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Metabolic profiles of *Nannochloropsis oceanica* IMET1 under nitrogen-deficiency stress

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HIGHLIGHTS

- ▶ The lipid, fatty acid and metabolite profiles of *Nannochloropsis* were studied.
- ▶ The accumulated neutral lipids had nearly consistent fatty acid compositions.
- ▶ The polar lipids were partially consumed, which changed the fatty acid composition.
- ▶ The concentration of cellular osmolytes varied with the nitrogen concentration.

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ABSTRACT

To understand the mechanism of lipid accumulation and the corresponding metabolic changes of the microalga *Nannochloropsis oceanica* IMET1, the lipid content, fatty acid composition and metabolic profile were investigated via batch culture under nutrient deficiency and chemostatic culture under nitrate limitation. The results indicated that the triacylglycerol-neutral lipids were significantly accumulated through an acyl-CoA dependent pathway, while the polar lipids were partially converted to triacylglycerol through an acyl-CoA independent pathway. The fatty acid compositions of the polar lipids changed concurrently with the length of time of the nutrient deficiency, while the fatty acid compositions of the neutral lipids remained nearly consistent. The concentrations of several major osmolytes were significantly changed under chemostatic conditions with different nitrogen concentrations, which reflect the membrane property changes caused by the alteration of the polar lipid composition.

1. Introduction

Biodiesel from microalgae as an alternative fuel has attracted increasing attention worldwide in the past several years, but the metabolic engineering of microalgae, which is vital for reducing the production cost, is hampered by the lack of understanding of the metabolism and an effective regulation mechanism for cellular lipid accumulation, as well as how the metabolism is affected by environmental factors in microalgae (Lü et al., 2011; Hu et al., 2008). The eukaryotic marine microalga *Nannochloropsis* has been studied as a potentially powerful candidate for biodiesel production. Rodolfi et al. (2009) reported that three *Nannochloropsis* strains have a lipid content of 30% or higher and lipid productivity ranging from 55 to 61 mg L^{-1} day^{-1}, making them the best lipid producers among 30 marine and freshwater microalgae in terms of both lipid content and lipid productivity. *Nannochloropsis oceanica* IMET1 is commonly cultivated in fish hatcheries as feed for rotifers and to create a “green-water effect” in fish larvae tanks (Lubzens et al., 1995). Due to its high content of eicosapentaenoic acid (EPA, C20:5), a high-value omega-3 polyunsaturated fatty acid (PUFA), *Nannochloropsis* has been proposed as an alternative source for commercial EPA production (Sukenik, 1991). At present, it has been successfully grown in indoor and outdoor systems for biodiesel or biomass production (Moazami et al., 2012; Quinn et al., 2012; Rodolfi et al., 2009). However, oil accumulation in the algal cells, commonly obtained via nitrogen-deficiency, was

Abbreviations: TAG, triacylglycerol; EPA, eicosapentaenoic acid; FA, fatty acid; NL, neutral lipid; PL, polar lipid; GL, glycolipid; PUFA, poly unsaturated fatty acid; DHA, docosahexaenoic acid; GC–MS, gas chromatography–mass spectrometry; DSS, 4,4-dimethyl-4-silapentane-ı-sulfonic acid; LN, low nitrogen; MN, medium nitrogen; HN, high nitrogen; FAME, fatty acid methyl ester; PB, phosphate buffer; DCW, dry cell weight; DAGAT, diacylglycerol acyltransferase; PDAT, phospholipid:diacylglycerol acyltransferase; TMA, trimethylamine; DMA, dimethylamine; GABA, γ-aminobutyrate; SFA, saturated fatty acid; USFA, unsaturated fatty acid.

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