Biofuel and Bioremediation Potential of Microalgae

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Abstract

Escalating fuel prices, rising environmental concerns and dwindling stocks of fossil fuel have necessitated the exploration of viable alternative feedstocks. Biofuel from microalgae has been showing the prospects of a viable alternative to the conventional fossil fuels. This article assesses the prospects of biofuel from diatom consortia[1] and also the bioremediation[2] potential to treat the nutrient-rich aquaculture wastewater.

Introduction

Wastewater generated in domestic, industrial and agricultural sectors comprises mainly of 99 per cent water and 1 per cent solid (both organic and inorganic) constituents. The characteristics of wastewater, especially the proportion and properties of solid constituents alter depending on its sources of origin. For example, in domestic wastewaters, organic constituents include carbohydrates, fats, lignin, synthetic detergents, various aliphatic and aromatic chemical compounds from household pharmaceutical waste disposal [Ramachandra et al. (2013)]. On the other hand, wastewater generated in aquaculture from shrimp farms are characterized by large proportions of total suspended solids (TSS), which are mostly of inorganic origin due to eroded material from pond floor and embankments in addition to dissolved nutrients, particularly nitrogen from un-utilized protein feeds, phosphates and organic carbon from phytoplankton and detritus[3]. In addition to nutrients, shrimp wastewater also contains soluble and insoluble biochemical compounds such as pesticides,

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[1]Diatom consortia is an association of several microscopic unicellular algae of a particular category called the phylum. Bacillariophyta, occurring in marine or fresh water in single or in colonies. In such algae, each cell has a cell wall made of two halves and impregnated with silica.

[2]Bioremediation is a process that uses mainly microorganisms, plants, or microbial or plant enzymes to detoxify contaminants in the soil and other environments.

[3]Detritus is an organic matter produced by the decomposition of organisms.

disinfectants, antibiotics, immunostimulants, vitamins and feed additives. This can cause substantial sediment loading and eutrophication[4] when discharged to the surrounding water bodies as partially treated or untreated. India has the distinction of having higher aquaculture production next to China, which results in the humongous generation of wastewater and its subsequent release to the surrounding coastlines. India's coastal line with a stretch of 7,517 km has land-based aquaculture in estuarine brackish water regions contributing significantly to the global production of fishes, molluscans and crustaceans. Among aquacultures, shrimp aquaculture is becoming the fastest growing economic activity in Asia-Pacific regions with India becoming a leading exporter of commercial farmed shrimps. India's shrimp production is constantly increasing, since 2011, with an estimated annual production of 0.48 MMT (Million Metric Ton) in 2018. Figure 1 depicts the spatial extent of aquaculture ponds, shrimp productivity and an estimate of wastewater generated across the Indian states.

Microalgae help in bioremediation of wastewaters through bio-assimilation of nutrients into numerous organic molecules either fixed autotrophically or heterotrophically [Mahapatra et al., 2014; Ramachandra et al., 2013]. The autotrophic mechanism involves the utilization of CO_2 from the atmosphere and light energy from the sun during photosynthesis for biomass production in the form of carbohydrates and lipids. Mostly, inorganic mineral constituents (nitrogen, phosphorous and silica) are utilized in autotrophy, whereas in the heterotrophic mechanism, organic carbon is directly consumed by algae for nutrition, replacing the necessity of light energy.

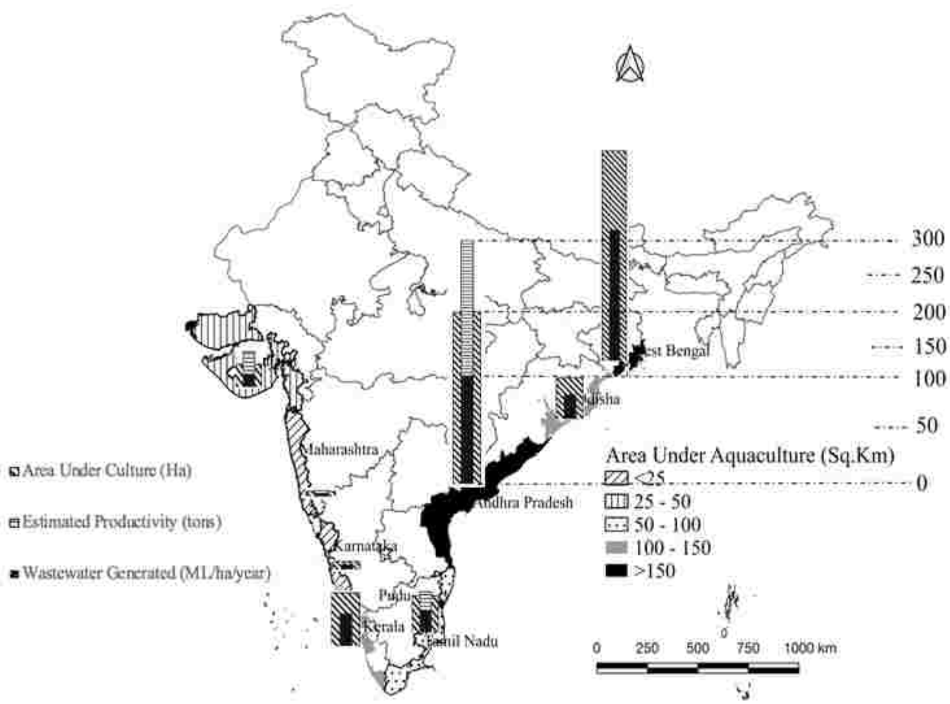
Microalgae diatoms are known to possess promising capabilities including its predominant presence in estuarine and continental shelves, accumulate 8 per cent more lipid content (per cent as of dry cell weight) than green microalgae during its exponential growth phase.

