Universitat Rovira i Virgili

Escola Tècnica Superior d'Enginyeria Química

Predicting the thermoforming behavior of PE-rich films

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to obtain the master's degree in Chemical Engineering from the Universitat Rovira i Virgili

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Tarragona, May 2023

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Sections ***Nomenclature, List of figures and tables, 2. Scope of the project and specific objectives, 4. Methods/Approach, 5. Results and discussion and 6. Conclusions*** have been omitted for confidentiality reasons.

NOMENCLATURE

This section has been omitted for confidentiality reasons.

LIST OF FIGURES AND TABLES

This section has been omitted for confidentiality reasons.

SUMMARY

Meat and cheese packaging represents a significant part of the Food and Specialty Packaging market. Among the various types of flexible packaging, thermoformed packaging has a large market share due to its ability to extend the shelf-life of products and enhance their appearance on store shelves among others. Recently, the European Parliament, the Council, and the Commission have set recycling targets for packaging. These targets aim for 50% recycling of plastic packaging by 2025, 55% by 2030, and that all plastic packaging should be designed to be recyclable or reusable by 2030. Companies like Dow are implementing plans to enable a circular economy.

One of the main challenges to understand and optimize the thermoforming process is the difficulty in predicting how a particular multilayer film will behave during the process. Without a reliable method for predicting its performance, the thermoforming process can be inefficient, and it results in wasted resources. This research's objective is to create a model that accurately predicts the thermoforming behavior of films from their mechanical and rheological properties.

Additionally, in the pursuit of sustainability, there is an increasing trend toward downgauging films for flexible packaging and enhancing transportation efficiency. However, this reduction in thickness makes the films more susceptible to package failure, as they become less capable of enduring abuse and abrasion during handling and transportation processes. While the mechanical characterization of the packaging is well defined by performing standardized tests, the assessment of the performance of the package during handling and transportation is yet missing. To address this gap, the aim of this project is to develop a method that can reproduce in films the abuse and abrasion mechanisms experienced by the final package during handling and transportation and establish correlations with the final package performance to predict package durability.

1. INTRODUCTION/BACKGROUND

1.1. Flexible packaging

Flexible packaging refers to any packaging made from non-rigid materials, such as plastic, foil, or paper, which can easily change shape to accommodate the product being packaged. This type of packaging typically consists of a combination of materials that provide the necessary barrier properties, mechanical strength, and other functional requirements to protect and preserve the product. Flexible packaging can be used as a primary packaging solution, where it comes in direct contact with the product, or as a secondary packaging layer that provides additional protection and aesthetic appeal (1).

Common products found in flexible packaging include:

- Food products: Snack foods, confectionery, baked goods, frozen foods, dairy products, meat, poultry, seafood, ready-to-eat meals, and more.
- Beverages: Pouches and bags for liquid products, such as juices, water, and even alcoholic beverages, offer a convenient and lightweight packaging option.
- Personal care and household products: Flexible packaging is also utilized for products like detergent pods, wipes, and personal care items, including toothpaste, shampoo, and soap.

Figure 1.1. Common flexible packaging products (2).

Flexible packaging offers several advantages over traditional packaging methods, making it an attractive option for food manufacturers and consumers alike. Some of these advantages include (3):

- Material efficiency: Flexible packaging requires less material than rigid alternatives, as it can conform to the shape of the product. This results in reduced packaging weight and material usage, contributing to a lower environmental footprint and cost savings.
- Lightweight: The reduced weight of flexible packaging, as compared to rigid packaging, translates to lower transportation costs and carbon emissions. This is particularly relevant in today's world, where reducing the overall environmental impact of packaging is of utmost importance.
- Barrier properties: Flexible packaging materials often possess excellent barrier properties, which help preserve the freshness, flavor, and quality of food products. This contributes to extended shelf-life and reduced food waste, as products remain fresh for a longer period.

