CHAPTER 5

Conclusion and Future Scope

5. Conclusion and future scope

This chapter summarizes the findings of the current research, from the photobioreactor development to the characterization of the biomass, lipid, and biodiesel derived from the microalgae cultured in the developed photobioreactor. Finally, the chapter describes the future scope of the developed photobioreactor system and possible research methodologies to carry technology forward toward commercialization.

5.1 Conclusion

Three microalgae culture systems were designed, developed, and tested successfully to determine their viability for mass-scale microalgae cultivation applications. Two of the developed microalgae culture systems, namely Internally Illuminated Stirred Light Column Photobioreactor (IISLCP) and Internally Illuminated Airlift Photobioreactor (IIAP) systems, developed severe issues due to biofouling, raising concerns towards being suitable for mass-scale microalgae culture application. The third microalgae culture system developed, named the Stacked Tray Automated Modular Photobioreactor (STAMP), successfully tackled the issue of biofouling. The light path from the light source to the microalgae culture in the STAMP system remained clear for the entire period of the investigation. The transparency of the glass slides used to determine microalgae growth on the light source remained above 97%, indicating no microalgae growth over one month of culture. The initial biomass productivity evaluated in the STAMP system was 0.22 $gL^{-1}day^{-1}$, which was much higher than that of commercial open culture systems. The biomass productivity was improved further later on by optimization of the culture parameters.

The culture parameters like light wavelength, light intensity, light duration, nitrogen content, and airflow rate of the developed STAMP system were optimized using Response Surface Methodology (RSM). The Face Centered Central Composite Design (FCCCD) approach of RSM was implemented for optimization due to its higher accuracy and requirement for a lesser number of experimentations. Cool-white LED illumination resulted in the maximum biomass productivity of 512.0 ± 12.23 mg L^{-1} day^{-1}. Also, it consumed the least energy of 228.6 Wh day^{-1}. In contrast, pink LED performed the best in terms of lipid productivity (69.8 ± 1.1 mg L^{-1} day^{-1}) at a nitrogen concentration of 1.02 g L^{-1} and with energy consumption of 240.0 Wh day^{-1} during the experimental analysis. The microalgae biomass productivity improved by 2.04 folds in the STAMP system using the optimized culture parameters.

Finally, the *C. homosphaera* microalgae biomass and lipid produced in the STAMP system were characterized, and subsequently, the biodiesel synthesized from the microalgae lipid was also characterized. The biomass obtained demonstrated a calorific value up to 14.72 ± 0.04 kJg^{-1}, which is suitable to be used as a solid fuel for heat generation. The fuel properties for synthesized biodiesel, like calorific value of 36.84 MJ kg^{-1}, carbon residue of 0.01%, acid value of 0.11 mg KOH g^{-1}, density of 892 kg m^{-3} at 15 ℃, and kinematic viscosity of 3.6 mm^2s^{-1} at 40 ℃ were promising to be used for energy applications.

Overall, the STAMP system developed during the investigation showed promising results and has the potential to be used for mass-scale microalgae cultivation. Further design refinements and optimization are required to make STAMP ready for commercialization.

5.2 Future scope

The STAMP technology has immense potential for further development and technology upgrades to be suitable for commercial applications. The scope of technology development is listed below.

1. Implementation of Computational Fluid Dynamics (CFD) based optimization to improve mechanical performance of STAMP.
2. Implementation of an advanced AI/ML-based control system to improve the efficiency and reliability of STAMP and make it more user-friendly.
3. Further testing and optimizing the culture of different microalgae species in the STAMP system.
4. Incorporation of a suitable harvesting system to make STAMP a standalone system for microalgae cultivation and harvesting.
5. The fuel properties for synthesized biodiesel have scope for further improvements.
6. Further design refinement and optimization of the STAMP, to make it market-ready.