Abstract

In order to develop the 3rd generation microalgal biomass based biofuels, a holistic approach is quintessential towards achieving feedstock, process, environmental and economic sustainability. Present study implements the idea of strategic cultivation of microalgae with simultaneous waste utilization for subsequent downstream processing of biomass constituents into biofuels. Initial pH, nitrate and phosphate concentration of the medium were optimized using single parameter optimization technique. The interactions of different parameters were determined using the Box-Behnken design. The optimal values of pH, nitrate and phosphate concentrations were 7, 4.4 mM and 2.7 mM respectively. The maximum biomass obtained was 1.26 g L^{-1} at a constant light intensity of 100 μmol m^{-2} s^{-1} and temperature of 30 ^{o}C considering above mentioned physico-chemical parameters. The effect of CO_2 concentration on the biomass production was also investigated in customized airlift reactors which had an A_d/A_r ratio of 4.4 with a constant surface by volume (S/V) ratio of 0.57 cm^{-1}. The inner draft tube had a diameter of 3 cm. The biomass concentration was found to be a maximum of 4 g L^{-1} at 5% air-CO_2 mixture (v/v). On the other hand, maximum lipid yield of 24.6% (w/w) was observed at 2% air-CO_2 mixture (v/v). A biomass concentration of 6.78 g L^{-1} was observed in 20 L airlift photobioreactor at 5% air-CO_2 mixture (v/v). The use of spent media of acetogenic dark fermentation was investigated further for mixotrophic algal cultivation for biodiesel production. Mixotrophic growth conditions were optimized in culture flask (250 mL). Maximum lipid accumulation (58 % w/w) was observed under light intensity, pH, nitrate and phosphate concentration of 100 μmol m^{-2} s^{-1}, 7, 2.7 mM and 1.8 mM, respectively. Under optimized conditions, air lift (1.4 L) and flat panel (1.4 L) reactors were used for algal cultivation. Air lift showed 58 % improvement in biomass and lipid production, respectively as compared to flat panel reactor. The results could help in development of sustainable technology involving acetogenic hydrogen production integrated with sequential mitigation of spent media by algal cultivation for improved energy recovery. Suitable conditions were investigated for maximization of biodiesel production. HCl showed the highest lipid extraction efficiency and biodiesel conversion as compared to other catalysts and organic extraction solvents. The optimal temperature and reaction time were determined to be 70°C and 90 min, respectively. Under the optimal conditions, the biodiesel conversion based on the total lipid content was 84.2%. The fatty acids content of biodiesel from the lipids of the microalgae suggested its potentiality as a promising fuel for the future. The fuel properties of *Chlorella sp.* MJ 11/11 biodiesel were found to be comparable with the international and Indian biodiesel standards. Life cycle analysis of the process was performed to analyze the holistic effect on the environment. The energy intensive processes were identified and sustainable methods were suggested to reduce the energy consumption. Thus, the thesis highlights the importance and necessity of strategic production of microalgal biomass by utilizing cheap substitutes followed by bioconversion of the biomass constituents into biofuel products sustainable development of bio-based economy in the near future.

Keywords: Microalgae; *Chlorella sp.* MJ 11/11; Box-Behnken design; Medium optimization; Biomass; Lipid; Spent medium; Biodiesel; Transesterification; Life Cycle Analysis.