Course Code ESE-802	Credit Hours (Th-Pr) 3-0	**Photobioreactor Engineering & Bio-Processing (core)**	Contact Hrs/Week (Th-Pr) 3-0	Total Contact Hrs (Th-Pr) 45-0

Course Outline:

- Photobioreactor systems
- Modeling & simulation
- Cultivation Fundamentals
- Algae Separation Technology
- Comparison of seed oil & algal oil extraction
- Mass transfer in Extraction processes
- Super critical fluid Extraction

Eligibility Criteria: B.E (Chemical, Mechanical, Electrical, Environmental and Materials)

Recommended Books:

S. No.	Title	Author(s)	Assigned Code	Remarks
1.	Advances in biochemical engineering biotechnology: Bioprocess and Algae reactor technology	J. F. Cornet, J. Gomes, K. Scheibenbogen	JF	Reference
2.	Hand book of Micro-Algal culture Biotechnology and applied Phycology	Amos Richmond	AR	Reference
3.	Airlift Bioreactors	Yusuf Chisti	YC	Reference
4.	Technology and solvents for extracting oilseeds and nonpetroleum oils	Phillip J. Wakelyn	PW	Reference
5.	Supercritical fluid extraction**:** principles and	Mark A. McHugh, Val J. Krukonis	MV	Reference

	practice			

Course Objectives:

The primary objectives of this course are to familiarize students with stimulated algae growth in Photobioreactors using engineering approach and comprehensive overview of algae harvesting/separation techniques. Design of Mechanical & Supercritical extraction techniques.

Learning outcome:

The students will be familiarized with the core concepts of green energy production in Photobioreactors. Growth modeling, material & energy balance and airlift system design to operate in neutral energy cycle will be self evident. Modeling & simulation of multi phase flow in the Photobioreactors and bio-processing in downstream processing will come to light.

Topics Covered:

No.	Topics	Book	Contact Hours
1.	**Principles for mass cultivation of microalgae:** interactions between radiation, cell density and turbulence; oxygen as an indicator for culture condition; maintenance of pH, optimal cell density and mono-algal cultures**.**	JF & AR	3
2.	**Technological aspects involved in microalgal production:** various types of reactors: open and closed systems; turbulence and flow; separation, drying and marketing; simple technologies for algal production.	AR	3
3.	**Photobioreactor design and operation:** CSTR concept and algal growth kinetics photobioreactor instrumentation: On-line probes and off-line analyses.	JF & AR	3
4.	**Photobioreactor performance modeling and process simulation:** Energy and mass balances (Aspen/hysys),	Any related	6

	yield expressions for bio-systems mathematical models for the photobioreactor system and its performance simulation.		
5.	**Photobioreactor Hydrodynamics & Mass Transfer:** Shear stress calculations, Oxygen & CO_2 Mass transfer and Bioreactor scale-up and scale-down criteria (Ansys fluent)	YC & AR	3
6.	**Down-stream processing:** Comparative evaluation of Algae Harvesting/ Dewatering Techniques, Quantitative evaluation of dewatering performance: ○ Centrifugation ○ Floculation ○ Filteration & Screening ○ Gravity Sedimentation ○ Flotation Drying techniques: ○ Air drying ○ Solar drying ○ Oven drying ○ Freeze drying ○ Spray drying	Any related	3
7.	**Bio-Processing Lab:** 1. Experiments on Photobioreactor (Growth rate determination, nutrition media variations, pH and temperature variations) 2. Identify the algal strain for bio diesel production **3.** Algae cells harvesting using centrifuge, sedimentation and filteration (observation of efficient extraction process)		8

8.	**Lipid Extraction: Mechanical Processes** 1. Expression/ Extruder Expeller 2. Ultrasonic assisted extraction 3. Microwave assisted extraction	PW, JMC FG,	2

9.	**Lipid extraction: Chemical Processes** 1. **Solvent extraction**: basic principles, Mass transfer evaluation through ternary diagrams, solvent selection and applications 2. **Super Critical Fluid Extraction**: Basic principles, Thermodynamics of Super critical fluids, Solubility/ Mass transfer measurements of lipid constituents in Sc fluids, Sc fluid extraction of algae; Pressure & energy requirements and economic analysis 3. **Soxhlet extraction**: Overview of principles and operation of soxlet extractor 4. **Single step extraction by Quantum Fracturing <u>Technology</u>**: Electromagnetic pulses generation for efficient extraction, Potential difference requirements, pH criteria for extraction, single step extraction process flow diagrams	JF, AR & Any related	8
10.	**Lipid-Extraction Lab:** 1. Perform experiments on super critical fluid extraction unit (Find extraction efficiency with different operating pressures using feed stocks like algae, Jatropha, Rapseed etc) 2. Find the lipid contents in the dry algae sample using soxhlet extraction (Find Extraction rate using solvents chloroform & hexane)	YC & AR	6