A metabolomic approach to investigate effects of ocean acidification on a polar microalga Chlorella sp.

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\textbf{A B S T R A C T}

Ocean acidification, due to increased levels of anthropogenic carbon dioxide, is known to affect the physiology and growth of marine phytoplankton, especially in polar regions. However, the effect of acidification or carbonation on cellular metabolism in polar marine phytoplankton still remains an open question. There is some evidence that small chlorophytes may benefit more than other taxa of phytoplankton. To understand further how green polar picophytoplankton could acclimate to high oceanic CO\textsubscript{2}, studies were conducted on an Antarctic Chlorella sp. Chlorella sp. maintained its growth rate (∼0.145 fg cell\textsuperscript{-1}) and carotenoid (0.06 fg cell\textsuperscript{-1}) contents under high CO\textsubscript{2}, while maximum rates of electron transport decreased and non-photochemical quenching increased under elevated CO\textsubscript{2}. GCMS-based metabolomic analysis reveal that this polar Chlorella strain modulated the levels of metabolites associated with energy, amino acid, fatty acid and carbohydrate production, which could favour its survival in an increasingly acidified ocean.

1. Introduction

Atmospheric carbon dioxide (CO\textsubscript{2}) levels are projected to increase to 1000 ppm from the present day 410 ppm by the end of the century unless significant mitigation steps are taken (IPCC, 2014). Since the year 1800, oceans have absorbed 26 % of annual anthropogenic CO\textsubscript{2} (Sabine et al., 2004). CO\textsubscript{2} dissolves into seawater and is then converted to bicarbonate (HCO\textsubscript{3}⁻) and carbonate (CO\textsubscript{3}²⁻) ions as well as hydrogen ions (H\textsuperscript{+}), the latter contributing to acidification of the oceans, with the prediction that ocean pH will drop by approximately another 0.3–0.32 units by the year 2100 (IPCC, 2014). Covering 20 % of the global oceans (Deppeler et al., 2017), the polar Southern Ocean (SO) is the largest carbon sink of all global oceans, taking up 43 % of the CO\textsubscript{2} produced by human activities (Frölicher et al., 2015). By the end of the century, carbon uptake of the SO is expected to increase by a further 20 % (Hauck and Völker, 2015), with biological uptake predicted to double (Hauck and Völker, 2015). Rapid changes of oceanic carbon chemistry arising from ocean acidification (OA) are likely to affect polar marine life especially the photosynthetic primary producers.

Marine phytoplankton are vital in the ocean ecosystem, contributing nearly half of the world’s primary productivity (Field et al., 1998) and serve as the base of most marine food webs. Marine phytoplankton play a major role in the biological carbon pump through carbon assimilation, drawing down CO\textsubscript{2} into the deep ocean (Siegel et al., 2014) and by releasing organic matter for bacterial respiration (Arnott et al., 2011). CO\textsubscript{2} and bicarbonate are the substrates marine phytoplankton use to incorporate inorganic carbon into cellular metabolites via photosynthesis (Cassar et al., 2004), hence any shifts in oceanic carbonate chemistry could likely change carbon assimilation and its distribution among metabolites. This in turn affects the macromolecular composition of marine phytoplankton. A number of studies have suggested that the cellular content and composition of polyunsaturated fatty acids (Fiorini et al., 2010; Torstensson et al., 2013) and essential amino acids and carbohydrates (Wynn-Edwards et al., 2013) of Southern Ocean phytoplankton can be altered by OA. Changes in intracellular metabolites of phytoplankton were also shown to affect higher trophic level organisms that are feeding on them (Rossoll et al., 2012; Cripps et al., 2016). Elevated CO\textsubscript{2} has also been found to promote extracellular organic carbon release in phytoplankton (Torstensson et al., 2013; Song et al., 2014), changing the dynamics of the biological carbon pump and the remineralization of organic carbon.

Picophytoplankton are phytoplankton with effective diameters less than 5 μm (Barber, 2007). In contrast to the oceans in lower latitudes, eukaryotic chlorophytes have been reported to be the dominant