- Design versatility: Flexible packaging offers a wide array of design options, such as resealable closures, easy-open features, and transparent windows, which enhance consumer convenience and product appeal.
- Enhanced branding and marketing: The adaptability of flexible packaging enables eye-catching graphics and innovative designs that can effectively communicate brand messages and capture consumer attention on retail shelves.

Plastic is one of the most widely used materials in flexible packaging due to its versatility, cost-effectiveness, and performance characteristics. There are several types of plastic materials employed in flexible packaging, each with distinct properties that make them suitable for specific applications (polyethylene, polyamide, polypropylene, polyvinyl chloride, polyethylene terephthalate, etc.). These various plastic materials are chosen based on the specific requirements of the packaged product, as well as factors such as cost, availability, and processing considerations. As innovations in plastic materials and processing technologies continue to emerge, the role of plastic in flexible packaging will likely evolve to meet new demands and address environmental concerns.

The flexible packaging market has experienced significant growth in recent years, becoming one of the dominant segments within the global packaging industry. It is particularly important in the food sector, where it addresses the increasing demand for convenience, sustainability, and extended shelf-life. As consumer preferences shift towards more environmentally friendly and convenient packaging options, the flexible packaging market is expected to continue its growth trajectory, outpacing other traditional packaging formats such as rigid containers, cartons, and metal cans (4, 5).

In addition to these advantages, flexible packaging often employs thermoforming as a key production technique. Thermoforming is a process in which plastic sheets are heated to a pliable state and then formed into desired shapes using a mold. This technique allows for the efficient production of customized packaging solutions that can be tailored to the specific requirements of the product being packaged. Thermoformed packaging, such as trays and clamshells, provide numerous benefits, including improved product protection, better utilization of shelf space, and enhanced aesthetic appeal. The thermoforming process also enables the use of multilayer films, which can be designed to deliver optimal barrier properties, mechanical strength, and other functional attributes. As a result, thermoformed packaging has become an important component of the flexible packaging market, catering to a wide range of applications in the food industry and beyond (4, 5).

Figure 1.2. Flexible packaging market trends (4, 5).

1.2. Thermoforming

Thermoforming is a widely used manufacturing process in the packaging industry, particularly to produce flexible and rigid plastic packaging. The process involves heating a plastic sheet or film to a pliable state, followed by shaping it using a mold, and then cooling it to retain the desired shape. Thermoforming offers several advantages, such as design flexibility, efficient material usage, and the ability to produce complex geometries with relative ease. The thermoforming process can be divided into the following steps (6):

- Heating: The plastic sheet or film is heated uniformly to a specific temperature range, where it becomes pliable and ready for forming. The heating is typically achieved using infrared heaters, hot air, or contact heating.
- Forming: The heated plastic is then formed into the desired shape using a mold. This can be achieved through various methods such as vacuum forming, pressure forming, or mechanical forming. The choice of the forming method depends on factors like the material properties, thickness, and complexity of the final product.
- Cooling: Once the plastic has been formed, it is cooled to solidify and retain its shape. Cooling is typically done by circulating air or water around the mold, or by using a cooling medium such as chilled air.
- Trimming: After the formed plastic has cooled, excess material is trimmed away, leaving the final product with the desired shape and dimensions. This can be done using cutting tools, dies, or laser cutting systems.

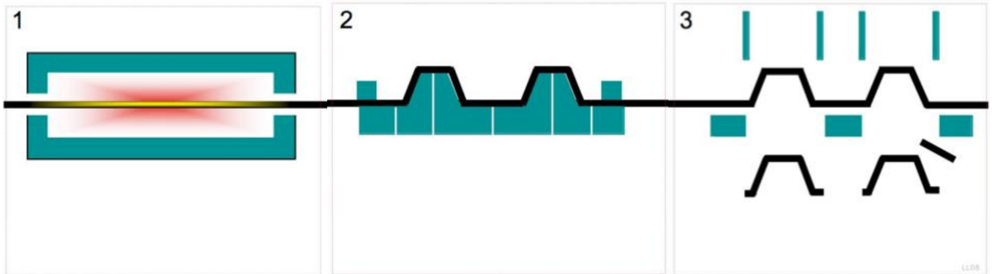

Figure 1.3. Thermoforming process (1: heating; 2: forming; 3: trimming) (6)

