Course guide
295579 - 295PB022 - Biopolymers and Bioplastics

Last modified: 04/06/2026

Unit in charge: Barcelona East School of Engineering
Teaching unit: 713 - EQ - Department of Chemical Engineering.
702 - CEM - Department of Materials Science and Engineering.

Degree: MASTER'S DEGREE IN POLYMERS AND BIOPLASTICS (Syllabus 2024). (Compulsory subject).

Academic year: 2026 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish, English

LECTURER

Coordinating lecturer: LUIS J. DEL VALLE

Others: ORLANDO SANTANA
NOEL LEÓN
JAVIER GÓMEZ MONTERDE

PRIOR SKILLS

NO

REQUIREMENTS

NO

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Generical:
CGMUEQ-06. Have the capacity to analyze and synthesize the continuous progress of products, processes, systems and services using safety, economic viability, quality and environmental management criteria
CGMUEQ-10. Adapt to changes, being able to apply new and advanced technologies and other relevant developments, with initiative and entrepreneurial spirit

Transversal:
02 SCS. SUSTAINABILITY AND SOCIAL COMMITMENT. Being aware of and understanding the complexity of social and economic phenomena that characterize the welfare society. Having the ability to relate welfare to globalization and sustainability. Being able to make a balanced use of techniques, technology, the economy and sustainability.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

LEARNING RESULTS

Knowledges:
K1. Identify the molecular chemical structure of polymers and biopolymers.
K5. Relate the structure and properties of polymers and biopolymers in order to predict their behaviour and to obtain materials with new functionalities.

Skills:
S3. Interpret the results of polymer analysis and characterisation techniques.

Competences:
C3. Apply acquired knowledge and problem-solving skills both in discipline-specific environments and in new or unfamiliar environments in broader (or multidisciplinary) contexts related to the field of study.
C2. Apply appropriate methods of analysis, production and management in the field of polymers and biopolymers.
C4. Make effective use of information resources, managing the acquisition, structuring, analysis and visualisation of data and information within the field of specialisation and critically evaluating the results of this process.

TEACHING METHODOLOGY

Lectures and presentation of works
MD.1 - Participative lecture.
MD.3 - Case studies.
MD.4 – Laboratory.

LEARNING OBJECTIVES OF THE SUBJECT

Specific:
CEMQ1. Apply knowledge of mathematics, physics, chemistry, biology and other natural sciences, obtained through study, experience, and practice, with critical reasoning to establish economically viable solutions to technical problems.
CEMQ9. Manage Research, Development and Technological Innovation, taking into account the transfer of technology and property and patent rights.
CEMQ13. Realization, presentation and defense, once all the credits of the syllabus have been obtained, from an original exercise carried out individually before a university court, consisting of a comprehensive project of Chemical Engineering of a professional nature in which the competences acquired in the teachings are synthesized. .
Generic:
CGMQ4. Carry out the appropriate research, undertake the design and lead the development of engineering solutions, in new or unfamiliar environments, relating creativity, originality, innovation and technology transfer.
CGMQ6. Be able to analyze and synthesize the continuous progress of products, processes, systems and services using criteria of safety, economic viability, quality and environmental management.
CGMQ11. Possess the skills of autonomous learning to maintain and improve the skills of chemical engineering that allow the continuous development of the profession
Transversal:
CT3. TEAMWORK: Being able to work as a member of an interdisciplinary team, either as a member or performing management tasks, in order to contribute to develop projects with pragmatism and sense of responsibility, assuming commitments taking into account the resources available.

STUDY LOAD

Type	Hours	Percentage
Self study	108,0	72.00
Hours large group	21,0	14.00
Hours small group	21,0	14.00

Total learning time: 150 h

CONTENTS

1. Biopolymers and bioplastics

Description:
Introduction to biopolymers and bioplastics. Macromolecules: carbohydrates, lipids, proteins, and nucleic acids. Polymeric biomaterials.
Flow of genetic information: The central dogma of molecular biology. Processes of replication, transcription, and translation. Application in prokaryotic and eukaryotic systems.

Specific objectives:
At the end of this topic, the student will be able to:
• Understand that biological systems (prokaryotic and eukaryotic cells) or their components have specific mechanisms for the biosynthesis of biopolymers and bioplastics.

Related activities:
Summary and key words. Additional problems.

