Insights into marine cell adhesion to surfaces: a Computational Fluid Dynamics approach

TÉCNICO LISBOA

iBB

Ricardo F. S. Pereira[1,2], José M. C. Pereira[3], Carla C. C. R. de Carvalho[1,2]

[1]iBB-Institute for Bioengineering and Biosciences, Department of Bioengineering, Instituto Superior Técnico, Universidade de Lisboa, Portugal;
[2]Associate Laboratory i4HB-Institute for Health and Bioeconomy, Instituto Superior Técnico, Universidade de Lisboa, Portugal;
[3]IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Pav. Mecânica I, LASEF, Lisboa, Portugal

E-mail: ricardofspereira@tecnico.ulisboa.pt

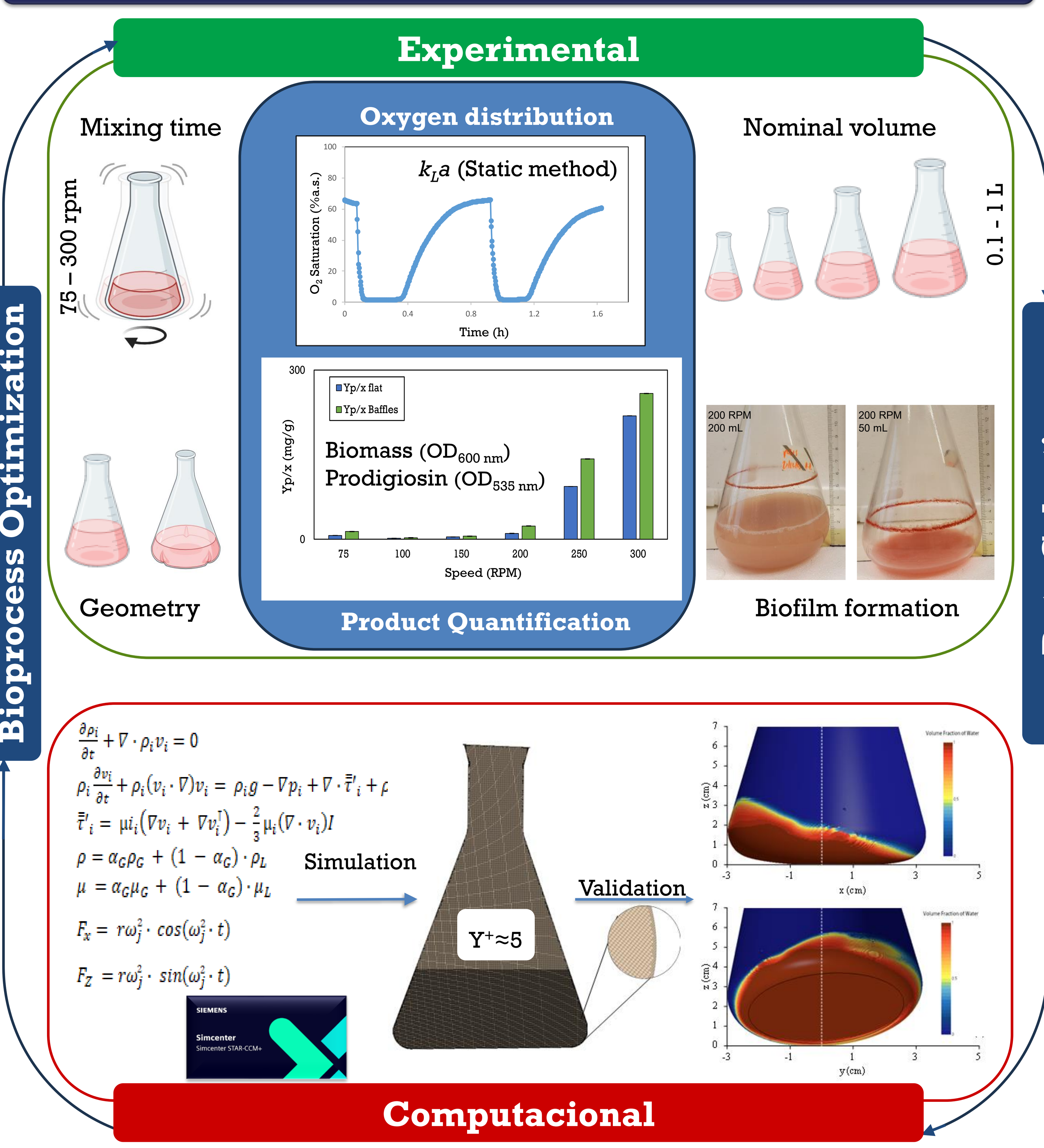
i4HB Institute for Health and Bioeconomy

INTRODUCTION & AIM

Marine bacteria readily attach to wetted surfaces and form biofilms[1]. Local hydrodynamics strongly influence biofilm development, structure, and population dynamics, as bacteria sense shear stress and organize accordingly[2,3]. In shake-flask cultures, fluid rotation generates multidirectional shear and varying mass transfer patterns, causing cells to adhere at the highest point reached by the liquid.

