Course guide
390336 - BREA - Bioreactors

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Unit in charge: Barcelona School of Agri-Food and Biosystems Engineering
Teaching unit: 745 - DEAB - Department of Agri-Food Engineering and Biotechnology.

Degree: BACHELOR'S DEGREE IN BIOSYSTEMS ENGINEERING (Syllabus 2009). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: Cerrillo Moreno, Míriam

Others: Cerrillo Moreno, Míriam

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. Ability to use and manage the technology and operational methods of bioreactors.
2. Design of processes and facilities for production of biological materials.

Transversal:
3. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.

TEACHING METHODOLOGY

The teaching methodology varies depending on whether referring to lectures -based on theoretical concepts- (large group) or practical sessions (small group).
In the lectures (large group), the professor will introduce general knowledge related to the concepts of matter, and will promote motivation and engagement of the students to actively take part of their learning. Teaching materials will be shared via ATENEA. On the other hand, the teaching methodology also includes practical classes to solve exercices or numerical problems. Eventual tasks can be proposed after each session needing dedication outside the classroom, such as oriented readings and problem solving, which are the basis of the guided and autonomous learning.
The objective of the practical classes (small group) is to give prominence to the students, create the habitude to the techniques applied, size and design equipments, and learn about operation techniques through visits to facilities.

LEARNING OBJECTIVES OF THE SUBJECT

The bioreactors are the enclosures in which biological reactions are controlled to obtain products or services. The design of these devices depends on the stoichiometry and kinetics of the reactions, the state of aggregation of the biocatalysts (enzymes or microorganisms) and the environmental and operational requirements of the process. The general objective of the subject is to get familiarized with the basic tools of characterization of the bioprocesses, the choice of an adequate reactor design, its sizing, and the programming of the operation parameters. Specifically, the objectives are:
- Know the main types of bioreactors, their basic characteristics and their most important applications, for enzymatic reactions and for microorganism mediated reactions.
- Acquire knowledge on relevant aspects of the bioindustrial processes such as mass balances, design, sizing, and the approppiate use of a bioreactor according to its application.
- Study the elements needed to carry out the sizing and operation of a bioreactor, such as for instance the most common kinetic equations, interaction between kinetics and mode of operation, agitation and aeration systems, as well as the instrumentation and basic control methods.
- Acquire the calculation skills, through the resolution of exercises and guided problems, for the sizing of bioreactors and control of the operating parameters.

STUDY LOAD

Type	Hours	Percentage
Hours small group	20,0	13.33
Hours large group	40,0	26.67
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

BIOPROCESS ENGINEERING

Description:
1.- Process engineering, reactions and reactors
- Applications of the continuity equation to ideal reactors for reactions of different orders
2.- Enzymatic kinetics
- Enzymatic kinetics. Modifications of enzyme activity. Inhibition
3.- Microbial kinetics
- Kinetics of cell growth, substrate utilization and product formation. Measure of the growth. Growth models

Related activities:
Activity 1. Theory lectures
Activity 2. Exams
Activity 3. Solving exercices and problems with calculator and/or computer

Full-or-part-time: 26h
Theory classes: 8h
Laboratory classes: 4h
Self study : 14h

BIOENERGETICS AND BIOLOGICAL REACTIONS STOICHIOMETRY

Description:
1.- Mass and energy balances in biological reactions
- Stoichiometry of microbial growth and product formation
- Reaction bioenergetics
- Simultaneous processes and matrix notation
2.- Estimating the substrate to biomass conversion rate
    - Based on experimental measurements
    - Based on thermodynamic relationships

Related activities:
Activity 1. Theory lectures
Activity 2. Exams
Activity 3. Solving exercices and problems with calculator and/or computer
Activity 4. Practices of design in the lab

Full-or-part-time: 27h
Theory classes: 8h
Laboratory classes: 3h
Self study : 16h

REACTORS WITH IMMOBILIZED BIOCATALYSTS

Description:
1.- Immobilized biocatalysts
- Objectives and methods of immobilization. Immobilization of enzymes. Immobilization of microorganisms
2.- Biofilm kinetics
- Equations of diffusion and reaction. Simplifications and assumptions. Biofilms efficiency
3.- Kinetics of reactors based on biofilms
- Integration. Flow regimes (perfectly mixed and plug flow)
4.- Limitations to external transport
- Analysis by dimensionless numbers: Damköhler and Thiele modules; Sherwood number

Related activities:
Activity 1. Theory lectures
Activity 2. Exams
Activity 3. Solving exercices and problems with calculator and/or computer
Activity 4. Practices of design in the lab
Activity 5. Visit to installations

Full-or-part-time: 29h
Theory classes: 8h
Laboratory classes: 5h
Self study : 16h

BIOREACTORS DESIGN

Description:
1.- Design of bioreactors
- Typical configurations and components of a bioreactor. Instrumentation
2.- Aeration
- Oxygen transfer. Aeration efficiency. Determination of the kLa. Related equipment
3.- Mixing
- Homogenization in perfectly mixed reactors. Stirring power and kLa. Related equipment
4.- Experimental determination of the hydraulic residence time. Use of tracers
5.- Separation and product recovery
- Coagulation and flocculation. Precipitation. Centrifugation. Filtration

Related activities:
Activity 1. Theory lectures
Activity 2. Exams
Activity 3. Solving exercices and problems with calculator and/or computer
Activity 4. Practices of design in the lab
Activity 5. Visit to installations

Full-or-part-time: 50h
Theory classes: 8h
Laboratory classes: 8h
Self study : 34h

CASE STUDIES

Description:
1.- Case study
- Bioreactors application for the production of products from a raw material

Related activities:
Activity 1. Theory lectures
Activity 2. Exams
Activity 5. Visit to installations

Full-or-part-time: 18h
Theory classes: 8h
Self study : 10h

ACTIVITIES

ACTIVITY 1: THEORY LECTURES

Description:
The professor makes a presentation to introduce the learning objectives related to the fundamentals of the subject. Subsequently, through the resolution of exercises, will motivate and engage the students to take part actively in the learning process.

