BTPE3009 BIOREACTOR DESIGN AND ANALYSIS (3-0-0)

Module - I: (08 Hours)
Introduction to Bioreactor Fundamentals Overview of Bioreactors Definition, historical evolution, and applications in bioprocessing. Classification: Aerobic/ anaerobic, batch/fed-batch/ continuous, microbial/ mammalian/ environmental. Bioreactor Components Vessel design, impellers, spargers, seals, heating/cooling systems. Material selection (stainless steel, glass) and sterilization methods. Monod equation, substrate utilization, and product formation. Case study: E. coli fermentation dynamics.

Module - II: (08 Hours)
Bioreactor Operations and Modes Batch Bioreactors Design equations, substrate limitation, and cell death kinetics. Productivity calculations and endogenous metabolism. Fed-Batch Systems Feeding strategies, dynamic mass balance models. Applications: Antibiotics (penicillin), recombinant protein production. Continuous Bioreactors Chemostat design, steady-state analysis, washout criteria. Tubular reactors and chemostats in series (wastewater treatment).

Module - III: (08 Hours)
Mass Transfer and Rheology Oxygen Transfer (KLa) Estimation methods (static gassing-out, dynamic), power consumption in agitation-aeration. Rheology of Fermentation Broths Newtonian vs. non-Newtonian fluids, viscosity effects on mixing. Heterogeneous Reactions Immobilized enzyme/cell systems, diffusion limitations. Case study: Biofuel production using Saccharomyces cerevisiae.

Module - IV: (08 Hours)
Heat Transfer and Scale-Up Heat Transfer Systems Metabolic heat generation, cooling jacket design, thermal profiling. Scale-Up Principles Criteria: Constant power/volume, tip speed, Reynolds number. Challenges: Oxygen gradients, shear stress, foaming. Non-Ideal Reactors Dead zones, bypassing, tanks-in-series model.

Module - V: (08 Hours)
Advanced Bioreactors and Applications Specialized Bioreactors Airlift, packed-bed, fluidized-bed, membrane, and photobioreactors. Instrumentation & Control Sensors (pH, DO, temperature), PID loops, foam control. Case Studies Large-scale vaccine production, algal biofuel systems, hazardous waste bioremediation.

Course outcomes (Cos)
1. Design bioreactor systems (batch, fed-batch, continuous) by applying mass/energy balance equations, Monod kinetics, and operational parameters to meet specific production goals.
2. Analyze oxygen transfer efficiency (KLa) and rheological properties of fermentation broths to optimize agitation-aeration systems for microbial and mammalian cell cultures.
3. Evaluate scale-up challenges (shear stress, oxygen gradients) using dimensionless numbers (Reynolds, power/volume) and propose solutions for industrial bioreactor configurations.
4. Operate advanced bioreactors (airlift, membrane, photobioreactors) with PID-controlled sensors (pH, DO) for applications in vaccine production, biofuels, and waste bioremediation.
5. Simulate non-ideal reactor behavior (dead zones, bypassing) using computational tools and recommend design modifications to enhance productivity.

Program outcomes (Pos)-
1. Apply principles of mathematics, kinetics, and thermodynamics to solve complex bioreactor design problems in bioprocessing and environmental biotechnology
2. Design sustainable bioreactor systems with consideration for societal, economic, and environmental impacts (e.g., reducing carbon footprint in algal biofuel production).
3. Utilize modern tools (CFD software, MATLAB) for modeling, optimization, and real-time monitoring of bioreactor performance.
4. Communicate bioreactor design strategies effectively through technical reports, presentations, and interdisciplinary collaboration.
5. Demonstrate ethical practices in bioprocess engineering, including adherence to biosafety protocols and waste management regulations.

Program Specific Outcomes (PSOS)-

1. Innovate in bio-based manufacturing by integrating bioreactor technologies with circular economy principles (e.g., valorizing agro-industrial waste)
1. Develop scalable bioremediation solutions for hazardous pollutants using immobilized microbial systems and advanced reactor configurations.
2. Design energy-efficient photobioreactors and microbial electrolysis cells (MECs) to support renewable energy transitions and carbon neutrality goals.
3. Implement AI/ML-driven bioreactor control systems to enhance yield prediction, process automation, and fault detection in industrial bioprocessing
4. Contribute to global health initiatives by optimizing bioreactor systems for vaccine and therapeutic protein production in compliance with GMP standards

Books:

1. Bioprocess Engineering: Basic Concepts – Shuler & Kargi
2. Biochemical Engineering – Bailey & Ollis