BIOMETHANE FROM ALGAL BIOMASS: FEASIBILITY ENHANCEMENT THROUGH PRETREATMENT, CODIGESTION AND COUPLING WITH WASTEWATER TREATMENT

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by

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DEDICATED

TO

MY DAUGHTER

NIHARIKA

CERTIFICATE

This is to certify that the thesis entitled **"Biomethane from algal biomass: Feasibility enhancement through pretreatment, codigestion and coupling with wastewater treatment"** being submitted by **Mr. Sanjeev Kumar** to the Indian Institute of Technology Delhi for the award of the degree of 'Doctor of Philosophy' is a record of bonafide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis. To the best of our knowledge the results contained in this thesis have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

The present study was targeted towards enhancing the feasibility of algal biomethanation through various innovative interventions. To begin with, multifarious screening of procured as well native algal culture was done with respect to biomass productivity, biochemical composition as well as the stoichiometric methane potential (SMP). Biomass composition of tested algae depicted their suitability for biomethanation. Indeed, the SMP of all the tested algae was relatively higher than the non-algal biomass reported in literature. The biochemical methane potential (BMP) and digestibility estimation lead to selection of native alga *Chroococcus* sp.1 for biomethane production. *Chroococcus* sp.1, having good biomass potential (biomass concentration ≈ 1.35 g L^{-1} in 12 d growth assay) and balanced biochemical composition, showed maximum BMP (up to 254 mL CH_4 g^{-1} VS_{fed}),) among the tested algae. On the other hand, *Spirulina* sp., which was highest biomass producer (biomass concentration ≈ 1.35 g L^{-1}) had poorest BMP (89 mL CH_4 g^{-1} VS_{fed}) due to improper biochemical composition. From the present findings, it was experimentally confirmed that along with biomass productivity, biomass composition is also a crucial parameter in the selection of algal strain for biomethane production.

During the detailed anaerobic digestion of *Chroococcus* sp.1 poor digestibility was evident from presence of intact algal cells in the digestate after 45 d of anaerobic digestion. The pioneering attempts focusing pretreatment of algal biomass with fungal crude enzymes (produced by *A. lentulus* under solid state fermentation using sugarcane bagasse as substrate) and its subsequent codigestion with cattle dung depicted great potential for improving algal digestibility and BMP. In fact, up to 50 % COD solubilisation from algal biomass was observed during its pretreatment with crude enzyme under optimal conditions (pH = 5.0 and temperature = 60 ºC) within 2.5 h. The corresponding enhancement recorded in the BMP was 27 %, which eventually increased to 62.54 %, when it was codigested (in 1:1 ratio on VS basis) with cattle

dung. In contrast, the codigestion of fresh algae with cattle dung showed only 14 % enhancement in BMP. Hence, fungal crude enzymes as pretreatment agent and cattle dung as cosubstrate have immense potential to improve the feasibility of algal biomethane process. Besides this, a novel bioagent was also identified which was efficient for simultaneous harvesting (nearly 100 % in 6 h) and pretreatment of selected algae which eventually resulted in >50 % enhancement in BMP. Overall, the bioagent based harvesting and pretreatment had potential to decrease the algal digestion time to 15 d (instead of 30 d needed for fresh algal biomass) with BMP up to 370 mL CH_4 g^{-1} VS_{fed}.

With the view to reduce nutrient input cost, rural sector grey water (RSW) and algal digestate were used for algae cultivation. RSW supplemented with 30 % of algal digestate was found optimal for algal growth with simultaneous nutrients/COD reduction below safe discharge limits. Hence, a "closed loop process" for bioenergy generation employing anaerobic digestion of algal biomass and simultaneous nutrient recycling for wastewater and algal digestate was proposed. Feasibility analysis for a typical village (population ≈ 4000 adults) showed that the proposed process had renewable power generation potential up to 5413 kWh d^{-1}. It also had capacity to treat > 0.5 MLD of RSW (with 0.199 MLD of algal digestate). The calculations validated the feasibility enhancement hypothesis of algal biomethane through coupling with wastewater treatment and liquid digestate recycling.

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