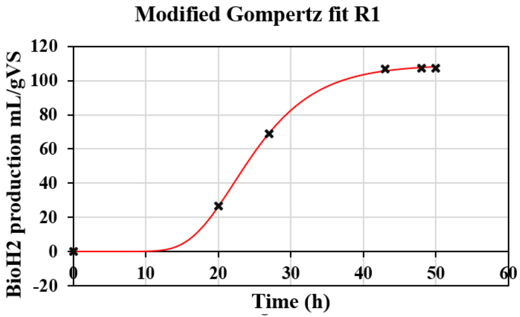
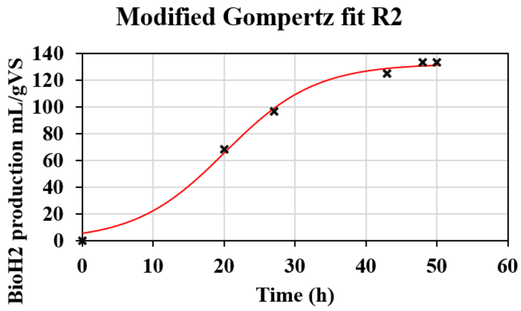
# Kinetic study of biohydrogen production from the macroalgae species Laminaria digitata in the presence of biochar derived from digestate

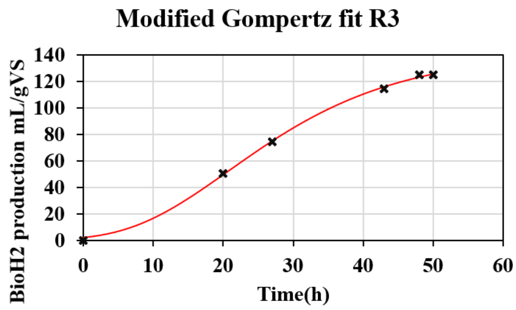
Anaerobic digestion is a promising biological process that enables the production of bioenergy from various organic residues. This process can be applied to the valorization of marine biomass, which is rich in nutrients. Among these, Laminaria digitata, a brown macroalgae abundantly found along coastlines, represents a valuable resource due to its high polysaccharide content, absence of lignin, and low cellulose concentration.

The addition of conductive additives such as biochar has recently attracted growing interest because of its ability to enhance process stability and mitigate the effects of inhibitors.

This work aims to study the effect of biochar derived from digestate on hydrogen production through dark fermentation of Laminaria digitata and to characterize the kinetics of the process using two distinct mathematical models.




Three continuously stirred batch reactors, each with a capacity of 3.5 liters, were operated under mesophilic conditions. The first served as the control reactor, the second was enriched with biochar pyrolyzed at 400°C, and the third contained biochar pyrolyzed at 600°C.

The incubation lasted 50 hours, and monitoring revealed a significant improvement in hydrogen production in the presence of biochar, justifying a detailed kinetic study to better understand its influence.

The evolution of hydrogen production was fitted using two kinetic models, Gompertz and Logistic, which are widely used for fermentation processes. These models provide three essential comparative parameters: maximum production (P), production rate (Rm), and lag phase (λ). The fittings showed an excellent coefficient of determination (adjusted $R^2 > 0.99$) for all tests, confirming the reliability of the selected models.

The results demonstrated that the addition of biochar enhanced hydrogen production yield, although it decreased the production rate. It also reduced the lag phase by half, suggesting a more gradual but more stable fermentation over time.

At 400°C, biochar exhibits a surface rich in oxygenated functional groups, promoting metabolite adsorption and microbial colonization, which explains the rapid startup observed. At 600°C, the more intense carbonization increases conductivity and porosity, enhancing electron transfer and process stability, although with a slower kinetics. These differences illustrate a trade-off between initial reactivity and overall substrate conversion.

In conclusion, the combination of Laminaria digitata and biochar derived from digestate appears to be an innovative and sustainable strategy to enhance biological hydrogen production. The kinetic study, supported by two complementary models, highlights the importance of pyrolysis temperature in modulating fermentation dynamics. These findings pave the way for an integrated optimization of the substrate–biochar coupling, contributing to the valorization of organic waste within a low-carbon circular bioeconomy framework.