Microalgae Biorefineries as multi-product integrated biorefineries: A course on combined modelling and experimental approaches.

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Bioprocess development represents an onward challenge for world sustainability, and economy. Microalgae as bio-factories of the future are currently facing an increasing interest as they possess a range of interesting properties.

The cultivation of microalgae is part of a wider context of bio-refinery exploitation due to their capability to produce high-value molecules, biofuels, fertilizers, antioxidants, anti-inflammatory, and antimicrobials making them potentially exploitable in a refinery context. These properties are key aspects to be improved when the bio-refinery is developed (García Prieto, et al 2017).

Moreover, in recent years, microalgal biomass is regarded as a long-term and fast-growing promising feedstock capable of meeting global biofuel demands due its ability to accumulate carbohydrates and lipids, carbon-based molecules from which both sugar- and oil-based fuels could be obtained (Chen et al., 2013; Scaife et al., 2015). Starch and lipid accumulation is additionally known to be significantly induced during nutrient-stress algal cultivation, but the associated drop in biomass growth complicates the implementation of such a strategy for large-scale biofuel production (Bekirogullari et al., 2017). Thus, it is essential to identify optimal nutrient-based strategies capable of balancing the trade-off between algal growth and starch-lipid formation. In order to establish the best microalgae-to-biofuels route, we have developed multi-scale multi-parameter kinetic models capable of predicting the simultaneous dynamics of biomass (mixotrophic) growth, and starch and lipid formation as a function of nutrient availability (Figueroa-Torres et al., 2017, Usai et al 2019).

This mini course will offer an overview of microalgae potential as integrated biorefineries of the future, from basic concepts, to advanced combined experimental and modelling approaches. Focus will be placed on the cultivation process from the laboratory scale to the pilot scale and a range of experimental and modelling approaches will be presented from basic concepts to state-of-the art research. In addition, extraction methodologies using novel green solvents, which significantly enhance the sustainability of microalgal biorefineries, will be discussed.

An outline of the course is given below:

1. **Microalgae – The biorefinery potential.**
   - 1.1. Microalgae: basic concepts.
   - 1.2. Microalgal biorefineries.
   - 1.3. Microalgae selection and cultivation.
     - 1.3.1. Open vs closed cultivation systems.
2. **Microalgae Cultivation Strategies.**
   - 2.1. Strategies based on light and temperature.
   - 2.2. Strategies based on nutrient stress.
   - 2.3. Strategies based on carbon fixation mechanism.
   - 2.4. Strategies based on operating mode
3. **Microalgae Modelling Approaches.**
   - 3.1. Overview

3.2. Single-substrate models.
3.3. Multiple-substrate models.
3.4. Modelling of lipid and carbohydrate formation.

4. Microalgae cultivation multi-factor macroscopic modelling.

4.1. Model-based optimisation of cultivation media for increased starch and lipid formation.
4.2. Production of biobutanol and biodiesel from microalgal biomass

5. Scaling-up of microalgae cultivation

5.1. Open raceway ponds
5.2. Modelling and optimisation of photoautotrophic growth

6. Multi-scale models of microalgae cultivation for added value products

6.1. Population balance modelling approaches for biotechnological applications
6.2. Combined population balance modelling and experimental studies

7. Lipid extraction methods using novel green solvents

References

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