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The effect of short-term preharvest strategies on the carbon constituents of *Ulva ohnoi* M. Hiraoka et S. Shimada

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Abstract One of the main challenges of seaweed culture is to maximize the content of potentially valuable carbon constituents while maintaining high growth rates, thereby improving the value of culture process. This may be achieved by the manipulation of cultivation conditions, inducing a short-term imbalance in carbon metabolism. Here, we tested this concept in the chlorophyte seaweed *Ulva ohnoi* in a pilot land-based seaweed cultivation system. A first experiment used an abrupt 95 % reduction in water flow and therefore nutrient flux. The content of carbohydrate and lipid of *Ulva* increased by 16 and 14 % respectively within 2 days compared to the control, whereas growth rates decreased by <5 %. Consequently, the total yield of carbohydrate and lipid increased by ≥10 % compared to the control treatment. A second experiment used a reduction in the density of *Ulva* under culture by 50 % compared to a control thereby significantly increasing light and the proportional supply of nutrients. The growth rate of *Ulva* increased by 50 % within 4 days compared to the control, however, there was no change in biochemical composition. Photosynthetic efficiency (effective and maximum quantum yield of photosystem II using Chl *a* fluorescence) did not respond to the conditions in both experiments. We conclude that short-term treatments can contribute to a preharvest strategy to either improve the biochemical composition or the growth rate of cultivated algae that can in turn lead to an increased yield of targeted compounds.

Keywords *Ulva ohnoi* · Chlorophyta · Carbon composition · Seaweed cultivation · Preharvest strategy · Nutrients

Introduction

Seaweeds are an important food crop and an essential source of phycocolloids and gelling agents (FAO 2012). However, there is increasing interest in the application of seaweeds across a diversity of industries ranging from the expansion of the existing natural food market through to bioremediation, biopolymers, and bioenergy. Each of these applications requires an understanding of the biochemical composition of the seaweed biomass. Furthermore, the opportunity to manipulate the biochemical profile of the biomass offers the opportunity to maximize the application and value of seaweed (Angell et al. 2014; Neveux et al. 2014a; Paul et al. 2014). The potential to manipulate the carbon content of seaweeds through increasing the proportion of carbohydrates or lipids, the major carbon-rich compounds within seaweed, provides the opportunity to enhance the value of targeted species. This is true for biomass produced for low-value applications, such as bioenergy, where the yield of energy is proportional to the content of carbon (Neveux et al. 2014a), through to biomass produced for high-value carbohydrates with nutraceutical or biomedical applications (Lahaye and Robic 2007). Species of *Ulva* are key examples of the developing use of seaweeds as a biomass resource as they can be produced across a diversity of production systems both at sea and on land. They are highly adaptable across a broad range of environments and can be efficiently integrated for the bioremediation of nutrients from animal production systems (Bolton et al. 2009; Yokoyama and Ishihi 2010). Importantly, species of *Ulva* can be used for a diversity of applications ranging from the low-value production of bioenergy (Bruhn et al. 2011; Neveux et al. 2014a, b) and biochar (Bird et al. 2011), through to the production of

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