

Transitioning from conventional batch to microfluidic processes for the efficient singlet oxygen photooxygenation of methionine

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Highlights

- Photooxygenation of (L)-methionine by ¹O₂ has been studied in a batch reactor.
- Photosensitizer concentration, light intensity and O₂ flow have been optimized.
- Reaction has been studied in a microfluidic system through pseudo first-order kinetics.

1. Introduction

Singlet oxygen (¹O₂) has received considerable attention over the last decade in several areas: depollution, disinfection and photodynamic applications, but also for the production of high-value added organic molecules. The most popular methodology for the production of singlet oxygen involves a photoinduced electronic energy transfer from an excited state of a catalytic photosensitizer (PS) to triplet oxygen (³O₂). Rose Bengal (RB) is a popular, non-toxic photosensitizer that has been widely utilized for the production of ¹O₂ upon visible light aerobic irradiation.

The amino acids tyrosine, tryptophan, methionine, histidine and cysteine constitute one of the most relevant families among the photooxidizable biological substrates. Of particular interest is the photooxidation of methionine (Met) to methionine sulfoxide (MetO) which is a particularly valuable synthetic intermediate with applications ranging from peptide sciences, material sciences, to organic synthesis [1].

In this work, intrinsic reaction kinetics of this photosensitized reaction were studied as a function of the RB concentration, the light intensity and the O₂ flow. Apparent first-order kinetic constants, initial rates and space-time yields were calculated and then, optimized reaction parameters were transposed to a microfluidic reactor for the photocatalytic oxidation of Met under continuous-conditions.

2. Methods

The photooxygenation rates for the ¹O₂-oxidation of Met toward MetO were determined in macroscopic batch and microfluidic systems. All experiments were carried out in thermostated reactor setups at 30 °C with 15 mL·min⁻¹ of pure O₂ (Alphagaz™ 1 grade). The light source was a linear halogen Osram R7S Haloline (230 W, 114.2 mm). The RB spectra were obtained by UV-Vis on a Genesys 10S UV-Vis (Thermo Scientific) and the evolution in the concentration of Met and MetO was measured by ¹H NMR with a Bruker Avance III 400 MHz in D₂O by monitoring the appearance and disappearance of characteristic signals.

3. Results and discussion

No significant conversion was observed without photosensitizer (Fig.1). As expected, kinetic rates of the process were improved with a larger amount of RB. For low RB concentrations (ranging from 0 to 0.073 mM), *k*_{app} values presented a linear growth due to the Lambert-Beer law. Then, the kinetic rates plateaued at 0.073 mM, and stayed constant for higher RB concentrations.

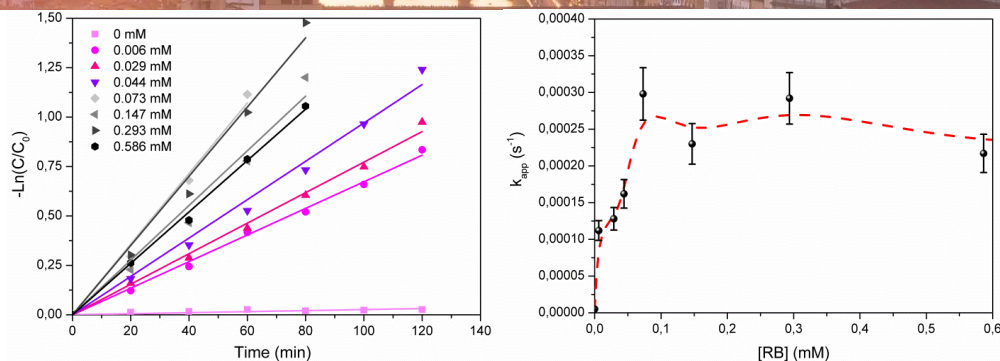


Figure 1. a. Pseudo first-order relationship $-\ln([Met]/[Met]_0) = k_{app}t$ as a function of RB concentration and b. k_{app} as function of RB concentration.

Similar calculations were done as a function of the light intensity and the O_2 flow in order to optimize the transition from batch reactor to microfluidic system. Space time yields (STY) were also calculated as a key parameter to study the production efficiency of both technologies (Fig.2b).

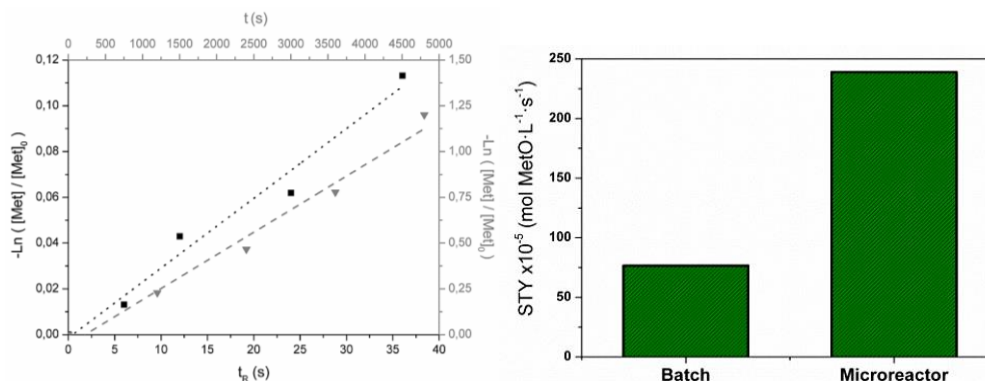


Figure 2. a. Pseudo first-order relationship $-\ln([Met]/[Met]_0) = k_{app}t$ for batch (black squares and dotted line) and microreactor (gray triangles and dashed line). b. Comparison between the batch reactor and microreactor in terms of STY.

The kinetic values for the catalytic photooxygenation of Met under continuous-flow microreactor are remarkable, since apparent first-order constants and reaction rates are about 100 fold faster than under batch conditions. In the case of STY the difference between both systems is lower, but stays worthy of consideration with a STY 3.12 times higher, similar to the improvement obtained for the synthesis of pinocaryone from a TPP-sensitized microflow photooxygenation of α -terpinene [2].

4. Conclusions

This work reports the technological transition of the catalytic photooxygenation of methionine from macroscopic batch to microreactor. RB concentration, light intensity and O_2 flow have been evaluated in batch reactor showing that the light penetration as well as mass transfer limitations plays an important role in this photosensitized process as limiting parameters with an important impact on the production of methionine sulfoxide *via* 1O_2 . Pseudo first-order kinetics and space-time yields have been also calculated in both technologies obtaining an enhancement of 12 and 3 fold for r_0 and STY, respectively when using continuous-flow microreactor.

References

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Keywords

“Methionine” “Microfluidic” “Photooxygenation” “Singlet Oxygen”.