SUMMARY OF THESIS

Physicochemical Properties and Adsorption Capacity of Biochars Produced from Residues of Two Varieties of Rice *(Oryza sativa)*, Japanese *Koshihikari* and Vietnamese *IR50404*

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Biochar, a highly porous pyrolyzed biomass, has been receiving an increased interest as an efficient adsorbent for the removal of chemicals including environmental pollutants. As renewable resources and rich in nutrients, rice straw and rice husk become potentially attractive feedstocks for making biochar. This PhD research focused on two different rice varieties, namely Japanese *Koshihikari* and Vietnamese *IR50404* rice straw and rice husk as representative varieties from the two countries, and analyzed the physicochemical properties and adsorption capacity of those biochars produced under temperature range of 300 – 800 °C for their potential in environmental and agronomic applications.

The first experiment thoroughly explored the pore characteristics of studied biochar, using N_2 adsorption and I_2 adsorption methods. Results showed that the comparative N_2 adsorption isotherms illustrated the micropore filling and formation of monolayers within $P/Ps < 0.1$, mesopore filling and formation of multilayers when $P/Ps > 0.1$ of biochar. In general, the values of surface area increased as pyrolysis temperature increasing from 300 to 700 °C then decreased at 800 °C prolysis. The results of pore size distribution showed that the majority of studied biochars were in the range of 1.2- 9.9 nm. Under the same pyrolysis temperature, biochar produced from Vietnamese rice straw (VRS) and rice husk (VRH) showed abundance of micropores, higher total pore volume, higher specific surface area and higher iodine numbers than Japanese rice straw (JRS) and rice husk (JRH), respectively (i.e. VRS>JRS, VRH>JRH).

The second experiment investigated physical and chemical properties of biochars. This study found that despite of insignificant difference in holocellulose and lignin contents between rice husks, Japanese *Koshihikari* rice straw had higher proportions of holocellulose and lignin than Vietnamese *IR50404* rice straw) (71.7% holocellulose and 31.5% lignin in JRS; 69.4% holocellulose and 25.1% lignin in VRS). Biochars produced at high pyrolysis temperatures (> 500 °C) showed higher surface area (approximately 3 times, as found in the first experiment) and higher Si content (by more than 15%), but lower H/C and O/C ratios than biochars produced at lower temperature. With regard to rice variety, JRS and JRH biochars had higher C content but slightly lower H and O contents than the VRS and VRH. Japanese *Koshihikari* biochars had also higher volatile matter and ash contents than Vietnamese *IR50404* biochars. They also possessed higher Si content (almost 20%), but lower specific surface area and O/C and H/C ratios than Vietnamese *IR50404* rice residues biochars. FTIR spectra also showed the higher Si peaks at ~467 and ~1093 cm^{-1} in Japanese *Koshihikari* biochars. The paper concluded that higher Si content in Japanese *Koshihikari* biochars was predicted as one of the main reasons for the lower surface area in their biochars, due to the higher possibility of pore-filling or blocking by Silica.

The third experiment investigated the adsorption capacity and mechanisms of two cationic dyes, i.e. Methylene Blue (MB) and Safranin O (SO), and two anionic dyes, i.e. Methyl Orange (MO) and Bromocresol Green (BG), on biochars. The adsorption isotherm study showed that the Langmuir model well described the isotherms of the binding process. Cationic dyes were more effectively adsorbed than anionic dyes by all biochars examined. Vietnamese *IR50404* biochars showed higher capacity of adsorption of all four dyes than Japanese *Koshihikari* biochars. In varying pH 2 to 10, alkaline condition increased adsorption of cationic dyes, albeit slight decrease in adsorption of anionic MO and BG dyes, suggesting existence of negative charges in the biochars and their electrostatic interaction with dyes. The adsorption kinetic study supported intra-particle diffusion of dyes into biochars. Thermodynamic analysis of adsorption suggested that the process was spontaneous with negative ΔG^0 values and endothermic with positive ΔH^0 values. This work discussed possible explanation of dye adsorption with physisorption through porous diffusion, hydrogen bonding, π-π interaction or π^+-π interaction, common to both anionic and cationic dyes, with additional electrostatic interaction for cationic dyes with biochars in aqueous solution.

Overall, the effects of rice variety and pyrolysis temperature on the physicochemical properties of biochars were thoroughly investigated. The adsorption studies also demonstrated the effectiveness of studied biochars for the removal of MB, SO, MO and BG as model pollutants from aqueous solution.