Sequential Electro-Fenton – Microalgae Process for the Treatment of Real Food Processing Wastewater with Resources Recovery

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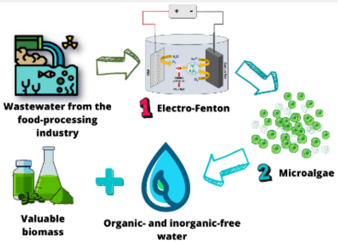

This study demonstrates the feasibility of a two-step sequential process consisting of Electro-Fenton (EF) followed by microalgae to treat highly loaded real food processing wastewater along with resource recovery. In the first step, EF was used to decrease the amount of organic matter and turbidity and enhance biodegradability. In the second step, the EF effluents were submitted to microalgal treatment using a mixed culture. Results showed that EF achieved 77.5% of COD removal at 6.32 mA cm^{-2} with >95% and 74.3% of TSS and PO_4^{3-} removal, respectively. With respect to microalgae, they achieved 85% of COD removal in the EF effluent. Additionally, microalgae were also able to remove the totality of inorganic N and P compounds, as well as 65% of the Fe catalyst that was left after EF. A maximum of 0.8 g L^{-1} of biomass was produced after cultivation, with an accumulation of 32.2% of carbohydrates and 25.9% of lipids. Such two-step approach represents a promising sustainable option for the management of industrial effluents, incorporating the production of value-added biomass.

Introduction

Due to their outstanding oxidation capacity, Advanced Oxidation Processes (AOPs), based on the generation of highly reactive free radicals, have been widely applied to treat industrial wastewaters from different sectors [1]. However, since AOPs are generally costly and/or energy intensive, they have been proposed as excellent conditioning options to increase the biodegradability of refractory effluents prior to conventional biological processes for treatment and/or energy recovery [2]. Among AOPs, electrochemically driven methods (electrochemical advanced oxidation processes, EAOPs) have stood out because they rely mainly on electricity to produce the strong oxidants responsible for the degradation/mineralization of organic matter [3]. Electro-Fenton (EF) has become one of the most popular EAOPs. It makes use of accessible carbon-based materials to continuously produce H_2O_2 by the 2-electron reduction of O_2. H_2O_2 promotes the Fenton reaction in solution in the presence of Fe^{2+} [4]. When it comes to wastewater valorization, microalgae have become an excellent option, as they are capable of degrading organic contaminants and assimilating nutrients, while producing biomass enriched with valuable compounds such as proteins, carbohydrates, pigments and lipids that are suitable to produce energy and value-added products [5]. However, the use of industrial wastewater is generally limited by the presence of high amounts of organic matter, toxic compounds, suspended solids and high turbidity that impedes light penetration.

This work presents a two-step integrated process for the valorization of real food processing wastewater consisting of i) EF as conditioning treatment, and 2) microalgae as a polishing step accompanied by the production of valuable algal biomass.

Material and Methods

EF experiments were conducted in a glass tubular undivided electrolytic reactor using DSA anode and carbon felt cathode under different current densities. Microalgae cultivation was made in small photoreactors illuminated with artificial light (15 days cultivated). The pH of the EF effluents was neutralized prior to microalgae cultivation. Details can be found in **Fig. 1**.

Results and Discussion

The main results are summarized in **Fig. 1**. Such findings demonstrated the high compatibility of both processes as part of a promising two-step strategy to process highly loaded industrial wastewater such as that from the food processing sector along with resource recovery. EF increased biodegradability through partial oxidation of organic pollutants, reducing the organic load and suspended solids (turbidity) at the same time in only 6 h of treatment (the highest COD removal of 77.5% was achieved at 6.32 mA cm^{-2} with >95% and 74.3% of TSS and PO_4^{3-} removal, respectively). The resulting effluent allowed the cultivation of microalgae that could not grow in the raw wastewater otherwise. Microalgae degraded a large part of the remaining organic matter (85% of COD removal). In addition, they consumed most of the remaining inorganic species as nutrients (N-compounds, P and Fe), highlighting their great complementarity with EF, which does not have the capacity to remove inorganic compounds. The assimilation of Fe ions by microalgae (65% removal of the remaining Fe after EF) is also a major asset because the Fe catalyst is another inorganic compound that needs to be removed after EF to avoid the formation of secondary pollution. Overall, the two-step sequential strategy achieved more than 95% COD removal under all the experimental conditions, removing a net value of 3475.9-3500.9 mg L^{-1}. TN, mainly composed of NH_4^+, was removed by 99% by the microalgae, showing a net removal of 271 mg L^{-1}. Total-P was also virtually completely removed at the end of the treatment, mainly reduced by EF (78.3% removal), with the microalgae consuming the remaining amount. The implementation of both stages makes it also possible to create valuable biomass that could be valorized into biofuels.

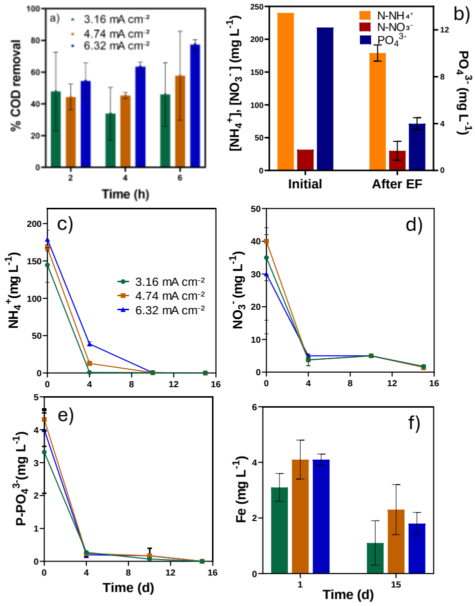

Figure 1. Summary of main results. a) COD removal during EF, b) removal of inorganic compounds after 6 h of EF (EF experimental conditions: V = 0.45 L, Fe^{2+} = 0. 2 mmol L^{-1}, pH = 3, j = 6.32 mA cm^{-2}, room temperature, and constant air supply). c-f) Changes in nutrients concentrations during the microalgal cultivation with EF effluents produced at different current densities.

Conclusions

The results demonstrated the high compatibility of both processes as part of a promising two-step sustainable strategy to process highly loaded industrial wastewater such as that from the food processing sector along with resource recovery. The implementation of both stages makes it possible to create microalgal biomass that could be valorized into biofuels or other value-added products. Finally, this work widens the range of applications of EF, which has typically been used to degrade/mineralize wastewater pollutants, into the field of wastewater valorization.

Acknowledgments

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