CHEMICAL ENGINEERING

Ammin/DISAT - Freeze-drying of vaccines in nested vials and advanced polymer caps

Funded By	Dipartimento DISAT Politecnico di TORINO [P.iva/CF:00518460019]
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Context of the research activity	Characterization and modeling of heat and mass transfer in nested vial systems to enable robust, equipment-independent freeze-drying cycle design for biopharmaceutical applications.
Objectives	Freeze-drying is the method of choice for stabilizing heat-sensitive biopharmaceuticals. This project aims to develop a robust and scalable freeze-drying cycle that is independent of specific equipment or vial configurations. The focus is on emerging technologies such as nested vials and advanced polymer caps, which are distributed sterile and housed in plastic racks. Unlike bulk-loaded vials, these systems modify heat transfer and freezing behavior due to limited shelf contact and altered nucleation dynamics. The research objectives are: (i) to characterize heat and mass transfer during primary drying in nested configurations; (ii) to develop a mechanistic model capturing these effects; (iii) to design and optimize freeze-drying cycles using a design space approach; and (iv) to create a model-based strategy for cycle transfer from conventional to nested vial systems. The project will also explore the impact of nested formats on freezing and secondary drying. This work supports next-generation pharmaceutical manufacturing.
Skills and competencies for the development of the activity	The project requires a strong background in chemical engineering, with a focus on heat and mass transfer, thermodynamics, and mathematical modeling of thermal processes. The candidate should be capable of analyzing complex systems and developing mechanistic models. Experience with simulation tools (e.g., MATLAB, Python, or COMSOL) is highly desirable. Strong problem-solving skills, the ability to work independently, and an interest in applied research within a regulated industrial environment are essential.