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Autotrophic and heterotrophic culture of Nordic microalgae in wastewater for lipid production

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Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av filosofie doktorexamen framläggs till offentligt försvar i KB.E3.01 (Lilla Hörsalen), KBC huset, Måndag den 15 juni, kl. 10:00.

Avhandlingen kommer att försvaras på engelska.

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Abstract

It is well established that society's main means for producing energy, the combustion of fossil fuels, is unsustainable and contributes to global warming. Microalgae have high potential for the production of biodiesel and energy source that can at least partially replace fossil fuels. In addition, microalgae are a valuable resource for cleaning up the wastewater that developed societies produce on a daily basis. The research presented in this thesis covers how various growth conditions affect the production of lipids – potential energy source – in Nordic microalgae species, and how these species can benefit municipal wastewater treatment.

The research presented in Paper 1 demonstrated that the combination of Fourier-Transform IR (FTIR) and Multivariate Curve Resolution-Alternating Least Squares (MCR-ALS) is a powerful tool for monitoring changes in the biochemical composition (lipids, carbohydrates and proteins) of microalgae grown under different conditions. Experiments showed that *Chlorella sp.* isolated from Umeå was able to grow under heterotrophic conditions using glycerol as a carbon source and, more importantly, demonstrated high lipid content. The substantial accumulation of lipids observed in *Chlorella sp.* corresponded to a decrease in carbohydrate content. Paper 2 covered the key metabolites associated with the observed high lipid content under heterotrophic conditions. The low carbohydrate content observed under these growth conditions may be linked to low levels of the metabolites involved in gluconeogenesis. Conversely, the increase in lipid content may be associated with an increase in fatty acid metabolites and/or certain amino acids. The research presented in Paper 3 showed that microalgae grown under high light intensity ($300 \mu\text{E m}^{-2} \text{s}^{-1}$) have higher lipid contents than microalgae grown under low light intensities (50 and $100 \mu\text{E m}^{-2} \text{s}^{-1}$). The increase in lipid content under high light intensity conditions corresponded with a decrease in protein content. The research described in paper 4 demonstrated that among various Nordic strains, *Desmodesmus sp.* is the best candidate for biomass and lipid production under heterotrophic conditions with glycerol as the carbon source. Furthermore, the research covered in Papers 1, 3 and 4 demonstrated that the increase in lipid content under certain growth conditions corresponded to better biodiesel quality based on fatty acid composition. The experiments described in Papers 1,3 and 4 also showed that microalgae were able to remove most of nitrogen and phosphorus in wastewater, and thus, could be beneficial to municipal wastewater treatment plants.

In summary, we showed that coupling FTIR to MCR-ALS is useful for evaluating changes in the biochemical composition of microalgae. Nordic microalgae were able to produce high amounts of lipids, which showed a favorable fatty acid profile in terms of biodiesel quality, under certain growth conditions. Subsequent analyses provided insight into which metabolites were responsible for the observed changes in lipid accumulation. We also showed that Nordic microalgae can contribute to wastewater treatment.

Keywords

Biodiesel, Algae, *Chlorella*, FTIR, Heterotrophy, Wastewater, Light intensity, Metabolites, Lipids, Carbohydrates

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