Full-or-part-time: 3h
Theory classes: 3h

2. Macromolecules: Nucleic Acids

Description:
Heterocycles and nucleic acids. Pyrimidine and purine. Nucleic acids and nucleotides. Structure of DNA. Base pairing in DNA: The Watson-Crick model. Nucleic acids and heredity. Replication of DNA. Structure and synthesis of RNA: Transcription. RNA and protein biosynthesis: Translation. Sequencing of DNA. Chemistry synthesis of DNA and RNA. Primary structure. Secondary structure. Thermal denaturation and hypochromism.

Specific objectives:
By the end of this unit, the student will be able to:
• Differentiate between DNA and RNA. Understand the structure of nucleic acids as polyanionic chains.
• Understand that all genetic information is translated into proteins, which subsequently mediate the biosynthesis of other macromolecules.

Related activities:
Nucleotide structure. Nucleotide complementarity. Nucleic acid synthesis: Replication and transcription.
Structure of nucleic acids (DNA and RNA).
UV-visible spectroscopy for studying nucleic acids. DNA melting curve.
Summary and key words. Summary of reactions. Additional problems.

Full-or-part-time: 4h 30m
Theory classes: 4h 30m

3. Macromolecules: Proteins

Description:
Amino acids, peptides, and proteins. Structures of amino acids. Dipolar structure of amino acids. Isoelectric point. Synthesis of alpha-amino acids. Resolutionof R, S amino acids. Peptides. Covalent bonding in peptides. Peptide structure determination: amino acid análisis. Peptide sequencing: The Edman degradation. Peptide sequencing: C-terminal residue determination. Peptide synthesis. Automated peptide synthesis: The merrifield solid-phase technique. Classification of proteins. Protein structure. Enzymes. Protein denaturation. Structure-function relation.
Recombinant DNA technology. Cloning and expression of recombinant proteins. Molecular tools: plasmids and vectors. Restriction enzymes. Polymerase chain reaction (PCR). Sequencing PCR. Preparation of extracts and purification of proteins.

Specific objectives:
By the end of this topic, the student will be able to:
• Interpret the structure and function of proteins;
• Understand the production of recombinant proteins in bacterial and eukaryotic cell systems;
• Identify the phenomena that occur in the different stages of protein purification.

Related activities:
Protein secondary structure and denaturation: application of FTIR study.
Summary and key words. Summary of reactions. Additional problems. Seminars.

Full-or-part-time: 4h 30m
Theory classes: 4h 30m

4. Macromolecules: Polysaccharides and Lipids

Description:
Carbohydrates. Classification of carbohydrates. Fischer projections for depicting carbohydrates. D, L sugars. Configurations of the aldoses. Cyclic structures of monosaccharides: hemiacetal formation. Monosaccharide anomers: mutarotation. Conformations of monosaccharides. Reactions of monosaccharides. Stereochemistry of glucose: The Fischer proof. Disaccharides. Polysaccharides. Other important carbohydrates. Carbohydrates on cell surfaces.
Lipids. Waxes, fats, and oils. Soaps. Phospholipids. Biosynthesis of fatty acids. Prostaglandins. Terpenes. Biosynthesis of terpenes. Steroids. Stereochemistry of steroids. Steroid’s biosynthesis.

Specific objectives:
By the end of this unit, the student will be able to:
• Interpret and understand that polysaccharides and phospholipids are biopolymers based on sugars and lipids, respectively.
• Recognize the combination of proteins with polysaccharides (glycoproteins) and with lipids (lipoproteins) as copolymers.

Related activities:
Structure and function of polysaccharides as hydrogels.
Structure and function of phospholipids for micellar assembly and encapsulation to transport molecules of interest.
Summary and key words. Additional problems. Seminars.

