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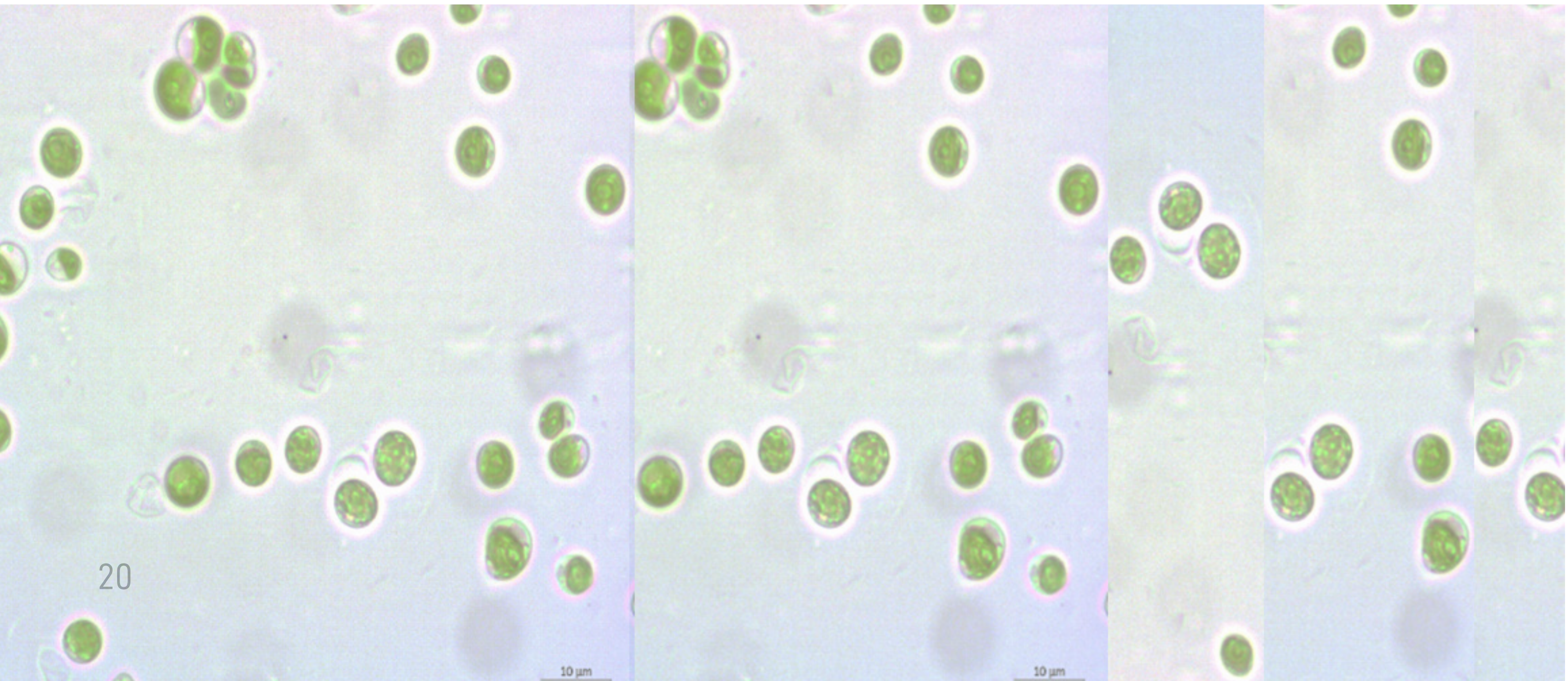
Microalgae: A Promising Bioresource for a Sustainable Future

Microalgae are highly diverse unicellular photosynthetic organisms found in aquatic environments. Microalgae produce oxygen during their proliferation, contributing to nearly 50% of the total oxygen production in the world. Concurrently, microalgae consume carbon dioxide in the atmosphere, thereby serving as carbon sinks to alleviate the effects of global warming. In comparison to terrestrial plants, microalgae exhibit rapid growth rates, higher photosynthetic efficiency, shorter harvesting time and higher biomass productivities. Moreover, they do not require arable land or potable water to facilitate their growth, hence becoming a more sustainable feedstock as compared to conventional crops. Altogether, microalgae have been identified as a bioresource with great industrial potential due to their ability to accumulate commercially valuable metabolites that can be extracted and subsequently processed into diverse bioproducts such as biofuels, pharmaceuticals/nutraceuticals, biofertilizer and animal feed.



