From misused feedstocks to valuable air purification materials

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Current trends of sustainability and environmental awareness push towards the exploitation of available less valued biomass. *Arundo Donax* (AD) is an invasive herbaceous species characterized by a fast growth rate and high biomass yield of about 38 tons of dry matter/ha/year when cultivated (Angelini et al., 2009). The Global Invasive Species Database ranks AD as number 10 among 100 worst invasive species in the world (Lowe et al., 2013). Another abundant and underexploited feedstock is olive stone, a side stream of olive mills. In Europe, olive solid wastes are estimated at 10 million tonnes yearly (European Commission, 2022). The valorization of such biomass by thermochemical conversion to produce biocarbon represents a sustainable approach toward waste management, better environment, and a profitable economy. Biocarbon is the solid residue generated during the thermal decomposition of organic matter under relatively high temperature and oxygen free conditions (Lehmann and Stephen, 2009). It is characterized by a large surface area and pores volume which makes it suitable for adsorption applications.

Indoor air pollution has been addressed as a serious problem since the 1970s as it became a main factor of human respiratory health (Settimo et al., 2020). In fact, the world health organization (WHO, 2022) reported that polluted indoor air is responsible for around 3.2 million deaths globally each year. The quality of the air within enclosed spaces can have a significant impact on both short- and long-term health. Volatile organic compounds (VOCs) are one of the major airborne pollutants that have high toxicity and hazardous health effects. For instance, formaldehyde, one of the most common indoor VOCs, is classified as a group 1 carcinogen (Humans, 2006). Given the associated health risks, it is necessary to keep formaldehyde levels as low as possible. Among several air purification techniques, adsorption on a porous support has been recognized as cost efficient, simple, yet efficient method for trapping gaseous pollutants under ambient conditions. Biocarbon has been widely applied for environmental remediation purposes given its high adsorptive potential. However, most of the research focused on application in soil and aqueous media, not in air.

In this study, the formaldehyde adsorption efficiency of AD and olive stones-derived biocarbon particles prepared at variable carbonization temperatures was investigated.

AD and olive stones biomasses were prepared by cleaning, grinding, and drying. Then, they were carbonized in a tube furnace at six different temperatures from 300 to 800 °C for 30 min under nitrogen flow. The obtained biocarbon powders were further treated by ball-milling at 400 rpm for 30 min to reduce the size and further expand the porosity of the samples. Physico-chemical properties were characterized by proximate, elemental, and pH measurements, while porosity and surface properties were assessed using physisorption analysis and FTIR analyses, respectively. The formaldehyde adsorption capacity was tested in a closed chamber and the fluctuation of the pollutant's concentration was continuously monitored using formaldehyde electrochemical detection sensor.

The physicochemical properties of the biocarbon were highly dependent on the carbonization temperature. The ash and carbon contents of the samples increased with the increase of the carbonization temperature from 300 to 800 °C while the volatiles content decreased gradually. Higher temperature favorized the degradation of biomass components (i.e., hemicellulose, cellulose, and lignin) and generation of carbon rich residue. In addition, the specific and microporous surface areas and pores volumes increased constantly with the temperature. Indeed, during thermal decomposition of the natural biomass components, volatile matter is released leading to the formation of pores and channels in the internal biocarbon's structure.

The formaldehyde removal percentages were determined for 1h exposition to biocarbon powders (Figure 1). The biocarbon samples exhibited different adsorption potential and the removal capacities ranged between 26 % and 64 %. Samples prepared at 800 °C exhibited the highest formaldehyde removal capacity which was attributed to the large porosity. It is worth mentioning that the increase in formaldehyde removal capacity by the different biocarbon was not linear. In fact, the formaldehyde removal increased with temperature increase from 300 to 400 °C, then dropped at 500 °C, then, increased again gradually from 600 to 800 °C. This can be explained by the different capture mechanisms. Samples prepared at temperatures below 500 °C had higher non-carbonized organic matter content and lower porosity, therefore the formaldehyde capture was mainly due to partition mechanism which happens through interaction between the pollutant's molecules and the non-carbonized matter. However, samples prepared at 500 °C or above had low non-carbonized organic matter content and a well-developed porosity, therefore the formaldehyde molecules were trapped in the pores through physical adsorption mechanism. The reusability of AD-derived biocarbon prepared at 800 °C was also assessed and the sample exhibited a relatively stable adsorption performance after five thermal regeneration cycles.

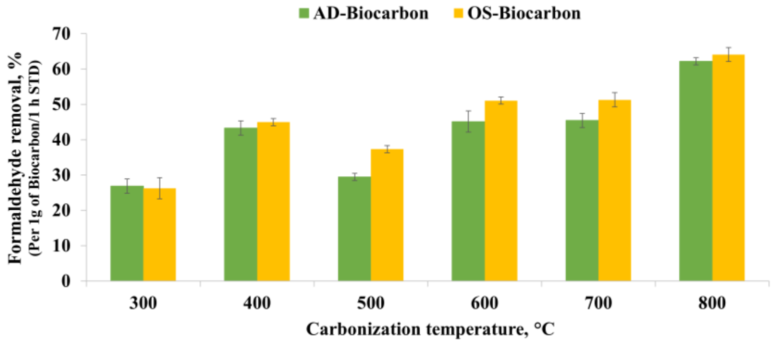

Figure 1. Formaldehyde removal percentage by biocarbon powders in function of their carbonization temperature

Biocarbon prepared from AD and olive stones waste was effective to mitigate gaseous formaldehyde levels. High porosity was the key parameter for optimal adsorption. Nevertheless, the biocarbon's adsorptive potential can be limited by the saturation and desorption phenomena. Doping the biocarbon with active photocatalysts that have the capacity to degrade the captured pollutants within the biocarbon's pores could be a promising solution for continuous purification via integrated adsorption photo-degradation technology. Current experiments on developing biocarbon-photocatalyst hybrids are being conducted and potential findings will be presented.

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