Full-or-part-time: 4h 30m
Theory classes: 4h 30m

5. Biopolymers and Bioplastics: Biomaterials

Description:
Biomaterials and biocompatibility: Classification. Biocompatibility and hemocompatibility. Response of living beings. Biocompatibility regulations and tests. Surface modification. Surface analysis. Sterilization Biomaterials: classification.
Biosustainability and biodegradability: Sustainable development. Green chemistry: the atomic economy. Sustainability parameters. Analysis of biological cycles. Toxicity. Biodegradability. Biodegradation mechanisms and evaluation methods. Sustainability regulation. Bioplastics.
Sustainable monomers: Traditional monomers of natural origin. Chemical and biotechnological production processes. Green catalysis. Sustainable ethylene: bioethanol. Sustainable additives: green plasticizers. Lignin as a source of monomers.
Sustainable polymers and bioplastics: Impact of the manufacture and use of polymers. New synthesis strategies. Sustainable polymerisation methods. Replacement of traditional toxic monomers: new alternatives. New bioplastics from carbohydrates and natural oils. Polylactic acid. Contribution of recycling techniques.
Nanostructured polymers and copolymers: Biopolymers of technological interest: starch and cellulose. Protein biopolymers. Industrial modifications and applications. Bacterial polymers: polyesters and polysaccharides. Industrial applications. Economic aspects.
Polymeric biomaterials: Surgical sutures. Adhesives. Polymeric cements. Dental restorations and implants. Hydrogels. Contact lenses. Artificial skin. Polymers in pharmaceutical tablets. Controlled drug release.
Advanced bioplastics: New biocomposites based on bioplastics. Flexible and low-migration bioplastics. Hybrid bioplastics. Sustainable coatings based on bioplastics: paints and plastic coatings.

Specific objectives:
By the end of this unit, the student will be able to:
• Understand the enzymatic biosynthesis of biopolymers and bioplastics based on amino acids, sugars, and lipids.
• Recognize that biopolymers and bioplastics are a result of the circular economy and the recycling of agri-food products.

Related activities:
Kinetic study of biodegradation.
Summary and key words. Additional problems. Seminars

Full-or-part-time: 4h 30m
Theory classes: 4h 30m

6. Introduction to rheological behavior and its characterization for biopolymer processing

Description:
Study of the flow and deformation behavior of biopolymers in the molten state. Analysis of shear viscosity and the limitations of the Melt Flow Index (MFI) in temperature-sensitive materials. Fundamentals of linear viscoelasticity using semi-oscillatory oscillatory tests (SAOS) and its application to determine thermal stability, hydrolytic degradation, and molecular weight. Introduction to elongational rheology and its critical impact on film blowing and foaming processes. Correlation between rheological parameters and processability window.

Specific objectives:
Upon completion of this module, the student will be able to:
• Differentiate between viscous, elastic, and viscoelastic behavior in molten biopolymers.
• Interpret flow (shear) curves and understand the limitations of the Melt Flow Index (MFI).
• Understand the usefulness of the SAOS test for determining thermal stability and molecular structure (molecular weight, branching).
• Relate elongational viscosity to processing problems (such as bubble stability in film blowing).

Related activities:
Laboratory session: Determination of MFI and effect of residence time on PLA

Full-or-part-time: 6h
Theory classes: 4h 30m
Practical classes: 1h 30m

7. Elastic Phenomena and Processing Defects

Description:
Study of the elasticity of polymer fluids and its impact on the quality of the final product. Concept of material memory and stress relaxation (Deborah number). Detailed analysis of extrudate swelling (Barus effect) and strategies for dimensional control in nozzles. Classification of flow instabilities: Sharkskin and melt fracture. Relationship between elastic defects and operating parameters (shear rate, temperature, and tooling design).

Specific objectives:
• Understand the concept of "elastic memory" and stress relaxation in biopolymers.
• Explain the phenomenon of die swell and how to compensate for it.
• Identify flow instabilities: Sharkskin and Melt Fracture
• Understand the importance of the Deborah number (De) in processing.

Related activities:
Summary and key words. Additional problems

Full-or-part-time: 3h
Theory classes: 3h

8. Biopolymer Extrusion and Compounding Technologies

Description:
Fundamentals of single-screw and twin-screw extrusion applied to thermally and hydrolytically sensitive materials. Critical moisture management: drying, crystallization, and the effects of hydrolysis on molecular weight. Low-shear screw design and melt temperature control to prevent degradation. Reactive extrusion (REX) for obtaining thermoplastic starch (TPS) and compatibilizing binary blends (PLA/PBAT). Co-extrusion and cast and blown film forming technologies adapted to the rheology of bioplastics.

Specific objectives:
• Understand the critical role of drying and hydrolytic degradation in bio-based polyesters (PLA, PHB).
• Select the appropriate screw geometry (L/D, compression ratio) for shear-sensitive materials.
• Differentiate between single-screw extrusion (for profiles/sheets) and twin-screw extrusion (for compounding and reactive TPS extrusion).
• Analyze inverse temperature profiles and their application in bioplastics.