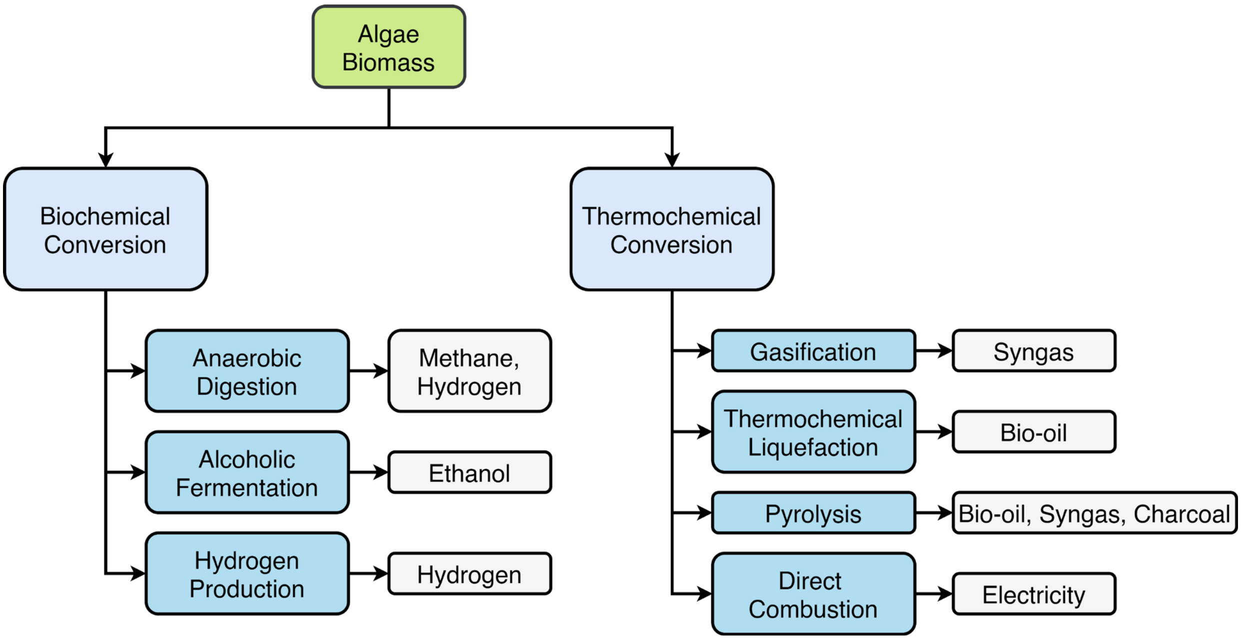


Figure 1: Biofuel production from microalgae [1]

Microalgae can be converted to biofuels via a variety of processes, as illustrated in Figure 1. Some microalgal species are capable of accumulating lipids or carbohydrates up to 60-70% of their dry cell weight, which can be used to produce biodiesel or bioethanol via transesterification or fermentation respectively. Various microalgae-based biofuels can also be produced via anaerobic digestion or thermochemical conversions such as pyrolysis, hydrothermal liquefaction and gasification. The most suitable process for biofuel production should be selected based on the biochemical composition of microalgae as well as comprehensive techno-economic and life cycle analyses.

Microalgae can also synthesize compounds with nutritional value, including carotenoids, proteins and vitamins. Compared to biofuels, bioactive compounds synthesized by microalgae secure a significantly higher market value. Thus, the use of microalgal biomass for pharmaceutical or nutraceutical applications is a far more lucrative and economically feasible option for biomass valorization compared to biofuels and bioenergy production. Sri Lanka, being an island surrounded by the ocean and comprising of numerous inland water resources, is undoubtedly teeming with diverse microalgae species. Despite the multitude of potential applications, the valorization of microalgae biomass is not well established in Sri Lanka. Considering the lucrative nature of microalgal bioproducts, the exploitation of this valuable bioresource would lead to the development of local bio-based industries in the country.

