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Improving the non-sterile food waste bioconversion to hydrogen by microwave pretreatment and bioaugmentation with *Clostridium butyricum*

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ABSTRACT

This work targeted the energy recovery from food waste (FW), aiming at the implementation of a potentially participative process of FW conditioning before the non-sterile biological conversion to hydrogen (H_2). Food waste conversion was initially performed under sterile conditions, achieving a maximum H_2 productivity of 249.5 ± 24.6 mL H_2 $(L\,h)^{-1}$ and a total H_2 production to 4.1 ± 0.2 L L^{-1}. The non-sterile operation was implemented as a way of process simplification, but the total H_2 production decreased by 59% due to the FW native microorganisms. To counteract this effect, FW was submitted to acid, microwave (MW), and combined acid and MW pretreatment. The application of 4 min MW, 550 W, efficiently controlled the FW microbial counts. The *Clostridium butyricum* bioaugmented conversion of MW-pretreated FW accelerated the H_2 production to 406.2 ± 8.1 mL $(L\,h)^{-1}$ and peaked the total H_2 production and conversion yield to 4.6 ± 0.5 L L^{-1} and 234.6 ± 55.6 mL (g sugar)$^{-1}$, respectively. These results exceeded in 63, 12 and 4%, respectively, the H_2 productivity, total production and sugar conversion yield obtained under sterile conditions, and are encouraging for the future implementation of increasingly responsible waste valorisation practices.

1. Introduction

According to the intergovernmental Food and Agriculture Organisation of the United Nations (FAO), part of the worldwide food production does not actually reach the consumer, being wasted or lost well before the consumption stage (Searchinger and Heimlich, 2015). FAO estimates that approximately 1.3 billion tonnes of food produced worldwide were wasted in 2012, a value that is equivalent to a total waste of 24% of all produced food (Lipinski et al., 2013). This wastage represents not only a lost opportunity for hunger mitigation and improvement of social equality, as it also has a very distinct and unsurmountable impact on the environment, increasing both carbon footprint and water/nutrients wastage, as well as instigating land use change and the associated biodiversity loss (Scherhaufer et al., 2018). While strategies for FW reduction are already in place, even a 50% reduction of the global FW seems a faraway goal due to financial, social and technological hindrances. As such, until such reduction is feasible, it would be of upmost importance to devise clean and sustainable FW valorisation practices (Lipinski et al., 2013).

Dark fermentation (DF) is one of such processes. Dark fermentation is a biological process undertaken by strict anaerobic microorganisms that is based on the conversion of carbohydrates to hydrogen (H_2) and a vast array of valuable byproducts, such as organic acids (Mohan et al., 2016). Its main product, H_2, is a versatile energy carrier and its conversion into useful energy is a carbon-free emission process (Sherif et al., 2014). Dark fermentation enables the highest productivities (>1 $m^3\,h^{-1}\,m^{-3}$) amongst the biological H_2 production processes, has low energy requirements, and is easy to operate (Ren et al., 2011). The conversion of FW to H_2 through DF is already well-established (Kanchanasuta and Sillaparassamee, 2017), reaching productivity values as high as 334 and 353 mL H_2 $(L\,h)^{-1}$ (Moreno-Andrade et al., 2015; Lee et al., 2014) by mixed and pure microbial cultures, respectively. Additionally, the FW conversion process into H_2 can also be performed and improved through bioaugmentation, which involves the introduction of specialised microorganisms into the native microbial community of the substrate. Ideally, these microorganisms should primarily employ the metabolic pathway for convert-

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