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The impact of nitrogen starvation on the dynamics of triacylglycerol accumulation in nine microalgae strains

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HIGHLIGHTS

- The dynamics of triacylglycerol accumulation in nine microalgal strains were compared.
- When exposed to nitrogen starvation, four species accumulated over 35% (w/w) TAG.
- Simultaneous TAG accumulation and sustained biomass productivity was achieved.
- Very high volumetric productivities were achieved (over 300 mg TAG l^{-1} day^{-1}).
- *Scenedesmus obliquus* and *Chlorella zofingiensis* are most promising for TAG production.

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ABSTRACT

Microalgae-derived lipids are an alternative to vegetable and fossil oils, but lipid content and quality vary among microalgae strains. Selection of a suitable strain for lipid production is therefore of paramount importance. Based on published results for 96 species, nine strains were selected to study their biomass, total fatty acid, and triacylglycerol (TAG) production under nitrogen-sufficient and deficient cultivation conditions. Under nitrogen-deficient conditions, *Chlorella vulgaris, Chlorella zofingiensis, Neochloris oleoabundans*, and *Scenedesmus obliquus*, accumulated more than 35% of their dry weight as TAGs. Palmitic and oleic acid were the major fatty acids produced. The main difference between these strains was the amount of biomass that was produced (3.0–7.8-fold increase in dry weight) and the duration that the biomass productivity was retained (2–7 days) after nitrogen depletion. *S. obliquus* (UTEX 393) and *C. zofingiensis* (UTEX B32) showed the highest average TAG productivity (322 and 243 mg l^{-1} day^{-1}).

1. Introduction

Microalgae-derived lipids are considered as an alternative to lipids derived from terrestrial plants because of their much higher areal productivity (Chisti, 2007). Microalgae can be cultivated on non-arable land and, when cultivated in closed photobioreactors, require less fresh water than terrestrial plants. Furthermore, production is not seasonally limited and microalgae can be harvested daily (Gouveia and Oliveira, 2008). In addition to their use in biofuels, microalgal lipids could also be used as feedstock for food (bulk edible oils and/or nutraceuticals), fish feed, and chemicals (Wijffels et al., 2010).

Many lipid classes are produced by microalgae, but triacylglycerols (TAGs) are considered the preferred lipid class for most applications. Bulk edible oils are composed of TAGs and TAGs are also preferred for biodiesel production, because of their high content (%w/w) of fatty acids (glycerol backbone with three fatty acids) and the absence of other chemical constituents besides glycerol, in contrast to, for example, phospholipids or glycolipids. Many microalgal strains have the ability to accumulate large quantities of lipids in the form of TAGs under environmental stress conditions such as nitrogen starvation (Hu et al., 2008). TAGs serve as energy and carbon storage compounds and as an electron sink in situations where the electron supply provided by photosynthesis exceeds the requirements for growth (Hu et al., 2008).

Large scale production of microalgae-derived lipids is currently uneconomical as costs exceed those for the production of vegetable oils (Ratledge and Cohen, 2008). However, the costs could be reduced several fold by improving process design and operation, for example by improving irradiation conditions, photosynthetic efficiency, and reducing the costs for nutrient usage (Norsker et al., 2011; Wijffels et al., 2010). Other important factors are lipid content, productivity, and lipid composition of the microalgal strains (Griffiths and Harrison, 2009). To develop a competitive

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