Valorization of food processing sludge through biochar production and application as a soil amendment in sustainable agriculture

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The food industry ranks among the largest contributors to global wastewater production and generates substantial amounts of food processing sludge. This growing accumulation and improper disposal of food processing sludge poses serious environmental challenges, necessitating sustainable waste management strategies. This study was designed with the objective of assessing the potential of converting food processing sludge into sludge-derived biochar (SDBC) and assess its effectiveness as a soil amendment in comparison to directly dried sludge (DDS). The raw dewatered sludge collected from an ice cream and beverage industry was pyrolyzed at 300°C and 500°C for 3 hours in a muffle furnace to produce biochar, SDBC300, and SDBC500, respectively. The enhanced properties of biochar were evaluated through biochar yield determination, proximate analysis, Scanning Electron Microscopy (SEM), Attenuated Total Reflectance–Fourier Transform Infrared (ATR-FTIR) spectroscopy, and X-ray Diffraction (XRD). Pyrolysis results showed that at 500°C, the biochar yield was 50.49 wt% with a fixed carbon content of 36.85 wt%. Increasing the pyrolysis temperature from 300°C to 500°C resulted in a 26.9% reduction in biochar yield. The parameters such as pH, electrical conductivity (EC), C/N ratio, total phosphorus (TP), and total potassium (TK) exhibited an increasing trend with higher pyrolysis temperatures, while organic carbon and total nitrogen (TN) decreased with increasing temperature. Soil (pH = 5.02) was amended with DDS, SDBC300, and SDBC500 at three different concentrations: 1%, 2% and 5% of its dry weight, with five replications. Three weeks old *Capsicum annuum* (chilli) plants were transferred to the pots and grew for 60 days. Soils amended with 1% SDBC300 biochar demonstrated higher biomass yield, chlorophyll content, and plant height compared to other treatments. These findings underscore the potential of low-dose SDBC300 as an effective bio-based soil amendment, supporting the sustainable reuse of food industry sludge in sustainable agriculture.

Keywords: *Food processing sludge, Directly dried sludge, Pyrolysis, Sludge derived biochar, Soil amendment*