There are several types of thermoforming processes, each with its own unique characteristics and applications, such as: vacuum forming (the heated plastic sheet is placed over a mold, and a vacuum is applied to draw the sheet onto the mold surface), pressure forming (involves applying compressed air or gas to the heated plastic sheet, forcing it onto the mold), mechanical forming (the heated plastic sheet is physically manipulated onto the mold using mechanical means such as plugs, pressure boxes, or rollers) and twin-sheet forming (simultaneously forming two sheets of heated plastic and then bonding them together to create a hollow or double-walled product).

In summary, thermoforming is a versatile and efficient process used in the packaging industry for producing a wide range of flexible and rigid plastic products. With various types of thermoforming techniques available, manufacturers can choose the most suitable process to meet the specific requirements of their packaging applications.

Thermoformed packaging is typically constructed using a combination of materials, each selected to provide specific performance attributes that meet the requirements of the packaged product. Common materials used in thermoformed packaging include polyamide (PA), polyethylene (PE), and ethylene vinyl alcohol (EVOH).

One of the primary challenges associated with multilayer thermoformed packaging is **recyclability**. The combination of different materials in a single package can make recycling more difficult, as each material typically requires separate processing. This issue is particularly relevant for PA and EVOH, which are not easily separated from other materials, such as PE, during the recycling process. This challenge has led to the exploration of new materials and recycling technologies that can address this issue, such as mono-material structures and more efficient separation methods.

1.3. Plastic circularity

With the expected growth in the flexible plastic packaging market presented in section 1.1, plastic waste in landfills and consequently the volume of incinerated plastic has augmented as well, leading to an increase of CO_2 emissions. To tackle this situation, the European Parliament, the Council, and the Commission have established recycling targets for packaging (7). Specifically, they have agreed to a target of 65% recycling of packaging by 2025 and 70% by 2030, with a specific target for plastic packaging recycling of 50% by 2025 and 55% by 2030. These targets aim to ensure that all plastic packaging is designed to be recyclable or reusable by 2030 (7).

In response to the growing concerns about plastic waste and its impact on the environment, the concept of plastic circularity has gained significant attention within the packaging industry. Plastic circularity focuses on minimizing waste and maximizing resource efficiency by designing packaging materials that can be easily recycled, reused, or repurposed at the end of their lifecycle. One approach to promoting plastic circularity is the development of new materials and packaging designs that are inherently more recyclable.

Another important aspect of plastic circularity is the promotion of eco-design principles, which encourage the minimization of material usage, the incorporation of recycled content, and the reduction of overall environmental impact throughout the packaging lifecycle. By adopting eco-design strategies, manufacturers can create packaging solutions that not only meet the performance requirements of their products but also contribute to a more sustainable and circular economy.

Consumer education and engagement are also crucial for achieving the ambitious recycling targets set by the European Parliament, the Council, and the Commission. By raising awareness about proper recycling practices and the importance of responsible consumption, consumers can play a key role in supporting the transition to a more circular plastic economy. Additionally, collaboration among stakeholders, including industry players, policymakers, and waste management organizations, is essential to develop effective strategies and infrastructures that facilitate the collection, sorting, and recycling of plastic packaging materials.

1.4. Dow flexible packaging development

As the need for sustainable packaging solutions becomes increasingly important, Dow has made significant strides in developing flexible packaging materials that not only meet the performance requirements but also contribute to reducing the environmental impact of packaging.