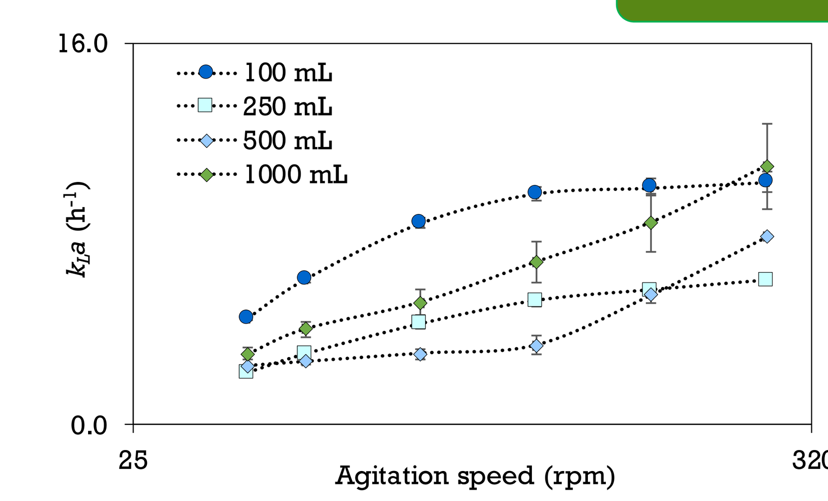
This work aimed to develop a multi-parameter Computational Fluid Dynamics (CFD) model to simulate broth hydrodynamics in Erlenmeyer flasks to identify the physical factors leading to cell adhesion and biofilm formation. The model was validated by using a marine, prodigiosin producing, *Serratia rubidaea* strain, which formed a distinctive red halo at the maximum height attained by the liquid, thus allowing for the confirmation of the predicted liquid height.

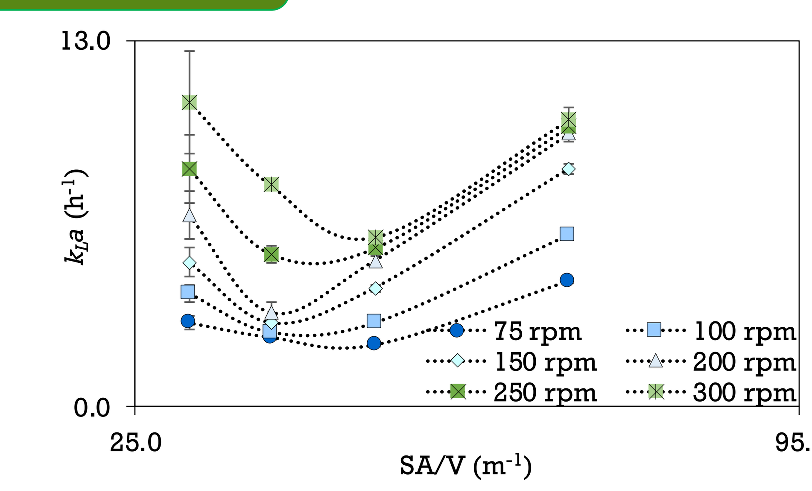
METHOD



RESULTS & DISCUSSION

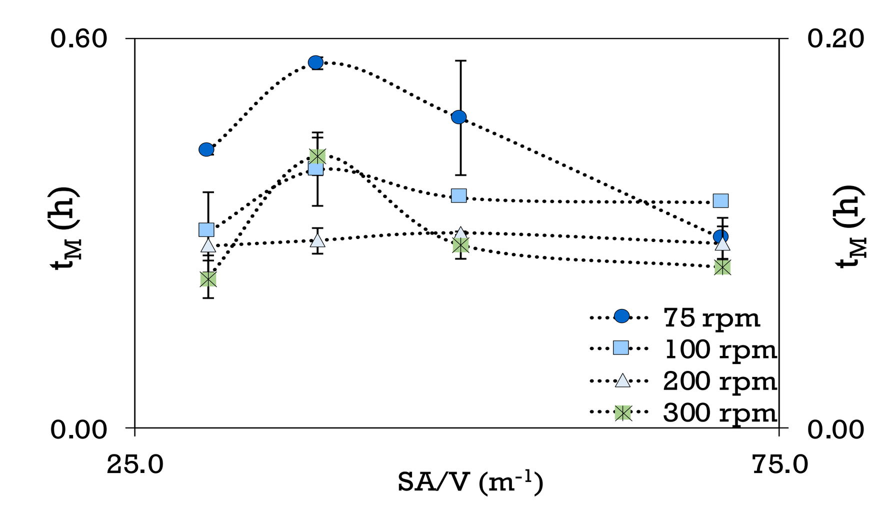
Nominal Volume





- 100 & 250 mL: logarithmic fit
- 500 & 1000 mL: exponential fit
- 100 mL flask - highest SA/V
- ↓ k_La with ↑ V as ↓ SA/V

