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ORIGINAL ARTICLE

Enhancing anaerobic digestion of poultry blood using activated carbon

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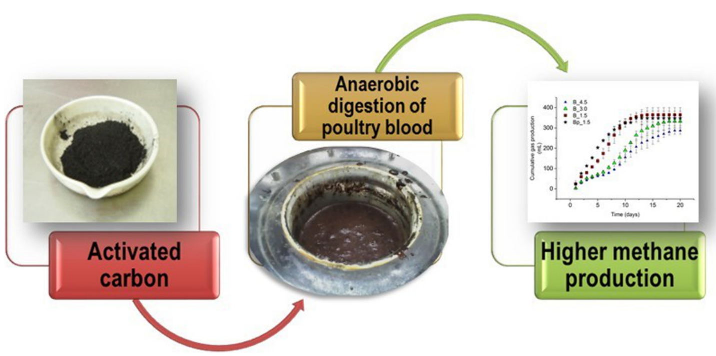
GRAPHICAL ABSTRACT



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ABSTRACT

The potential of using anaerobic digestion for the treatment of poultry blood has been evaluated in batch assays at the laboratory scale and in a mesophilic semi-continuous reactor. The biodegradability test performed on residual poultry blood was carried out in spite of high inhibitory levels of acid intermediaries. The use of activated carbon as a way to prevent inhibitory conditions demonstrated the feasibility of attaining anaerobic digestion under extreme ammonium and acid conditions. Batch assays with higher carbon content presented higher methane

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production rates, although the difference in the final cumulative biogas production was not as sharp. The digestion of residual blood was also studied under semi-continuous operation using granular and powdered activated carbon. The average specific methane production was 216 ± 12 mL CH_4/g VS. This result was obtained in spite of a strong volatile fatty acid (VFA) accumulation, reaching values around 6 g/L, along with high ammonium concentrations (in the range of 6–8 g/L). The use of powdered activated carbon resulted in a better assimilation of C3-C5 acid forms, indicating that an enhancement in syntrophic metabolism may have taken place. Thermal analysis and scanning electron microscopy (SEM) were applied as analytical tools for measuring the presence of organic material in the final digestate and evidencing modifications on the carbon surface. The addition of activated carbon for the digestion of residual blood highly improved the digestion process. The adsorption capacity of ammonium, the protection this carrier may offer by limiting mass transfer of toxic compounds, and its capacity to act as a conductive material may explain the successful digestion of residual blood as the sole substrate.

Introduction

Anaerobic digestion is a well-known process for the production of biogas, a mixture of methane and carbon dioxide, which is currently used and exploited at a local level in an efficient way. However, when considering large scale usage of biogas, the capital investment and upgrade costs associated with methane valorisation make it unfeasible in some cases [1]. Furthermore, the accumulation of toxic compounds and anaerobic intermediaries may cause a severe decrease in biogas yields, therefore compromising plant feasibility.

The use of adsorbents in anaerobic digestion has been widely studied to avoid inhibitory stages during the processes associated with high ammonia levels or to prevent odour emissions from the treatment of livestock wastes [2,3]. Many studies have focused on the addition of natural zeolites and clays for treating nitrogen-rich wastes [4] or their post-treatment to remove phenolic compounds [5]. Recently, the combination of anaerobic digestion and adsorption processes has led to using industrial clay residues [6], zeolites synthesised from coal fly ash [7], and low-cost adsorbents such as biochar [8] in an attempt to reduce the cost of the process.

Traditionally, slaughterhouse wastes have been considered a suitable co-substrate in digestion systems, with several authors reporting a marked increase in biogas production and stable performance of digesters as long as certain operational constraints are taken into account [9–11]. High amounts of solid organic by-products are generated from poultry slaughterhouses. These wastes usually comprise poultry manure, feathers, blood, and intestinal wastes [12]. Slaughterhouse wastes present a high potential for energy valorisation; this is particularly true for gastrointestinal residues characterised by high-fat content [13]. However, the main problems that arise when digesting this type of waste are associated with foaming and flotation of sludge, along with ammonium inhibition due to the high protein content [14,15].

The number of studies dealing with the digestion of residual blood has increased in the recent years [10,16,17]. However, residual blood is a complex substrate with high nitrogen content; therefore, its use as co-substrate has been widely studied, but attempting its individual digestion can lead to various difficulties due to the accumulation of ammonium in the reactor. Nitrogen is an essential nutrient in biological processes, but excess nitrogen can cause ammonia inhibition, as frequently reported, with inhibitory levels noted to be around 4–6 g N/L expressed as total ammonia nitrogen. It should also be taken into account, however, that particular characteristics of the process and substrate, such as pH condition, temperature, and type of seed sludge, among others, have a major effect on the degree of inhibition [18,19].

The digestion of nitrogen-rich wastes has been attempted with the aid of a carbon-rich substrate in order to increase the carbon to nitrogen (C:N) ratio. The digestion of abattoir wastes with mixtures of food wastes and cheese whey was evaluated by Allen et al. [20], who reported an increase in digestion performance based on the higher capacity of the reactor to treat the organic matter, which was associated with an increase in carbon content. The treatment of slaughterhouse wastes containing residual blood and grease was also investigated by Ortner et al. [21]. These authors reported volatile fatty acid (VFA) build-up ($>$8.0 g/L) and high free ammonia levels. The decrease in the organic loading rate that was achieved in an attempt to lower the ammonium content in the reactor to values below 6 g/L resulted in a successful alternative for the recovery of the digestion process and gas yields. Similar results were also reported by Alvarez and Lidén [22], who studied the co-digestion of slaughterhouse wastes containing residual blood from cattle and swine with food wastes. These authors reported on a decrease in biogas yield due to the accumulation of ammonia in the reactor.

To the author's knowledge, this paper is the first work focused on the anaerobic digestion of poultry blood as the sole substrate. The aim of the present study was to evaluate the digestion of residual blood under semi-continuous conditions. The effect on gas production and performance of the digester was evaluated when using granular and powder activated carbon as way to prevent ammonium and VFA inhibitory conditions. The digestion process was assessed with the aid of thermal analysis and scanning electron microscopy (SEM) for evaluating changes in the carbon surface and organic material.

Material and methods

Inoculum and substrate sources

The inoculum was obtained from a laboratory digester treating slaughterhouse waste adapted to an environment rich in ammonia. The acclimation procedure was performed based