Preparation and application of biochars and activated biochars derived from anaerobic digestate of organic fraction of municipal solid waste.

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The European Green Deal outlines the achievement of carbon neutrality by 2050 to ensure sustainable development. The anaerobic digestion (AD) of the organic fraction of municipal solid waste (OFMSW) emerges as a technology capable of mitigate greenhouse gas (GHG) emissions by converting organic waste into bio-energy. Despite its advantages, AD of OFMSW faces criticisms stemming from potential inhibitors, the presence of hydrogen sulphide (H_2S) in the biogas, and problems related to the management of the digestate. The use of digestate of OFMSW is critical due to its composition, which may include heavy metals, organic pollutants physical impurities, and pathogens (Novak 2009).

This study aims to investigate technical and environmental evaluations of converting OFMSW digestate into biochar using an integrated biorefinery system, incorporating biochemical and thermochemical processes. The biochar as well and the one activated with KOH are employed in AD with twofold targets: enhancing CH_4 content in biogas by improving inoculum activity, as well as an adsorbent material for H_2S removal from biogas. The study's novelty is the development of a valorising treatment for digestate and implementing an open-loop AD, aligning with Circular Economy and Biogas done right principles. The research is divided in four phases: the initial three focus on proving technical feasibility at the laboratory scale, while the fourth one involves an environmental comparison of the performances of biochar (B) and KOH-activated biochar (KB) as biocatalyst and adsorbent materials. The first phase concerns slow pyrolysis (sPY) of dried digestate from mesophilic anaerobic digestion of OFMSW performed in previous study (Demichelis et al., 2022). sPY is performed in a fixed-bed reactor at 600 °C for 1 h with a heating rate of 5°C/min (Zhao et al., 2022). Prior to pyrolysis, the digestate is divided into two samples. The first sample (named KB) was activated by impregnating it with a 1:4, 1:2 and 1:1 (mass ratio) KOH solution for 12 h, and the second sample (named B) was feed as well to the pyrolysis reactor. In the second phase, the produced biochars (KB and B) are applied as biocatalysts in AD, testing two doses 5 and 10 g/L according to (Ovi et al., 2023). AD of OFMSW supplied by San Carlo plant (Fossano, Italy) is performed in batch mode in a 500 mL (glass Duran Bottle, Germany) with a working volume of 400 mL at 37 °C and at 6 % w/w total solid (TS). The substrate: inoculum ratio (S:I) is 1:1 and the biogas is collected in 1 L Tedlar gas bag. The third phase assesses the performances of KB and B as adsorbent materials for H_2S removal in dynamic adsorption tests. The experiments are performed in a vertical fixed-bed reactor (10 mm inner diameter) with continuous flow at atmospheric pressure and 25 ± 2 °C. Gas head space velocities are tested. The fourth phase involves an environmental comparison of KB and B applications using Life Cycle Assessment (LCA) according to ISO 14040-44. All the impact categories are considered, with ReCiPe MidPoint (H) and Cumulative Energy Demand (CED) methods.

Preliminary results show that increasing the KOH/digestate ratio decreased the biochar and bio-oil yields while significantly increased the pyrogas production. This trend is attributed to KOH promoting the cracking of large molecular intermediates into smaller molecular gaseous products. The highest KOH/digestate ratio (1:1) achieved the highest specific surface area and porosity equal to 56.8 m^2/g (0.036 cm^3/g, respectively.

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