Shrimp Cultivation in India

Estimates indicate that about 343.53 ha. of land is under shrimp cultivation in Karnataka, India with an estimated productivity of 3.14 Mt/ha/yr. Uttara Kannada district with a total area of 218.06 ha. under shrimp cultivation, constitutes one of the major producers of shrimps. Uttara Kannada has the highest share (4200 ha.) of brackish water formations, out of which 1450 ha. of land are gazni lands (brackish water embayment). The local fisherfolks practise traditional shrimp farming in these gazni lands. The traditional method of shrimp cultivation is being practised extensively with no external feed inputs for shrimps' growth and such practice lowers

[4] Eutrophication refers to excessive richness of nutrients in a lake or other body of water, frequently due to run-off from the land, which causes a dense growth of plant life.

Figure 1: State-wise Aquaculture Production and Its Associated Wastewater Generation



environmental loadings and nutrient enrichment in the receiving water bodies. However, large-scale commercial activities involve semi-intensive and intensive types of shrimp farming where selective and higher seed stocking[5] is practised, which generates higher quantum of wastewater rich in total suspended solids (TSS) and dissolved nutrients such as Total Nitrogen (TN), Total Phosphorus (TP) and Total Organic Carbon (TOC). Also, intensive shrimp farming has inherent long-term management problems such as loss of coastal habitats and agricultural lands due to salinization, culture stock losses due to disease outbreaks, slow growth of shrimp fry and other socio-economic issues. This necessitates appropriate low-cost mitigation strategies to minimise organic pollution due to commercial shrimp production units. Thus, incorporation of the decentralised microalgal system near shrimp cultivation sites would aid in remediation of organic nutrients, through bio-assimilation as well as biofuel production from the microalgal

[5]Seed stocking is the selection of good quality seed for stocking into a pond and this is the first important step of the shrimp grow-out management.

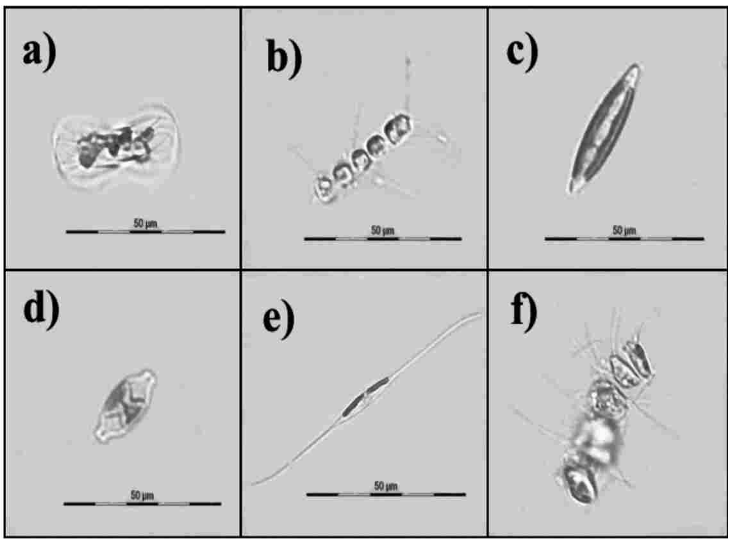
consortium. In this regard, lipid productivity potential of marine microalgae needs to be understood and the present research focussed on growing microalgal consortia, predominantly composed of benthic diatoms[6] using aquaculture wastewater under laboratory observations.

Biofuels Generation from Microalgae

Microalgae (benthic diatoms) were collected from sediments of a mangrove-rich brackish water region (14°31'9.55"N, 74°23'7.53"E) of the Aghanashini estuary. Figure 2 shows the light micrographic images of the diatoms that were present in the consortia.

Diatom consortium naturally occurring in the estuarine ecosystem were monitored in the laboratory with aquaculture wastewater in-order to understand the technical feasibility of the large-scale microalgae production. The biomass productivities of microalgae under diverse nutrient conditions varied between 32.3 – 41.6 mg $L^{-1}day^{-1}$, with lipid content ranging between 24 to 42 per cent of dry cell weight. Bioremediation potential is evident from the mean nutrient removal efficiencies of 89 per cent and 90 per cent for Total Nitrogen (TN) and Total Phosphorous (TP) respectively. Further analysis[7] provided insights to the treatment of aquaculture wastewater through microalgal biomass, extent of lipid accumulation and also the optimal day for harvest of microalgae. Moreover, the higher composition of mono-unsaturated and saturated fatty acids highlights the scope for biodiesel.

Figure 2: Light Micrographic Images of Diatoms Present in the Culture Consortium



[6]Benthic diatoms are the dominating group of benthic algae, and therefore play an important role as primary producers, especially in running water.

[7]Flow cytometric analysis of microalgal cells depicted the real-time accumulation of neutral lipids in-vivo during different phases of cell growth. Fatty acid profiling through GC-MS showed higher percentages of saturated and monounsaturated fatty acids of C16 and C18 carbon chains.

Conclusion

The removal of nutrients such as TN (~89 per cent) and TP (~90 per cent) and higher lipid content in algae, highlights the bioremediation potential with biofuel prospects of the microalgal consortia grown in aquaculture wastewater. India has the distinction of having higher aquaculture production next to China, which results in the humongous generation of wastewater and decentralized diatom based microalgae treatment system will help in treating wastewater as well as aid in ensuring energy security through biofuel.

References

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