One notable achievement of the development of flexible polyethylene (PE) packaging is showing the lowest CO_2 footprint among various types of packaging materials. This lower CO_2 footprint can be attributed to several factors, including efficient manufacturing processes, reduced material usage, and the potential for recycling. By offering a packaging solution that combines performance, convenience, and sustainability, Dow's flexible PE packaging serves as a prime example of how material innovation can contribute to a more circular and eco-friendly packaging industry. In Figure 1.6 a comparison between the different types of packaging CO_2 footprint can be found.

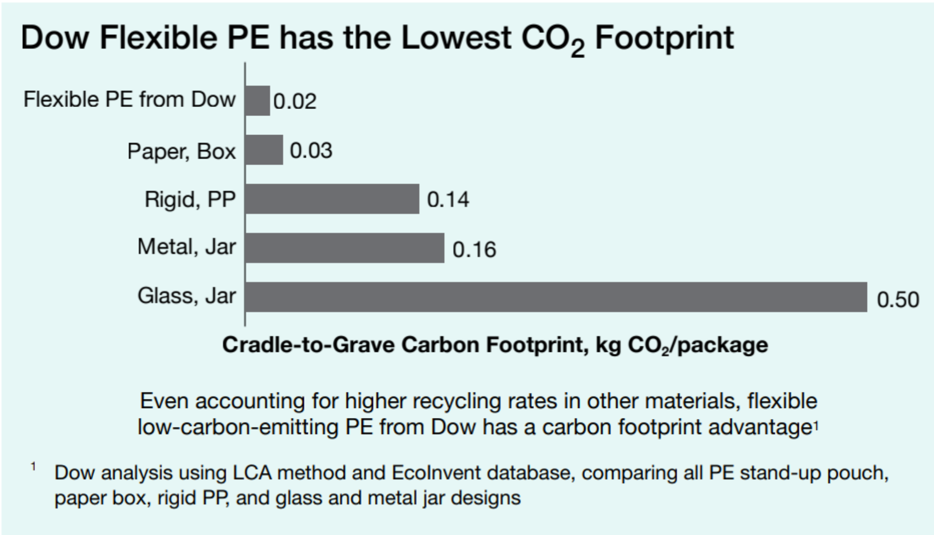

Figure 1.6. Carbon dioxide footprint comparison between different types of packaging (8).

With the aim to accelerate more developments and minimize workload, a model that predicts the thermoforming behavior directly from a multilayer film is needed.

1.5. <u>Ensuring package hermeticity</u>

The integrity of packaging is at risk at various points along the supply chain, where it may encounter impacts that could result in failure. These impacts might be due to environmental conditions, including climate and altitude, or connected to transportation, handling, and warehousing procedures, such as stacking, dropping, and exposure to shocks or vibrations. When packaging fails, it can no longer guarantee the quality of the product that is containing. To comply with the exigent quality standards, it is crucial to evaluate the performance of food packaging thoroughly—preferably as a proof of concept prior to market entry, as a part of quality assurance for monitoring production consistency, or, when failure occurs, to pinpoint and eliminate the causes. Packaging performance testing serves as a practical approach to optimizing packaging, ensuring product protection, and reducing customer complaints (9).

In the pursuit of sustainability, there is an increasing trend toward downgauging films for flexible packaging and enhancing transportation efficiency. Downgauging refers to the process of decreasing film thickness, which contributes to material conservation, lower transportation expenses, and diminished environmental footprint. However, this reduction in thickness makes the films more susceptible to package failure, as they become less capable of enduring abuse and abrasion during handling and transportation processes. Additionally, the industry has been moving toward recyclable mono-material structures to achieve more environmentally friendly packaging options. While these structures provide superior recyclability compared to multi-material alternatives, they often possess weaker mechanical properties. This makes them less resilient to abuse and abrasion, increasing the likelihood of packaging failure. This scenario presents a challenge for manufacturers striving to find a balance between sustainability and maintaining packaging durability (9).