At the Department of Chemical and Process Engineering (DCPE), University of Moratuwa, the Microalgae Research Group is working with dedication to make this concept a reality. As an initial step, different water bodies in Sri Lanka have been sampled and numerous microalgal strains have been isolated. Thus, the department hosts a vast culture collection of microalgae under controlled conditions. Following isolation, microalgal strains are screened for their capability to accumulate target metabolites, and most promising strains are identified using gene sequencing. Starter cultures of these strains are cultivated in flasks, and further scaled up in lab-scale photobioreactors (Figure 2). Experiments are carried out in photobioreactors to identify the optimum culture conditions for their growth and accumulation of target metabolites. Mathematical and neuron modeling techniques are often employed for this purpose as they can

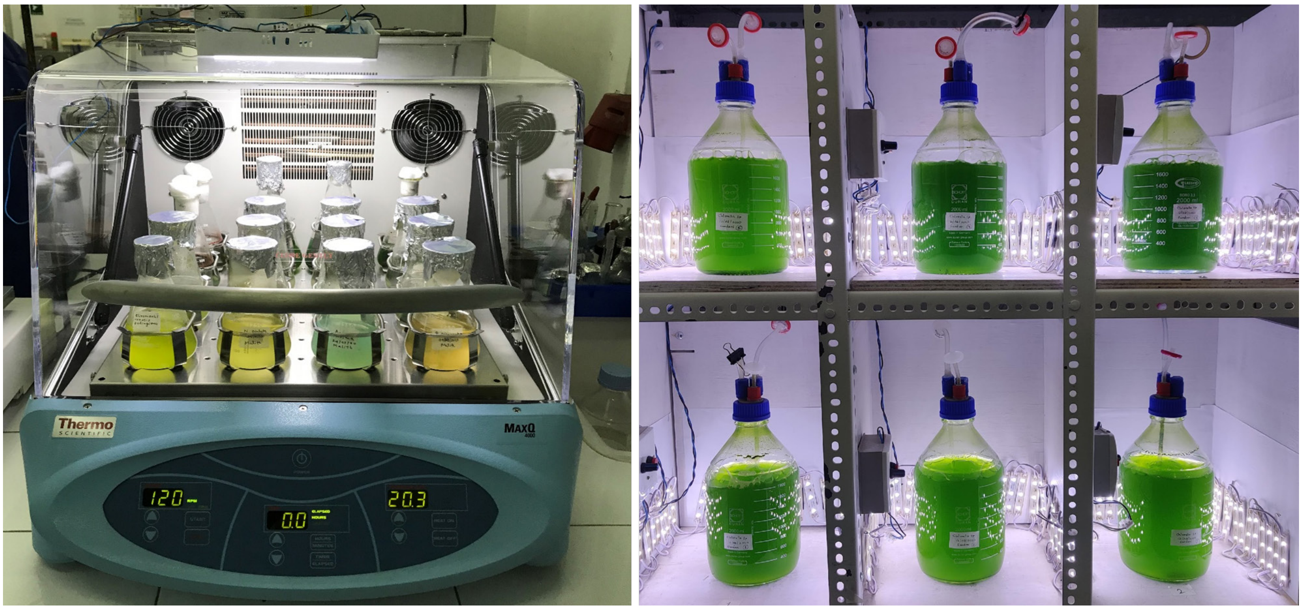


Figure 2: Microalgae cultures maintained in incubators (left) and cultivated in lab-scale photobioreactors (right) at the Department of Chemical and Process Engineering, University of Moratuwa

be used to identify the synergistic effects of different culture parameters [2]. In addition, the research group conducts experiments on process development for the extraction and purification of high-value compounds from microalgae for nutraceutical and pharmaceutical applications.

Developing sustainable microalgae-based biorefineries is another line of research undertaken by the group. This is to be achieved through the integration of target metabolite production and microalgae-based bioremediation. Microalgae have higher photosynthetic efficiencies than terrestrial plants. This enables them to fix carbon dioxide from flue gas streams that contain CO_2 concentrations far exceeding the atmospheric levels. The production of 1 kg of microalgal biomass can fix approximately 1.83 kg of carbon dioxide, and hence this can contribute significantly to alleviating the carbon footprint of industrial manufacturing processes. The ability of microalgae to assimilate nutrients and other constituents present in effluents can also be employed in the bioremediation of wastewater. It has also been reported that microalgae could successfully remove heavy metals, dyes, and other toxic compounds from wastewater through adsorption and biodegradation.

