REVIEW OF BIOCHAR APPLICATION IN ANAEROBIC DIGESTION PROCESSES

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Among a wide variety of promising uses, in recent years the possibility of using biochar (BC) as additive to improve anaerobic digestion (AD) processes has attracted a growing interest. AD is a well-established biochemical process converting biomasses into biogas, a renewable energy source that can be directly used in heating and power generation rather than upgraded to bio-methane. Further, digestate (i.e. AD solid residue) could be valorised as soil improver. However, despite a growing number of full-scale biogas plants in Europe, (from about 6,200 in 2009 to 17,600 in 2016, according to European Biogas Association), some challenges limiting optimal AD performances still exist. They mainly include risks of acidification and/or potential inhibition of methanogenesis, hazards of atmospheric and water pollution derived from digestate addition to soil, as well as high energetic and economic costs for cleaning and upgrading of biogas.

Thereby, many inorganic and carbonaceous additives have been investigated to stabilize AD and enhance methane production. Among them, BC is cost-effective and doesn’t need to be separated from digestate at the end of the AD process. Actually BC can improve digestate quality in terms of nutrients retention, increase of carbon to nitrogen ratio and reduction of nutrient leaching to soil. In addition, BC production and AD do not appear as competing processes, since biomasses with high lignocellulosic and low moisture contents, optimal for BC generation, are scarcely biodegradable during AD.

Although a growing number of studies has verified the possibility of increasing methane production by BC addition during AD, to date, a clear comprehension of potential interactions between BC and AD process has not been fully reached. Since BC can be produced with a wide variety of physico-chemical properties adapted to specific applications, a proper knowledge of these mechanisms and of the related BC properties represent crucial issues. Therefore, the present study aimed to: 1. analyse the mechanisms by which BC would counteract some of the main AD limitations; 2. to perform an economic and environmental assessment of BC production and application in AD. Around 200 studies were selected and analysed by means of an extensive literature review on Science Direct, Scopus, and other scientific databases.

Based on the analysis of the reviewed literature, it can be observed that the positive influence of BC on AD processes may act through different potential mechanisms: (1) increase of the buffering capacity of the AD system; (2) mitigation of potential inhibitors (NH_3/NH_4^+ and others); (3) acting as a support medium for biomass immobilization and acclimation; (4) promotion of interspecies electron transfer between microbial populations; (5) enhancement of digestate quality; (6) in-situ biogas cleaning and upgrading (depletion of CO_2 and H_2S).
In general, some of the key properties of BC for the above-mentioned mechanisms are high alkalinity, adequate sorption capacity for specific compounds, high surface area and porous structure able to promote microbial population immobilization and inhibitors’ adsorption, varied functional groups and superficial chemical properties, large electrical conductivity and electron exchange capacity.

The economic and environmental analysis suggested that BC environmental applications are encouraged by the net mitigation of carbon emissions; while the economic feasibility of BC production could be linked to the promising energy content of lignocellulosic feedstocks. Further, the environmental benefits related to BC application to AD processes can be synergistically improved by coupling the use of BC derived from lignocellulosic feedstocks to the carbon neutral AD to optimize biogas production