Related activities:
PLA extrusion lab session: parameters and elastic effects

Full-or-part-time: 4h 30m
Theory classes: 3h
Practical classes: 1h 30m

9. Thermoforming and Rotomolding of Biopolymers

Description:
Secondary Transformation Technologies. In Thermoforming: Analysis of the processability window based on thermal transitions (Tg and Tm). Use of mechanical assistance (Plug Assist) to compensate for low melt strength. Advanced in-mold crystallization processes (C-PLA) for high thermal resistance applications. Defect analysis and thickness control. In Rotational Molding: Study of thermo-oxidative stability in long cycles. Challenges in the micronization (spray coating) of biopolymer matrices. Successful application of bio-based polyolefins (Bio-PE) and current limitations of biodegradable polyesters.

Specific objectives:
• Relate thermal transitions to the processing window: Determine the operating parameters in thermoforming based on the glass transition temperature (Tg) and crystallization kinetics, differentiating between the production of amorphous and semi-crystalline articles with high thermal resistance (C-PLA).
• Analyze the rheology of drawing and its technical solutions: Justify the need for mechanical piston assistance (Plug Assist) in the thermoforming of biopolymers to compensate for low melt strength and ensure a homogeneous thickness distribution.
• Evaluate the technical feasibility in long-cycle processes: Identify the thermo-oxidative stability limitations that restrict the use of biodegradable polyesters in rotomolding, contrasting this behavior with that of bio-based polyolefins (such as Bio-PE).

Full-or-part-time: 3h
Theory classes: 3h

10. Injection Molding of Biopolymers

Description:
This unit delves into the most important transformation process for obtaining complex, high-precision parts. It analyzes the specific characteristics of the injection molding cycle for shear- and temperature-sensitive materials (PLA, PHB, natural fiber composites). Particular emphasis is placed on the thermodynamics of cooling (P-v-T diagrams) and its impact on shrinkage and crystallization in the mold. Finally, the unit systematically addresses the identification and resolution of specific defects in bioplastics, differentiating between problems related to moisture, thermal degradation, and mold design.

Specific objectives:
• Configure the injection unit: Select the appropriate dosing parameters (back pressure, screw speed) and screw design to minimize molecular degradation during biopolymer plasticization.
• Optimize the thermal cycle: Interpret P-v-T diagrams to control volumetric shrinkage and manage the trade-off between cycle time and crystallinity in biopolyesters (cold vs. hot molds).
• Diagnose and correct defects: Visually and analytically differentiate between defects caused by moisture (hydrolysis) and those caused by excessive temperature (degradation), and propose corrective solutions in parameters or mold design.

Related activities:
Laboratory session: Injection parameters and mold filling optimization for PLA.

Full-or-part-time: 4h 30m
Theory classes: 3h
Practical classes: 1h 30m

GRADING SYSTEM

Any academic fraud, plagiarism or use or possession of unauthorised means in an assessment activity leads to a mark of zero (0) for the affected test or assignment. Furthermore, in accordance with the University's regulations, if disciplinary proceedings are initiated the subject is recorded as "Pending Assessment" until a decision is reached. These incidents are managed in accordance with the **Action Framework for Academic Integrity in Assessment at the UPC**.

NP1: Midterm theoretical test (40%) + seminar (10%)
NP2: Final theoretical test (35%) + Laboratory performance (15%)

NC = NP1 + NP2
Where NC is the course grade and NP1-NP2 are the grades of the two parts into which the subject is divided (theme 1-5, and theme 6-10).

EXAMINATION RULES.

Exam: Consists of different theoretical and practical questions related to the content of the subject.
1. There will be supervised activities (type AD), with deliverables corresponding to the theory or problems approached at class, and the students will report the activities of laboratory practices (type AP).
2. There will be a middle-term exam (EP) at the first part of our subject and a final exam (EF), with 2h of duration, to evaluate the individual progress of each student in this subject.
There is not any additional exam, related to recover the abovementioned marks (called "re-avaluació").

BIBLIOGRAPHY

Basic:
- Lendlein, Andreas; Sisson, Adam L. Handbook of biodegradable polymers : synthesis, characterization and applications [on line]. Weinheim, Germany: Wiley-VCH, cop. 2011 [Consultation: 06/05/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9783527635818. ISBN 9783527635825.
- Bastioli, Catia [ed.]. Handbook of biodegradable polymers. 2nd ed. Shrewsbury: Smithers Rapra Technology, 2014. ISBN 9781847355270.
- Alemán, Carlos; Bianco, Alberto; Venanzi, Mariano. Peptide materials : from nanostructures to applications [on line]. Chichester: John Wiley & Sons, 2013 [Consultation: 06/05/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9781118592403. ISBN 9781118592403.

RESOURCES

Other resources:
Classroom material available at ATENEA