500 mL flask :"out-of-phase" phenomenon & O_2 transfer transition values



200 rpm

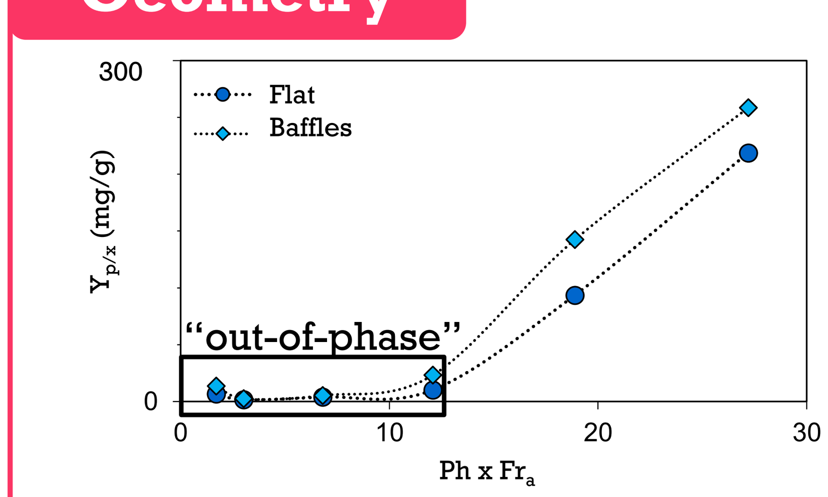
"in" & "out-of-phase" transition

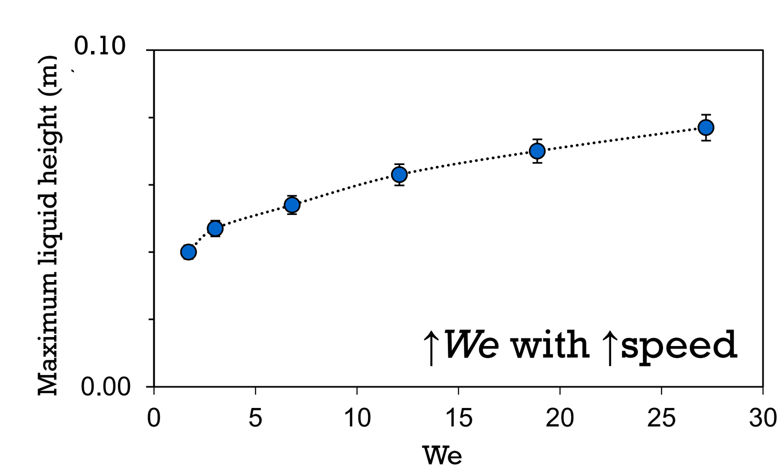
500 mL flask

"Max t_M attained in each velocity

Mixing time

Geometry

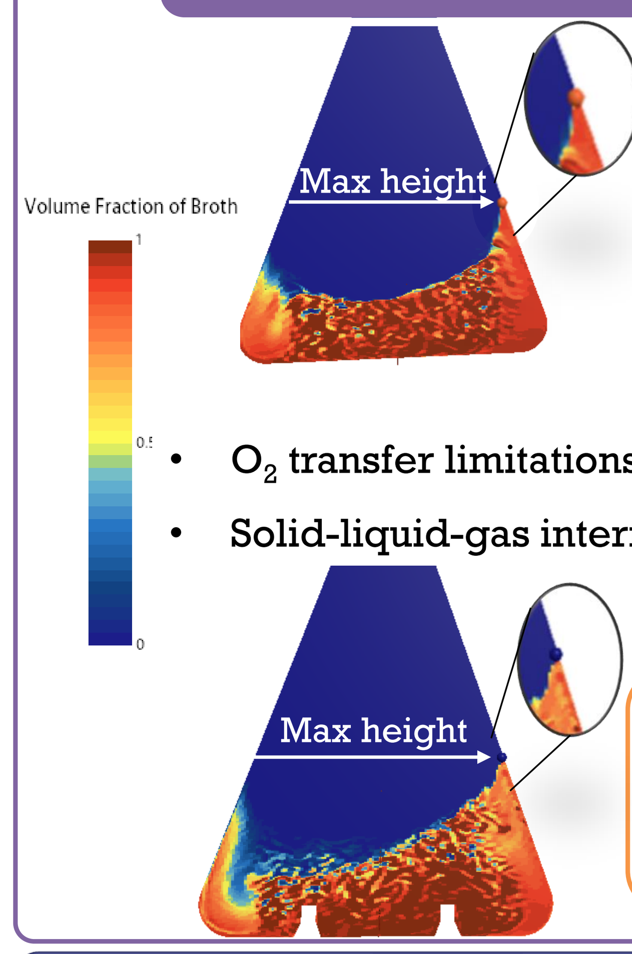




- ↓ O_2 mass transfer between phases
- ↓ Growth & product formation.
- Cells did not influence liquid movement

< 200 rpm: ↓ shear stress → Biofilm: ↓ thickness and ↓ density

Liquid distribution



Simulation = Real Fluid

500 mL flasks

200 rpm

200 mL

Max height – 6.0 cm

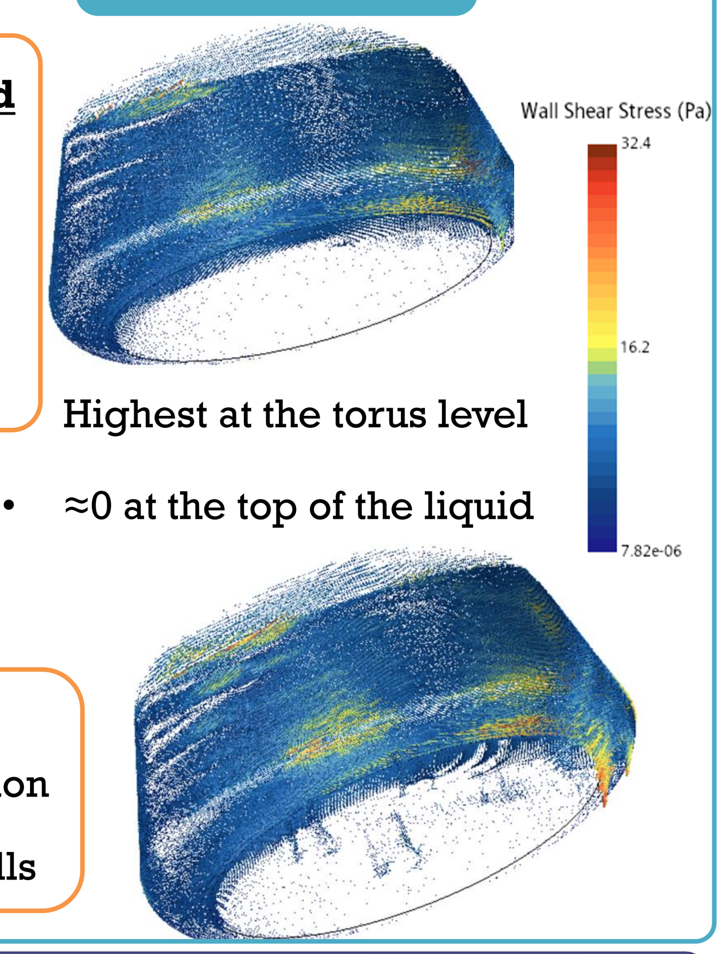
- O_2 transfer limitations
- Solid-liquid-gas interface conditions

Baffles:

Changed liquid distribution

No shear stress to the cells

Sheer stress



Highest at the torus level

- ≈0 at the top of the liquid

CONCLUSION

CFD provided information regarding:

- **Biofilm formation** occurring at the highest point reached by the rotating liquid due to lower shear stress conditions and frequent wetting;
- How the **fluid motion** influence dissolved oxygen in flasks with different geometries which affects the growing cell population.

REFERENCES:

1. de Carvalho, C.C.C.R. *Front. Mar. Sci.* **2018**, *5*, doi:10.3389/fmars.2018.00126.
2. Jones, A.-A.D.; Buie, C.R. *Sci. Rep.* **2019**, *9*, 2602, doi:10.1038/s41598-019-39267-2.
3. Rodesney, C.A et. al., *Proc. Natl. Acad. Sci.* **2017**, *114*, 5906–5911, doi:10.1073/pnas.1703255114.

Acknowledgments:

EU Horizon 2020 Programme - GA no. 101000327 (Project FuturEnzyme); FCT (Portugal) - in the scope of the projects UIDB/04565/2020 and UIDP/04565/2020 of the Research Unit iBB-Institute for Bioengineering and Biosciences, and of the project LA/P/0140/2020 of the i4HN-Associate Laboratory Institute for Health and Bioeconomy.