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Understanding the Influence of Biochar Augmentation in Anaerobic Digestion by Principal Component Analysis

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Abstract: Biochar addition in anaerobic digestion has been repeatedly reported to improve methane production, however, this ability is not well understood. This work aims to understand and correlate the most important factors influencing anaerobic digestion performance using principal component analysis along with quantitative and qualitative descriptive analysis to evaluate the variations of methane production with the addition of biochar. Reports from the literature using biochar produced from several feedstocks under variable pyrolysis conditions and therefore different compositions were carefully gathered and compared with their own non-biochar controls. Woody-derived biochars, produced at 450–550 °C, containing an ash content of 3.1–6.3%, and an O:C ratio of 0.20, were responsible for having the greatest positive effect. The amount of biochar added to the digesters also influences anaerobic digestion performance. Increasing biochar loads favours the production rate, although this can be detrimental to methane yields, thereby, biochar loads of approximately 0.4–0.6% (*w*/*v*) appear to be optimal. This work provides a guide for those interested in biochar augmentation in anaerobic digestion and identifies the main interactions between the variables involved.

Keywords: biochar; anaerobic digestion; pyrolysis; principal component analysis

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1. Introduction

The role of biochar (BC) in amending the stressful factors affecting the performance of anaerobic digestion (AD) has been highly reported but is not well understood. Among the general accounts, it has been stated that BC can couple the biological and chemical transformations occurring during AD, resulting in better performance and stability [1]. It is generally accepted that BC supports the immobilisation of cells from anaerobic sludge; provides a buffering effect; adsorbs metabolites; reduces ammonia inhibition; and acts as an intermediary during the direct interspecies electron transfer (DIET) process [2].

Wu et al. [2] proposed a mechanism for explaining the complexity of how BC facilitates methane generation. The H_2 produced during acidogenesis increases the partial pressure of the system, thus the rapid use of H_2 and subsequent production of methane is key. This requires transferring electrons between fermentative bacteria and methanogens through the electron carriers H_2 or formate via the hydrogenases and formate dehydrogenases (FDH) enzymes. DIET interactions are a mechanism involving bioelectric connections via biological compounds, such as conductive pili (e-pili), c-type cytochrome (OmcS) and electron transport proteins. It is necessary for the microorganisms involved in DIET to have intimate direct contact with the electron transport proteins on the outer membrane to deliver the electrical contact. Remarkably, microorganisms can also exhibit DIET via exogenous non-biological conductive materials that emulate the function of pili or OmcS, such as biochar [2].

The surface functionality of the BCs, particularly oxygenated functional groups (OFGs), such as C-O, C=O, OH and COOH, are the predominant and most important features of