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Exploring the possible effect of magnetic nanoparticles addition on biohydrogen production by dark fermentation

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Introduction

The search of alternatives for the sustainable production of fuels is, undoubtedly, one of the most important research activities in the world today. Waste treatment facilities are becoming, in this sense, an opportunity for the generation of renewable energy carriers. Until now, methane production was commonplace in biomass waste treatment processes, but the interest that **hydrogen** is awakening is turning to the generation of this other renewable gas with a great future.

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 4H_2 + 2CO_2$$

In recent years, **dark fermentation** has been established as the most promising method of biological hydrogen production motivated, on the one hand, by its higher productivity and biohydrogen yield compared to other biological methods, and, on the other hand, by its greater versatility in treating different substrates, from simple sugars to lignocellulosic biomass, food waste and high loaded wastewater streams, or glycerol. The use of these substrates brings a competitive advantage to this production route with added value in terms of its role in waste valorization, which is key in the transition to a circular economy.

Materials & Methods

The present work, developed in the frame of the **H24NEWAGE project**, focuses on exploring operational strategies that include harnessing the potential of nanotechnology in the activation of microorganisms of interest that favour biohydrogen production by dark fermentation, analysing the mechanisms involved, the influence of the substrate used and the operational changes that must be made to increase the overall efficiency of hydrogen production by this fermentative route. To do so, wet waste biomass (animal manure and high load effluents) will be subjected to treatment by anaerobic digestion in two phases, the first being a dark fermentation phase in which novel iron nanoparticles encapsulated in carbon (Figure 1) will be added.

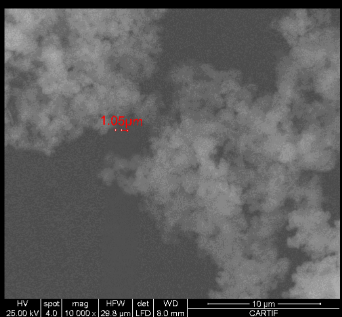

Figure 1: Fe^0 nanoparticles.

Figure 2: Lab test for bio-H_2 production.

Figure 3: Pilot plant for bio-H_2 production.

Initially, laboratory scale tests (Figure 2) have been carried out to optimise the dark fermentation process with direct generation of biohydrogen and inhibition of hydrogenotrophic bacteria. Finally, scale-up tests will be carried out in a 1.2 m^3 two-phase digestion pilot plant (Figure 3) in order to optimise the overall process and make it transferable to companies.

Results & Discussion

Dark fermentation is a technology based on the recovery of hydrogen that is generated during the first stages of anaerobic digestion, preventing it from being consumed by methanogenic bacteria. It is commonly carried out in two-stage anaerobic digestion processes, consisting of physically separating the microbiological stages of the process: in the first digester, the acidogenic reactor, hydrolysis and acidogenesis of the organic matter are carried out, while in the second digester, the methanogenic reactor, fed with the effluent from the previous one, the other two stages, acetogenesis and methanogenesis, are mainly carried out. Depending on the specific operating conditions applied in the acidogenic system, the production of biohydrogen from the organic waste can be optimised and dark fermentation takes place. However, the amount of biohydrogen produced by dark fermentation in practice is low. Many factors are involved in this low productivity, such as the emergence of alternative metabolic pathways in the process that consume hydrogen instead of producing it. To increase the quantity and quality of the search product, one strategy, nanotechnology has been introduced to improve the rate of dark fermentation. Nanoparticles, specifically inorganic ones such as iron, have demosntrated to increase the rate of biohydrogen production when added to the acidogenic reactor, probably due to the promoted activity of hydrogenases as well as the ferredoxin electron transfer.

Conclusions

Preliminary lab-scale results using glucose as substrate and a thermally pretreated anaerobic sludge as inoculum show a potential increase in hydrogen production by dark fermentation of up to 15% when adding Fe^0 nanoparticles to the bioreactor.

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