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Review

Carbon acquisition and accumulation in microalgae Chlamydomonas: Insights from "omics" approaches

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ABSTRACT

Understanding the processes and mechanisms of carbon acquisition and accumulation in microalgae is fundamental to enhance the cellular capabilities aimed to environmental and industrial applications. The "omics" approaches have greatly contributed to expanding the knowledge on these carbon-related cellular responses, reporting large data sets on microalgae transcriptome, proteome and metabolome. This review emphasizes the advances made on Chlamydomonas exploration; however, some knowledge acquired from studying this model organism, may be extrapolated to close algae species. The large data sets available for this organism revealed the identity of a vast range of genes and proteins which are integrating carbon-related mechanisms. Nevertheless, these data sets have also highlighted the need for integrative analysis in order to fully explore the information enclosed. Here, some of the main results from "omics" approaches which may contribute to the understanding of carbon acquisition and accumulation in Chlamydomonas were reviewed and possible applications were discussed.

Biological significance

A number of important publications in the field of "omics" technologies have been published reporting studies of the model green microalga *Chlamydomonas reinhardtii* and related to microalgal biomass production. However, there are only few attempts to integrate these data. Publications showing the results from "omics" approaches, such as transcriptome, metabolome and proteome, focused in the study of mechanisms of carbon acquisition and accumulation in microalgae were reviewed. This review contributes to highlight the knowledge recently generated on such "omics" studies and it discusses how these results may be important for the advance of applied sciences, such as microalgae biotechnology.

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Contents

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1. Introduction

The increase in the world's energy demand has revealed a weakness of the current energy system: the dependency of fossil fuels [1]. According to international reports, it is likely that fossil fuels will not be available in amounts large enough to supply the future energy demand [2]. In addition, environmental studies also indicate that burning of fossil fuels has strongly contributed to the accumulation of gases in the atmosphere, enhancing the so called "Greenhouse effect" likely causing impacts on the climate changes [3–5]. The observation and evaluation of these consequences have increased the world's interest towards the development of renewable and clean energy sources [6]. By developing new energy sources, it is expected that air contaminants can be reduced and air quality enhanced [1]. One of the strategies which may be applied to achieve this goal is the use of plant biomass for energy production. This strategy is not new and many countries, including Brazil and USA had improved their performance in biofuel production over the past 20 years [7,8]. However, this strategy uses fertile agricultural lands where crop plants are cultivated. This process may contribute to future destabilization of the food security plans, due to the imminent competition of agricultural lands for energy production instead of food production [9]. Moreover, only few studies evaluated the complete life-cycle assessment of these bioenergy systems and many questions still remain regarding the real advantages of these systems [6]. In an attempt to obtain biomass in a sustainable and renewable manner, without compromising land use, it has been proposed that algal biomass may be produced and serve as an alternative energy resource [10,11]. However, there are many improvements which have to be done in order to increase the participation of microalgae in the world's scenario of biomass production [12,13].

Among the advantages of the use of microalgae in biotechnology processes it is the fact that these organisms are found in different habitats worldwide and have been adapted to several environmental conditions. Some species were found to be able to survive in wide ranges of pH, temperature and nutrient deprivation [14,15]. Thereby, it is expected that each taxon has specific features that define their principal pathways in order to accumulate carbon. It has been noticed that oleaginous microalgae may accumulate triacylglycerol (TAG) as the main storage carbon in the form of neutral lipids under favorable conditions. Only a few microalgae species such as *Chorella* sp., *Nannochloris* sp., *Dunaliella* sp., *Neochloris oleoabundans* and *Parietochloris incise* are considered good lipid accumulators [16]. However, the organism *P. incise* produces triglycerides which are rich in polyunsaturated fatty acids [17], making it less suitable for biodiesel production. In contrast, the triglycerides produced by *N. oleoabundans* represents up to 80% of its total lipid content, and most of its fatty acids are saturated [18], representing an appropriate resource for biodiesel production. Furthermore, the genus Botryococcus (Chlorophyta, Trebouxiophyceae) stores photosynthetic carbon in the form of liquid hydrocarbons in which no chemical conversion is needed to provide biofuel crude [19]. This indicates that the size and the fatty acid saturation status can change significantly through microalgae species. Although Chlamydomonas is considered as non-oleaginous microalga, it has been demonstrated to accumulate TAG under adverse conditions [20].

Therefore, microalgae species, especially the photosynthetic ones, are very interesting model plants which may contribute to the development of integrated processes of biomass production and bioremediation [11] (Fig. 1). Nevertheless, the massive cultivation of algae cells for the biomass production through a sustainable process which requires low energy input and minimum water is still under development [13]. In fact, the energy spent in the management of microalgae cultures and

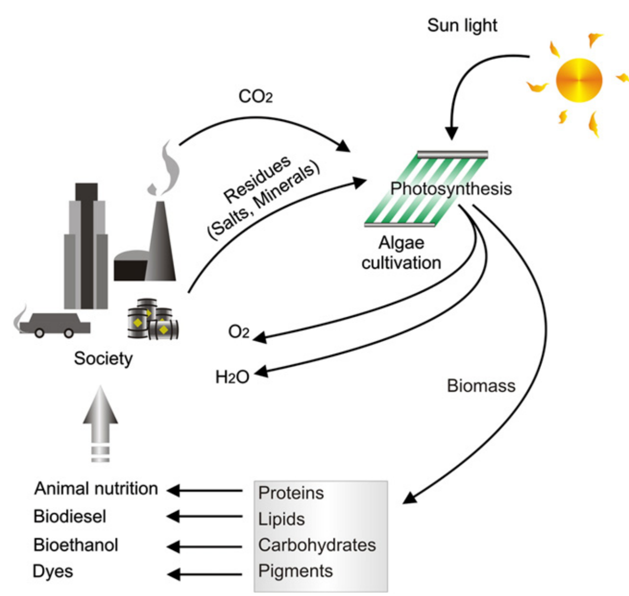

Fig. 1 – Biomass production in microalgae at the macro scale. Integration of biomass production and bioremediation by microalgae may be accomplished by recycling the residues from industries and society in the process of microalgae cultivation. Photosynthetic microalgae can produce biomass by capturing the carbon dioxide from the atmosphere and the minerals contained in different residues from industry, urban centers and waste water to finally generate biomass. Several bioproducts can be obtained from the biomass generated, including proteins, lipids and pigments. The inputs and outputs of interest in microalgae biomass production are highlighted.

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