CHEMICAL ENGINEERING

DM 630/Sanofi - Innovating Sustainable Packaging for Biotech Lyophilized Drugs: Smart Stopper Systems and IoT Integration

Funded By	MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] SANOFI SRL 00832400154]
Supervisor	PISANO ROBERTO - roberto.pisano@polito.it
Contact	
Context of the research activity	This project aims to develop an innovative primary packaging system for lyophilized biological drugs, focusing on optimizing stopper composition to enhance product stability and environmental sustainability. The project will include modifying stopper materials, integrating IoT sensors for real-time monitoring, and ensuring compliance with regulatory standards. The research includes hands-on work at pharmaceutical company sites in Italy and across Europe. Progetto finanziato dal PNRR a valere sul DM 630/2024 - CUP E14D24002400004
	This PhD project aims to develop innovative technologies for the production of biological drugs, with a particular focus on the primary packaging system used for the containment of parenteral drugs. Primary packaging plays a crucial role in the preservation and stability of lyophilized products, especially in the biotechnology sector. These products, which are extremely sensitive to moisture and external contaminants, require packaging solutions that provide an effective barrier against environmental agents, preserving product integrity throughout its lifecycle. Adequate primary packaging not only protects the product from potential chemical-physical degradation but also ensures patient safety and compliance with stringent pharmaceutical regulations. In 2023, the global market for lyophilized drugs was valued at over $2.5 billion, with an expected annual growth rate of 7.5% until 2030. Special attention must be paid to vial stoppers, whose material composition is critical for maintaining the product's sterility and stability. It is estimated that up to 10% of lyophilized product batches may be compromised due to stopper adhesion issues or material-product interactions. The choice of stopper blend, such as chlorobutyl or bromobutyl, can significantly influence the efficiency of the stoppering process, interaction with the lyophilized product,

Objectives	and moisture protection. Innovation in primary packaging, including the optimization of stopper composition, is essential to improve production efficiency, reduce costs associated with stopper adhesion issues and material-product interactions, and ensure greater environmental sustainability. Approximately 25% of commercially marketed injectable drugs require lyophilization processes, highlighting the importance of efficient and safe packaging solutions. Packaging errors or defects are responsible for an average loss of 5% of annual production volume, equivalent to around €125 million per year, with consequent economic and product quality impacts. These objectives align with the priorities of the National Recovery and Resilience Plan (PNRR), which promotes technological innovation, industrial efficiency, and sustainability. This project aims to develop a new packaging system that addresses these challenges, with the goal of improving the final product quality, optimizing production process performance, and ensuring greater environmental sustainability. The performance of the primary packaging system under investigation will be examined for the packaging of a lyophilized biotechnological product that is already in commercial production at Sanofi's Anagni plant. The study will involve an initial phase of modifying the stopper material (from a chlorobutyl to a bromobutyl blend) to reduce the adhesion issues observed with the stoppers on the stoppering heads and freeze dryer plates during the current process. The work will include identifying the most suitable stopper blend for the purpose, studying the washing and sterilization processes, verifying the seal integrity of the stopper-vial and seal system, studying the product-stopper material interaction, verifying moisture transfer from the stopper to the lyophilized product over time, and assessing the level of product protection from the external environment. The project will include, in addition to an initial theoretical study, the execution of laboratory and pilot scale lyophilization cycles, machinability tests, placebo batches, and the preparation of process performance verification, as well as the analysis and evaluation of data obtained from laboratory tests. Finally, the possibility of integrating miniaturized sensors into the stopper for local temperature and pressure monitoring will be evaluated. These sensors, in an Internet of Things (IoT) framework, would enable real-time monitoring and control of the lyophilization process. Potential applications include remote monitoring of critical process parameters, automation and control, thereby reducing the need for human intervention, and traceability. In summary, IoT applied to lyophilization represents an innovation that can improve the efficiency, quality, and sustainability of the process. The project will be carried out in collaboration with a pharmaceutical company, where the PhD student will spend at least 12 months in the Manufacturing Technology group in Italy and across Europe.

Skills and competencies for the development of the activity	The candidate should possess expertise in chemistry, pharmaceutical science, chemical and materials engineering, and lyophilization technologies. Laboratory experience, data analysis, and problem-solving skills are required. Knowledge of pharmaceutical regulations and IoT tools for process monitoring is preferred. Strong communication skills and a collaborative mindset are essential.