Flexible packaging can undergo a range of abuse and abrasion mechanisms during handling and transportation. These mechanisms include, but are not limited to, impacts from drops or collisions, exposure to repetitive vibrations, and friction from contact with other packages or surfaces. Constant movement and stress can lead to various forms of damage, such as punctures, tears, or delamination. Among the most common defects in flexible packaging is the formation of pinholes, which are tiny perforations that can compromise the package's hermetic seal, potentially allowing contaminants to enter and compromising the product's quality and shelf life (9).

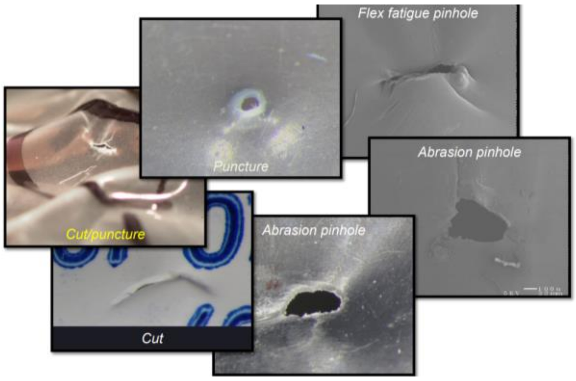

Figure 1.8. Common package defects (9).

2. SCOPE OF THE PROJECT AND SPECIFIC OBJECTIVES

This section has been omitted for confidentiality reasons.

3. STUDENT’S ROLE IN COMPANY

3.1. Company description

The Dow Chemical Company, commonly known as Dow, is a multinational corporation that produces chemicals, plastics, and agricultural products. Founded in 1897 by Herbert Henry Dow, the company has a long history of innovation and industry leadership. Dow operates in more than 35 countries and employs over 50,000 people worldwide. The company's portfolio of products includes chemicals for a wide range of industries, including agriculture, automotive, construction, and electronics. Dow is also a leading provider of specialty chemicals, such as silicone-based products and performance materials. These products are used in a variety of applications, from consumer goods to industrial processes. In recent years, the company has made a strong commitment to sustainability, investing in renewable energy and eco-friendly technologies. Dow's mission is to provide innovative solutions that improve the quality of life for people around the world. The company's long history of innovation and industry leadership has established it as a trusted partner to customers in a wide range of industries. Dow is committed to helping its customers address some of the world's most pressing challenges, from feeding a growing population to protecting the environment.

Building upon its rich legacy, Dow continues to focus on research and development to drive advancements in various sectors. The company invests significantly in cutting-edge technology and collaborates with universities, research institutions, and other industry partners to foster innovation. This collaborative approach has helped Dow stay at the forefront of the chemical industry, leading to numerous breakthroughs and patents in areas such as material sciences, biotechnology, and process engineering. Dow's diverse product portfolio is strategically organized into multiple business units, each targeting specific market segments. These business units include Performance Materials & Coatings, Industrial Intermediates & Infrastructure, and Packaging & Specialty Plastics. This structure allows Dow to better serve its customers with tailored solutions that meet their unique needs and challenges.

Figure 3.1. Dow Chemical business segments and products (10).

Focusing on the Packaging & Specialty Plastics (P&SP) business unit, Dow plays a crucial role in providing advanced and sustainable solutions for various industries, including food and beverage, personal care, and pharmaceuticals. As a key player in this sector, Dow's P&SP business unit is dedicated to creating innovative packaging materials that not only enhance product performance and consumer experience but also minimize environmental impact. The P&SP business unit offers a wide array of products, ranging from resins and adhesives to films and coatings, designed to meet the unique needs of its customers. These materials contribute to the production of lightweight, durable, and highly functional packaging, while also addressing critical sustainability challenges, such as waste reduction and recyclability. Some of the key product lines within this business unit include INNATE™ Precision Packaging Resins, AFFINITY™ Polyolefin Plastomers, and DOWSIL™ Silicone Solutions. One of the focus areas for the P&SP business unit is to develop and promote packaging solutions that support a circular economy. This includes designing packaging materials that can be easily recycled, reused, or repurposed, ultimately reducing waste and conserving resources. Dow's P&SP division works closely with its customers to create custom formulations that optimize the performance, aesthetics, and sustainability of their packaging products. In addition to circular economy initiatives, the P&SP business unit is committed to reducing the carbon footprint of its products and operations. Dow actively invests in energy-efficient technologies and renewable energy sources, such as wind and solar power, to minimize greenhouse gas emissions throughout the manufacturing process. The company also participates in industry-led initiatives, like the Alliance to End Plastic Waste, to collaborate on solutions for plastic waste management and promote a more sustainable future.

