Heat-resistant microalgae cultivation integrating into the sustainable built environment

Tzan-Chain, Lee

Anxi College of Tea Sciences, Fujian Agriculture and Forestry University, Fuzhou 350002, China

Abstract

Microalgae can transfer solar energy to chemical energy by photosynthesis, and supplied sustainable energy source for sustainable building. However, photosynthetic activity is highly sensitive and adversely affected by environmental changes. Therefore, how to overcome the decrease efficiency of photosynthesis is important.

A kind of edible and high-temperature resistant microalga, *Scenedesmus vacuolatus*, can culture at 32ºC and maintain a good efficiency of photosynthesis. Even if the microalgae treated by high temperature at 46.5ºC for 1 h, the heat-treated microalgae were found first to enter a degenerative stage with low chlorophyll contents almost right after the start of the cultivation, which was then followed by a revival. Stressed microalgae at the end of the degeneration stage were completely bleached and a dramatically changed profile of cellular proteins. All of the data indicate they were still alive but in a repair state than the control cells. Recovery microalgae would be re-greening, resuscitation of chloroplasts and recover photosynthesis completely.

This study offers a good microalgae model for sustainable building materials. For it's heat-resistant property, culture *Scenedesmus vacuolatus* can be apply for building in tropical zone and temperate zone, and reducing energy consumption for the thermal regulation in algae culture.

Introduction

Microalgae cultivation is a photosynthetically driven system applied to architectural integration. The first algae powered building in the world is BIQ house (Figure 1), which built in Hamburg, Germany [1]. Microalgae are energy source for biofuel production, which can transfer solar energy to chemical energy by photosynthesis. However, photosynthetic ability is very sensitivity to environmental changes, especially high temperature. Due to globe warming, heat stress is a general stress in natural environment and cultivation systems (e.g. photobioreactors, open ponds). For example, in Italy, an outdoor photobioreactor could be higher than 40ºC for several hours per day in the summer in Firenze [2]. There is also observed a temperature as high as 56ºC in the vertical alveolar panels [3]. Therefore, how to overcome the decrease efficiency of photosynthesis is important.

Figure 1.The first algae powered building in the world---BIQ house. Apart from generating energy using the algae biomass harvested from its own façade.

Results

Direct observations the culture solution

The colour variations of culture solution were difference between heat-resistant microalgae and heat-sensitive microalgae (e.g. *Chlamydomonas reinhardtii*). Although heat-resistant microalgae were bleached after light irradiation, they would regreening and continue growth under continuous light culture. However, heat-sensitive microalgae can't recover, and gradually decomposition (Figure 2).