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Such integrated microalgae-based bioremediation processes also serve the dual purpose of enhancing the sustainability and economics of microalgal biomass production via waste resource recovery. This is a new paradigm in global research on microalgae, which lies within the framework of a circular bioeconomy. Recently, a study conducted at DCPE followed this concept to successfully inte-

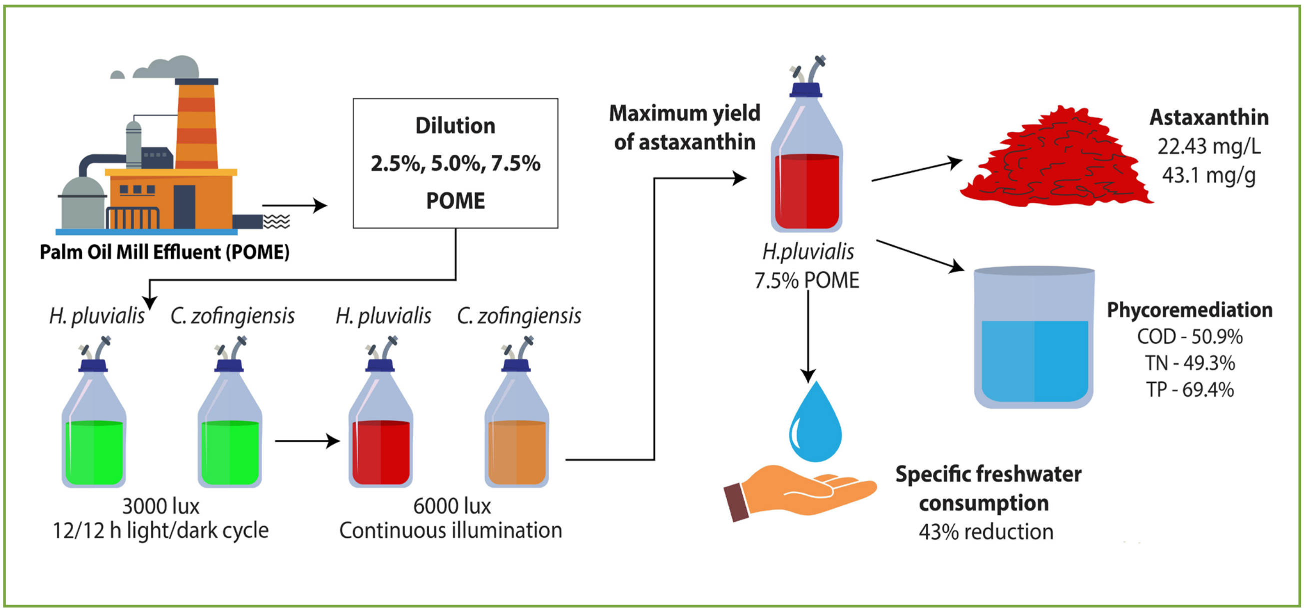

Figure 3: Integrated bioprocess for microalgae-based treatment of palm oil mill effluent (POME) and production of astaxanthin

grate the treatment of palm oil mill effluent (POME) and production of the high-value compound astaxanthin [3], as illustrated in Figure 3. Characterization of POME from an industrial facility revealed high concentrations of total nitrogen (TN), total phosphorous (TP) and low concentrations of heavy metals, indicating its suitability as an alternate growth media for microalgal astaxanthin production. High yields of astaxanthin were achieved while successfully reducing the specific freshwater consumption for astaxanthin production by 43%. The heavy metal content in biomass was within the permissible limits for food/feed products. Furthermore, a moderate performance in bioremediation was achieved, with removal of 50.9% chemical oxygen demand (COD), 49.3% TN and 69.4% TP.

From the research conducted thus far, it is evident that the microalgae is a valuable bioresource with potential applications in biofuels, nutraceuticals/pharmaceuticals, biofertilizer, food/feed industries and bioremediation. The Microalgae Research Group of DCPE conducts research in the field of microalgal bioprocess development with the ultimate goal of initiating sustainable microalgae-based industries in Sri Lanka.

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