In addition to its core businesses, Dow is deeply committed to promoting social and environmental responsibility. The company's sustainability goals are centered around three key areas: advancing a circular economy, protecting the climate, and safeguarding water resources. Dow actively engages in initiatives to reduce waste, lower greenhouse gas emissions, and promote responsible water use across its global operations. The company also partners with non-profit organizations and local communities to promote environmental stewardship and support educational programs in the areas of science, technology, engineering, and mathematics (STEM). As part of its commitment to a sustainable future, Dow actively supports the United Nations Sustainable Development Goals (SDGs) and aligns its business strategies to contribute positively to these global objectives. The company's sustainability initiatives extend beyond its own operations, as Dow also works with its suppliers and customers to promote responsible sourcing, product stewardship, and end-of-life management for its products.

Figure 3.2. Dow Chemical inclusion, diversity, and equity strategy (10).

3.2. Student role

The internship takes place in Technical Service and Development (TS&D) department, as a part of the Industrial Innovation Campus (I2C) program. The TS&D department is responsible for driving innovation and advancing the company's portfolio of products and services. The department comprises a team of highly skilled scientists and engineers who work on developing new technologies and improving existing ones. The TS&D department is a key driver of Dow's commitment to sustainability, working on projects that aim to reduce the company's environmental footprint and develop renewable energy solutions. The department also focuses on developing advanced materials and chemicals that can improve the performance of a wide range of products and processes. Overall, the TS&D department plays a critical role in Dow's mission to provide innovative solutions that improve the quality of life for people around the world.

The aim is to work on complex and scientific-driven research and development projects that are aligned with one of the markets that Dow serves. The main scope of the internship is to develop new and/or improve the existing market solutions with clear goals and objectives, provided the mentorship of an experienced technical supervisor and the support of a Scientist partner from the P&SP organization.

As a part of the I2C program, the student performs some of the tasks of two different roles inside the company at the same time: *Technical Service & Development Scientist* and *R&D/TS&D Technician*. Some of these responsibilities include:

- Collaborating with cross-functional teams to effectively implement new technologies, products, or applications.
- Understanding the scope and limitations of test methods, designing comprehensive testing protocols, and preparing internal test methods to achieve project objectives.
- Applying the scientific method consistently to solve technical problems.
- Developing innovative approaches and solutions to problems by considering issues from various perspectives.
- Delivering presentations and reports that effectively communicate complex ideas and results.
- Documenting work in various formats, such as internal reports, presentations, etc. when appropriate.
- Independently conducting laboratory experiments, analyzing results, and providing recommendations for next steps in project development.
- Managing complex laboratory tasks, including methods and procedures, while suggesting variations in problem-solving approaches as needed.
- Ensuring the safe operation of small-scale and large-scale laboratory equipment, implementing change management processes according to Dow standards.
- Leveraging knowledge of product, test methods, industry standards, and testing equipment to efficiently complete projects.
- Defining and implementing new testing methods for development purposes, which may involve unique configurations of existing equipment, development or fabrication of new equipment, test methodologies, or systems.
- Documenting laboratory findings in a timely and well-organized manner, ensuring proper recordkeeping and communication of results.

- Effectively interacting and communicating with other groups and departments to streamline critical laboratory operations, such as sample shipping and analytical support.