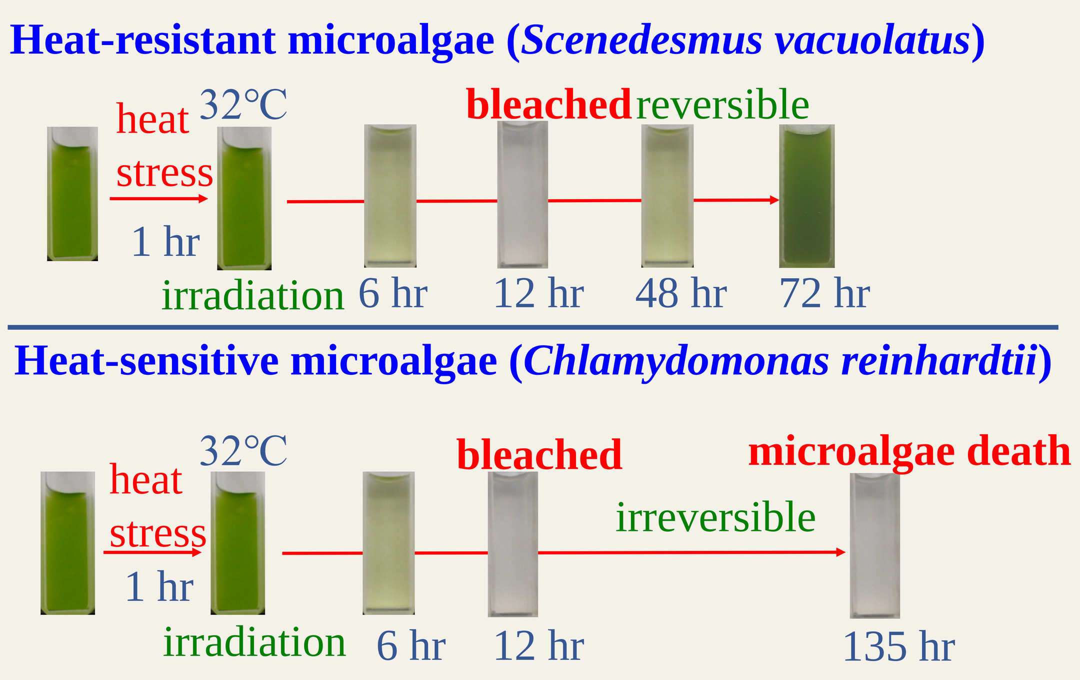

Figure 2. Direct observation of heat-resistant microalgae cells and heat-sensitive microalgae response to heat stress.

Observation of cells variation by light microscopic

Figure 3a showed synchronized small cells (control), each cell was around 5 μm in diameter. Figures 3b-d showed regreen process of bleached cells, regreen start from a site in a chloroplast (Figure 3c), chlorophyll separated gradually and cell growth (Figure 3d). This clearly indicates that bleached cells could transform into green cells and then became large cells.

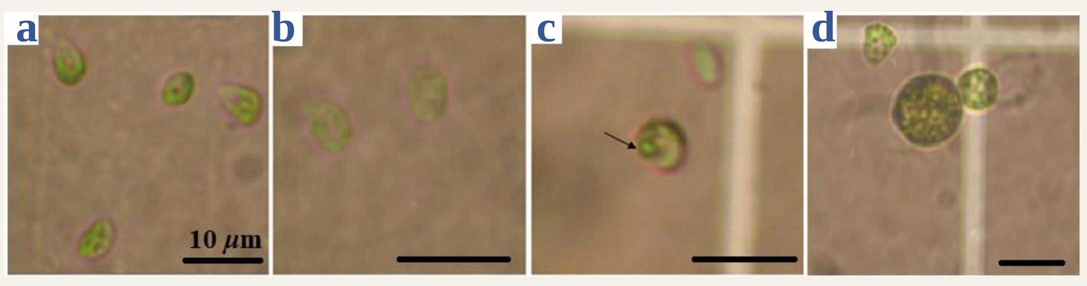

Figure 3. Direct observation of *S. vacuolatus* cells by light microscopic. (a) Synchronized small cells, (b) bleached cells (heat-treated cell and continuous cultured under illumination for 24 h), and (c) regreening cells. Regreening started from a single point in the cell (arrow head in c). (d) Cells fully recovered and growth, became large cells.

Flow cytometry analyzed the population responses

In order to test the recovery rate of green cells, the fluorescence intensity of 10 as the dividing line. As shown in figure 4, the frequency distribution of the fluorescence intensity of the cells that had been cultured for various times. There was no significant change in the chlorophyll content of *S. vacuolatus* cells right after the heat treatment (Figures 4a-b). The shift of the distribution toward left in later hours indicated cells were losing chlorophylls, and they subsequently became cells of very low fluorescence (Figures 4c-f). However, after about 24 h of cultivation, an increase in the high-fluorescent cell population was progressively significant (Figures 4f-i).

