1016/j.fuel.2019.115807.

Sun, J. *et al.* (2017) 'Effects of pyrolysis temperature and residence time on physicochemical properties of different biochar types', *Acta Agriculturae Scandinavica Section B: Soil and Plant Science*, 67(1), pp. 12–22. doi: 10.1080/09064710.2016.1214745.

Wang, P. *et al.* (2015) 'Removal of chlorpyrifos from waste water by wheat straw-derived biochar synthesized through oxygen-limited method', *RSC Advances*, 5(89), pp. 72572–72578. doi: 10.1039/c5ra10487d.

Wu, W. *et al.* (2012) 'Chemical characterization of rice straw-derived biochar for soil amendment', *Biomass and Bioenergy*, 47, pp. 268–276. doi: 10.1016/j.biombioe.2012.09.034.

Yang, X. *et al.* (2019) 'Preparation and modification of biochar materials and their application in soil remediation', *Applied Sciences (Switzerland)*, 9(7). doi: 10.3390/app9071365.

Yuan, J. H., Xu, R. K. and Zhang, H. (2011) 'The forms of alkalis in the biochar produced from crop residues at different temperatures', *Bioresource Technology*, 102(3), pp. 3488–3497. doi: 10.1016/j.biortech.2010.11.018.

Zhang, J. *et al.* (2016) 'Straw biochar hastens organic matter degradation and produces nutrient-rich compost', *Bioresource Technology*, 200, pp. 876–883. doi: 10.1016/j.biortech.2015.11.016.