Following the I2C program, different internal deliverables were elaborated and presented:

- *6-week presentation*: Initial 15’ presentation for the department (technicians, scientists, and leadership) after the initial 6 weeks of the student enrollment introducing the project scope, value, objectives, design of experiments and working hypothesis.
- *Midterm presentation + Brainstorming panel discussion*: 20-25’ presentation for the department after 4 months of student enrollment discussing project’s first results and updated design of experiments, followed by a brainstorming session to discuss new possible paths to follow.
- *Final presentation*: 30-35’ presentation for the department in the final week of the internship discussing project’s final results and next steps to follow.
- *CRI(s)*: Internal scientific report stating the project’s methodology and results.

Finally, as a part of the I2C program, there were different final thesis non-related projects related to innovation in the department, which accounted for 20% of the internship time.

4. METHODS/APPROACH

This section has been omitted for confidentiality reasons.

5. RESULTS AND DISCUSSION

This section has been omitted for confidentiality reasons.

6. CONCLUSIONS

This section has been omitted for confidentiality reasons.

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APPENDICES

A.1. SELF-EVALUATION QUESTIONNAIRE

a) Evaluate the acquired **competences** according to the **tasks** you have carried out.

Degree Competences		**Task in which you have observed the competence**	**Self-evaluation [Rank 1 to 10]**	**Aspects to be improved**
SPECIFIC COMPETENCES				
A1.1	Effectively apply knowledge of basic, scientific and technological materials pertaining to engineering.	TS&D Scientist R&D/TS&D Technician	10	None
A1.2	Design, execute and analyze experiments related to engineering	TS&D Scientist R&D/TS&D Technician	10	None
A1.3	Be able to analyze and synthesize the continuous progress of products, processes, systems and services, whilst applying criteria of safety, economic viability, quality and environmental management. (G6)	TS&D Scientist R&D/TS&D Technician	9	None
A1.4	Know how to establish and develop mathematical models by using the appropriate software in order to provide the scientific and technological basis for the design of new products, processes, systems and services and for the optimization of existing ones. (G5)	TS&D Scientist	10	None
A2.1	Be able to apply the scientific method and the principles of engineering and economics to formulate and solve complex problems that arise in processes, equipment, installations and services, in which the material undergoes changes to its composition, state or energy content, these changes being characteristic of industrial chemistry and other related sectors such as pharmacology, biotechnology, materials sciences, energy, food and the environment. (G1)	TS&D Scientist R&D/TS&D Technician	10	None
A2.2	Conceive, project, calculate and design processes, equipment, industrial installations and services in the field of chemical engineering and related industrial sectors in terms of quality, safety, economics, the rational and efficient use of natural resources and the conservation of the environment. (G2)	None	3	Little design involved in the project

A2.3	Lead and technically and economically manage projects, installations, plants, companies and technological centres in the ambit of chemical engineering and related industrial sectors. (G3)	TS&D Scientist R&D/TS&D Technician	10	None
A3.1	Apply knowledge of mathematics, physics, chemistry, biology and other natural sciences by means of study, experience, practice and critical reasoning in order to establish economically viable solutions for technical problems (I1).	TS&D Scientist R&D/TS&D Technician	10	None
A3.2	Design and optimize products, processes, systems and services for the chemical industry on the basis of various areas of chemical engineering, including processes, transport, separation operations, and chemical, nuclear, elctrochemical and biochemical reactions engineering (I2).	TS&D Scientist	8	None
A3.3	Conceptualize engineering models and apply innovative problems solving methods and appropriate IT applications to the design, simulation, optimization and control of processes and systems (I3).	TS&D Scientist	10	None
A3.4	Be able to solve unfamiliar and ill-defined problems by taking into account all possible solutions and selecting the most innovative. (I4)	TS&D Scientist R&D/TS&D Technician	10	None
A3.5	Lead and supervise all types of installation, process, system and service in the different industrial areas related to chemical engineering (I5).	R&D/TS&D Technician	8	None
A3.6	Design, construct and implement methods, processes and installations for the integrated management of waste, solids, liquids and gases, whilst also taking into account the impacts and risks of these products (I6).	None	1	No waste management design in the scope of the project
A4.1	Lead and organize companies and production and service systems by applying knowledge and abilities regarding industrial organization, commercial strategy, planning and logistics, mercantile and labour legislation, and financial and costs accounting (P1).	TS&D Scientist R&D/TS&D Technician	7	None
A4.2	Lead and manage the organization of work and human resources by applying criteria regarding industrial safety, quality management, occupation risk prevention,	TS&D Scientist R&D/TS&D Technician	8	None