Specific objectives:
At the end of the activity, the students will have the knowledge and the skills to be able to design a fermenter at both pilot and industrial scale; control the operating parameters of a bioreactor to reach its optimal performance; obtain industrial products by culturing microorganisms in bioreactors; and know the most important industrial applications of bioreactors.

Material:
- Class presentations
- Collection of exercises concerning bioreactors
- Basic textbooks

Full-or-part-time: 83h
Theory classes: 38h
Self study: 45h

ACTIVITY 3. EXAMS

Description:
Performance of individual tests, which consist of two parts: 1) theory, conceptual questions by which students demonstrate the achievement of knowledge and the capacity of interconnecting concepts; 2) exercises and problems with one or two problems to be solved, following the patterns of those problems solved in class or from the collection of exercises proposed.
The final exam will weight 40% of the final mark.
The partial exam will be completed individually, and will weight 20% of the final mark.

Specific objectives:
Assess the achievement of the learning objectives of the subject as well as the particular skills associated.

Material:
In the final exam, part of theoretical questions: no documentation can be consulted.
In the final exam, part of problems: documentation that the student deems appropriate can be consulted.
In the final exam, in both parts, the student must bring a calculator.
In the partial exam, in both parts, the student can consult any documentation it wishes.

Delivery:
Exam individually solved by the student.

Full-or-part-time: 2h
Theory classes: 2h

ACTIVITY 3. SOLVING EXERCICES AND PROBLEMS WITH CALCULATOR AND/OR COMPUTER

Description:
The exercises and problems to be solved will be proposed during the course.
Students will deliver the results of the exercises proposed, in groups of no more than three people, one week before the day of the final exam of the course.

Specific objectives:
At the end of the practices, the students should be able to solve problems regarding bioreactors sizing.

Material:
Collection of exercises proposed throughout the course.

Delivery:
Delivery of exercises and problems solved.
The solved exercises will weight 10% of the final mark of the course.

Full-or-part-time: 34h
Theory classes: 1h
Laboratory classes: 8h
Self study: 25h

ACTIVITY 4. PRACTICES OF DESIGN IN THE LAB

Description:
The objective is to solve a bioreactor design problem. At the beginning of the course, working groups will be created, and a bioreactor design exercise aiming to meet specific goals will be proposed to each group. There will be four sessions of two hours each, where every group will present the progress made in the calculations to the rest of the class, and doubts will be solved jointly. These sessions will have the format of technical cabinet. The design exercise will be delivered no later than the day of the final exam.

Specific objectives:
At the end of the practice the students should be able to solve problems related to the sizing of bioreactors, and to transform published data in scientific papers into useful information for the decision making.

Material:
Design exercise statement posed by the professor during the first month of the course.

Delivery:
Each working group must deliver three different reports:
1.- Literature review on the process to be implemented
2.- Stoichiometry of the reaction, kinetic parameters to be used, and draft design
3.- Final report with the sizing of the installation

Full-or-part-time: 28h
Laboratory classes: 8h
Self study: 20h

ACTIVITY 5. VISIT TO INSTALLATIONS

Description:
Visit to industries, research laboratories and other activities which use bioreactors in their processes.

Specific objectives:
Knowledge about constructive details and operational parameters usually applied to bioreactors.

Material:
Information related to the facilities to be visited.

Delivery:
No delivery report for this activity. Mandatory activity.

Full-or-part-time: 4h
Laboratory classes: 4h

GRADING SYSTEM

The final mark for the subject, Nfinal, is obtained as follows:
N1: final test rating
N2: partial test rating
N3: qualification of practical activities and problem solving exercises
N4: evaluation of lab design practices

Nfinal =0.4·N1 + 0.2·N2 + 0.1·N3 + 0.3·N4

EXAMINATION RULES.

The attendance and completion of activities related to the resolution of problems and exercises is mandatory. The no assistance to such activities will not exempt of the corresponding knowledge and skills. Tasks must be delivered before the deadline.

BIBLIOGRAPHY

Basic:

- Gòdia-Casablancas, F.; López-Santín, J.. Ingeniería bioquímica. Madrid: Síntesis, 2005. ISBN 8477386110.
- Díaz-Fernández, M.. Ingeniería de bioprocesos. Madrid: Paraninfo, 2012. ISBN 9788428381239.
- Doran, P.M.. Bioprocess engineering principles [on line]. London: Elsevier: Academic Press, 1995 [Consultation: 15/05/2020]. Available on: https://www.sciencedirect.com/science/book/9780122208515. ISBN 0122208560.

Complementary:

- Levenspiel, O.; Costa-López, J.; Puigjaner-Corbella, L.. El omnilibro de los reactores químicos. Barcelona: Editorial Reverté, 1986. ISBN 8429173366.
- Nielsen, J.H.; Villadsen, J.; Lidén, G.. Bioreaction engineering principles. 2nd ed. New York: Kluwer Academic / Plenum Publishers, 2003. ISBN 0306473496.
- Stanbury, P.F.; Whitaker, A.; Hall, S.J.. Principles of fermentation technology. 2nd ed. Oxford: Pergamon, 1995. ISBN 9780750645010.