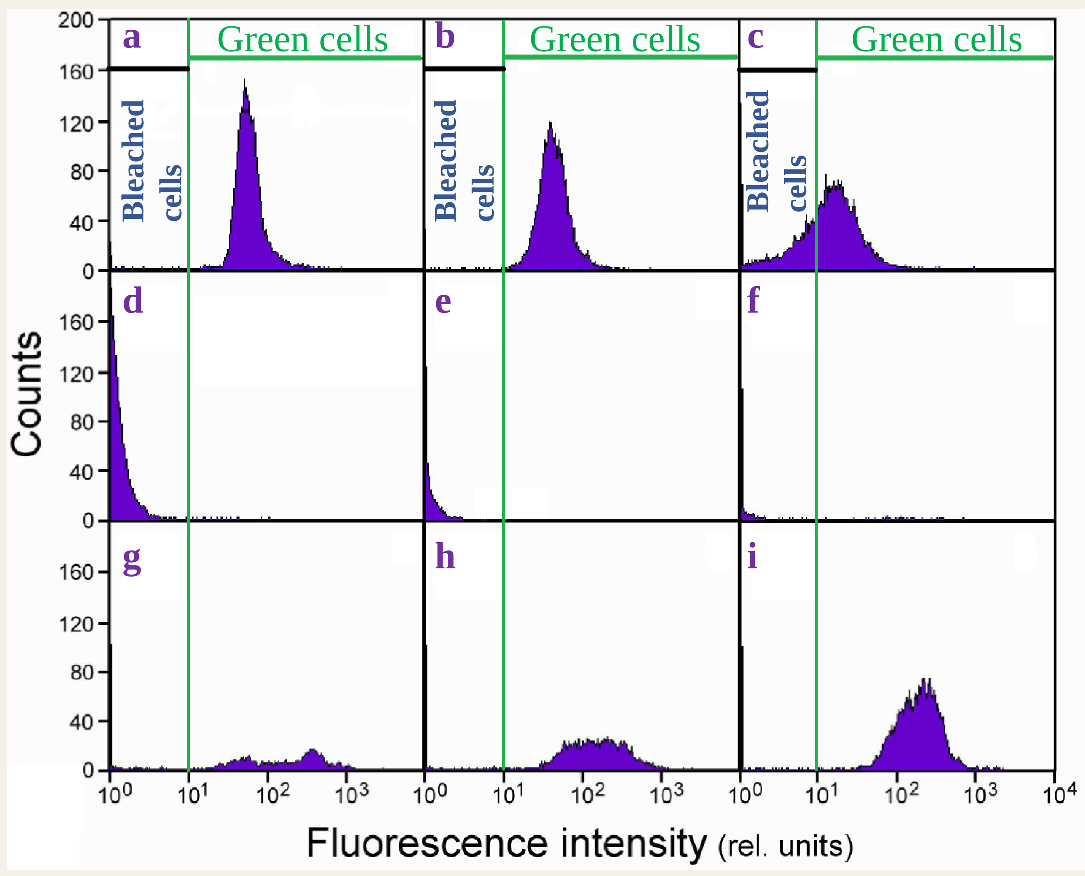

Figure 4. The frequency distribution histograms of *Scenedesmus* cells analyzed for chlorophyll *a* fluorescence. (a) Untreated synchronous small cells, and (b) treated by heat treatment (46.5 ºC, 1 h) and then cultured under illumination for (c) 6 h, (d) 12 h, (e) 24 h, (f) 48 h, (g) 72 h, (h) 85 h and (i) 105 h.

Photosynthetic activity assay

The variation of photosynthetic activity was accessed by measuring the maximal photosynthetic activity (Fv/Fm). The activity was completely inhibited after 20 min into the heat treatment (Figure 5a). Figure 5b shows that Fv/Fm signals of heat-treated cells became measurable starting around 24 h of continuous light cultivation, which coincided with the reincrease of the number of green cells (Figure 4e-f).

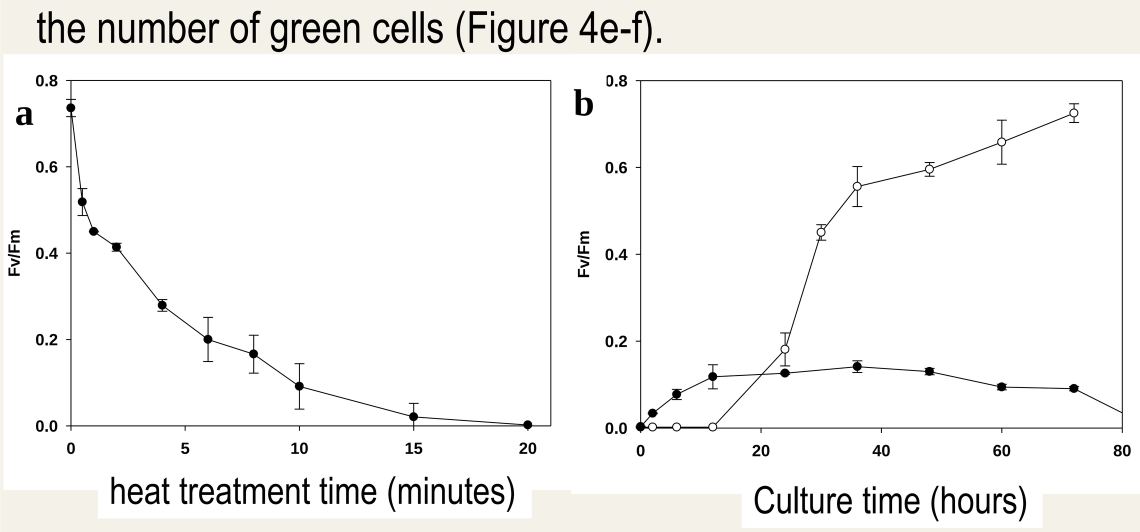

Figure 5. The variations of maximal photosynthetic activity (Fv/Fm) during and after the heat treatment. (a) The decay of the Fv/Fm value of cells during heat treatment (46.5 ºC). (b) The variations of the Fv/Fm values of heat-treated algae and then cultivation under continuous illumination.