	sustainability and environmental management (P2).			
A4.3	Manage research, development and technological innovation whilst ensuring the transfer of technology and taking into account property and patent rights (P3).	TS&D Scientist	9	None
A4.4	Adapt to structural changes in society caused by economic, energy or natural factors so as to be able to solve any resulting problems and to contribute technological solutions with a high commitment to sustainability (P4).	TS&D Scientist R&D/TS&D Technician	10	None
A4.5	Lead and monitor the control of installations, processes, products, certification, auditing, verification, testing and reports (P5).	TS&D Scientist R&D/TS&D Technician	10	None
A5.1	Carry out, present and defend (once all the curriculum credits have been obtained) an original individually produced piece of work before a university panel. The work will consist of a professional integrated Chemical Engineering project that synthesizes (TFM1)	TS&D Scientist R&D/TS&D Technician	10	None
TRANSVERSAL COMPETENCES				
B1.1	Communicate and discuss proposals and conclusions in a clear and unambiguous manner in specialized and non-specialized multilingual forums (G9).	TS&D Scientist R&D/TS&D Technician	10	None
B1.2	Adapt to changes and be able to apply new and advanced technologies and other important developments with initiative and entrepreneurial spirit. (G10)	TS&D Scientist R&D/TS&D Technician	9	None
B2.1	Lead and define multidisciplinary teams that are able to make technical changes and address management needs in national and international contexts. (G8)	TS&D Scientist R&D/TS&D Technician	10	None
B3.1	Work in a team with responsibilities shared among multidisciplinary, multilingual and multicultural teams	TS&D Scientist R&D/TS&D Technician	10	None
B4.1	Be able to learn autonomously in order to maintain and improve the competences pertaining to chemical engineering that enable continuous professional development. (G11)	TS&D Scientist R&D/TS&D Technician	10	None

B5.1	Carry out and lead the appropriate research, design and development of engineering solutions in new or little understood areas, whilst applying criteria of creativity, originality, innovation and technology transfer. (G4)	TS&D Scientist R&D/TS&D Technician	9	None
B5.2	Bring together knowledge, make judgements and take decisions on the basis of incomplete or limited knowledge whilst taking into account the social and ethical responsibilities of professional practice. (G7)	TS&D Scientist R&D/TS&D Technician	9	None
NUCLEAR COMPETENCES				
C1.1	Have an intermediate mastery of a foreign language, preferably English	TS&D Scientist R&D/TS&D Technician	10	None
C1.2	Be advanced users of the information and communication technologies	TS&D Scientist R&D/TS&D Technician	10	None
C1.3	Be able to manage information and knowledge	TS&D Scientist R&D/TS&D Technician	10	None
C1.4	Be able to express themselves correctly both orally and in writing in one of the two official languages of the URV	TS&D Scientist R&D/TS&D Technician	10	None
C2.1	Be committed to ethics and social responsibility as citizens and professionals	TS&D Scientist R&D/TS&D Technician	10	None
C2.2	Be able to define and develop their academic and professional project	TS&D Scientist R&D/TS&D Technician	10	None

b) Evaluate the final master project and suggest improvements.

Key steps	**Evaluation [Mark 1 to 10]**	**Improvement proposed**
Selection/assignment of the project (dissemination, communication, assignment requirements...)	10	None
Stay (welcome, length, relationship, follow-up made by the company...)	10	None
Follow-up made by URV tutor	10	None
Other aspects to be considered (which ones...)	None	None