Bleached cell still alive and repaired cell damage

In this study, heat treatment followed by cultivation under continuous illumination resulted in bleaching in the *S. vacuolatus* cells and the loss of chlorophyll and photosynthetic activity.

These bleached cells down-regulated many biochemical related proteins was published [5], such as ATP synthase α, β subunits, and glutamine synthetase, while up-regulated some stress response proteins, and protective proteins, like small heat shock proteins. The molecular evidence indicates that bleached cells can regulate their biochemical activity and activate certain protective mechanisms to repair the damage that is incurred by the heat stress and successfully resurrect (Figure 6).

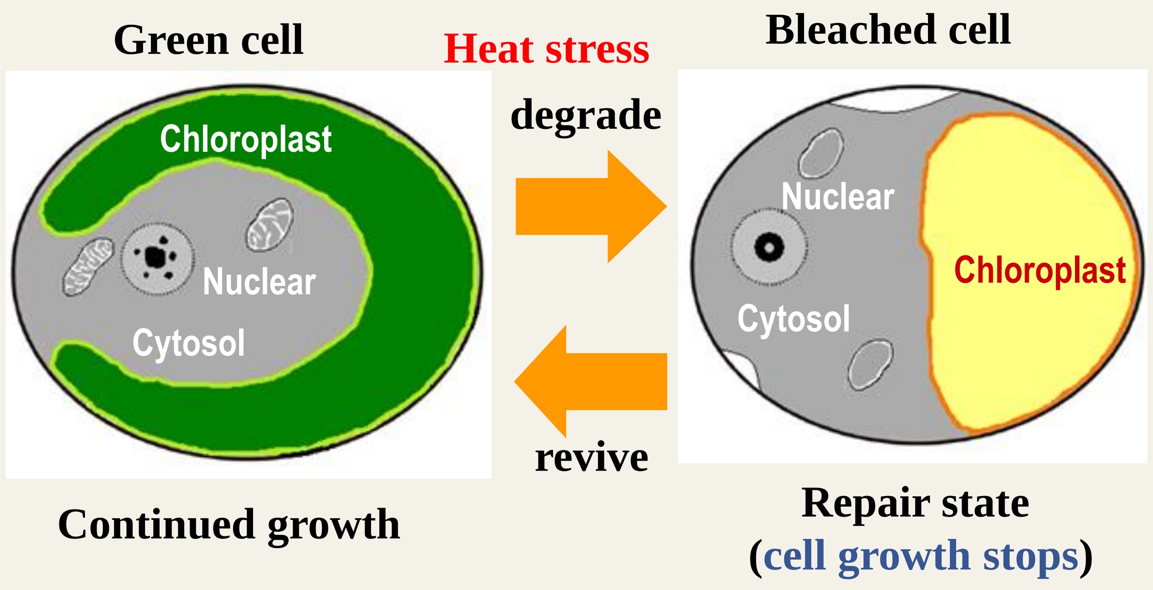

Figure 6. An outline of the results that combine the morphological and physiological studies from the relative reports, more detail information can be found in published papers [4-6].

Conclusion

This study offers a good microalgae model for sustainable building materials. Heat-resistant algae (e. g. *Scenedesmus vacuolatus*) can tolerant the high temperature, which recorded in photobioreactors, open ponds. For it's heat-resistant property, culture heat resistant algae can be apply for building in tropical zone and temperate zone, and reducing energy consumption for the thermal regulation in algae culture.

References

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Contact Information

Tzan-Chain, Lee

Expertise:
Phycology (algal research), Botany, biochemistry, plant physiology.

Tel: +86 18750677757
Email: crane173@yahoo.com.tw
https://axcxy.fafu.edu.cn/18/ff/c9498a268543/page.htm