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An exploration of the relationships between microalgae biomass growth and related environmental variables

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ABSTRACT

Algal community plays critical roles as the primary producer and as a major biotic component in the nutrient/energy cycle in aquatic ecosystems. The potential of fresh water algal biomass to mitigate global problems of food and energy and its significance as a carbon sink have been recognized. In this study, with a view to decreasing the cost of producing algal biomass for various purposes, the natural medium of unsupplemented freshwater was applied to mimic the real world to produce algal biomass. The relevant physicochemical variables in the improvised algal growth environment were analyzed and monitored, to investigate the algal growth mechanism. The simple regression analysis showed the applicability of the unsupplemented natural medium with sufficient natural nutrition for algal biomass production. The multiple linear analyses explained the complexity of the mimicked freshwater mixed–algal community in the laboratory. The laboratory results obtained in the present study also provide better insights that improve our understanding of the natural algal growth characteristics.

1. Introduction

Algae are the primary producers in aquatic ecosystems, and play a vital role in all the aquatic environments [1–3]. Through photosynthesis they fix light energy [4,5] and reduce simple inorganic molecules into complex organic molecules supporting the whole community of living organisms occupying higher trophic levels in the ecosystem. Besides producing biomass which meets the energy requirements of the natural ecosystem, algae extend a range of biosynthetic substances in ample amounts that can be exploited for biofuels and other important applications [6,7]. Algae are efficient carbon dioxide (CO_2) fixers [4,8,9] and thus they have much faster growth-rates than terrestrial crops [10–12]. Hence, in the present global crisis for resources, algae may become one of the most important innovative food and energy ‘crops’ on earth.

The conspicuous absence of reports in the literature describing the efficacy of unsupplemented natural water as a medium to produce algal biomass in controlled conditions is intriguing. In the present study, an attempt was made to understand algal growth characteristics in such conditions and to evaluate growth models. The microalgal biomass generated in unsupplemented natural water was statistically correlated with nutrients and growth parameters by multiple linear regression analysis to make a simultaneous consideration of all the factors and to evaluate the relative importance of each factor.

2. Materials and methods

The mixed culture of microalgae used in the present study was obtained from the Sustainable Resources and Sustainable Engineering research laboratory (SRSE Lab), the Department of Soil and Water Conservation, National Chung–Hsing University, Taichung, Taiwan. The natural freshwater used in the present study as the algal growth medium (feed) was collected from the Green River (24° 7′27.35″N; 120°40′22.79″E), at a location near Fu–Te Dao temple, Taichung, Taiwan. The collected river water was filtrated through a 0.45 μm filter paper. For the CO_2 source, this study not uses any artificial control or any extra CO_2 addition and used the open reactor to make the reactor gas exchangeable with atmosphere. This type of design could mimic the real condition in the natural ecosystem best. Three production units were used in this study: P1, P2, P3 for triplicate and the growth system was shown in Fig. 1. The detailed methodology of the study is illustrated in Fig. 2.

Initially, the mixed culture microalgae, comprising predominantly the species of the genera *Anabaena*, *Chlorella*, *Oedogonium* and *Oscillatoria* were grown in autotrophic conditions of algae/

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Fig. 1. Photo-bioreactor.

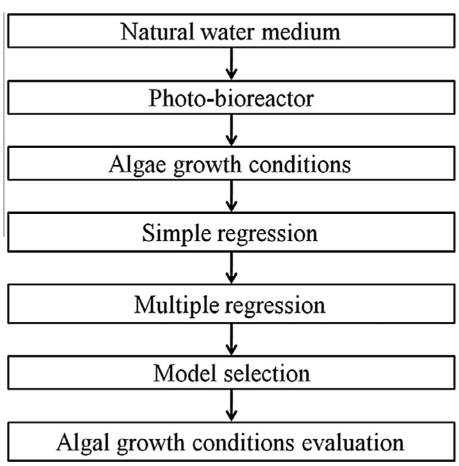

Fig. 2. Flowchart of methodology.

bacterial units with 10 days detention time. The batch-fed algal cultures of 4 l, in triplicate, were grown for 4.5 years, in continuously-stirred tank reactors (CSTR) under room temperature. All the reactors were continuously illuminated with the fluorescent lamps day and night for the photoautotrophic growth. The light intensity and temperature were monitored through the study and the average was 27.02 $\mu mol^{-1}\ m^{-2}$ and 28.38 °C.

All the indices including pH, alkalinity, dissolved oxygen (DO), chemical oxygen demand (COD), ammonia (NH_4^+–N), Kjeldahl (TKN), nitrate (NO_3–N), nitrite (NO_2–N), total nitrogen (TN), total phosphorous (TP) and algal biomass of total suspended solids (TSS), volatile suspended solids (VSS), fixed suspended solids (FSS), chlorophyll-a (Chl-a), chlorophyll-b (Chl-b) and chlorophyll-a + b (Chl-a + b) were continuously monitored throughout the study, following standard methods [13].

Table 1
Algae growth conditions.

Physico-chemical and biomass parameter	Feed		Reactor	
	Mean	Range	Mean	Range
Light intensity ($\mu mol^{-1}\ m^{-2}$)	–	–	27.02	35.33–32.65
Temperature (°C)	–	–	28.38	22.00–23.03
COD (mg/L)	5.54	1.69–14.04	11.52	4.66–23.49
TN (mg N/L)	7.06	4.06–15.06	2.22	0.50–7.63
TP (mg/L)	0.58	0.21–1.15	0.09	0.01–0.42
pH	7.15	6.45–8.05	10.13	9.24–10.75
DO (mg/L)	6.02	3.28–8.33	7.36	6.34–9.45
Alkalinity (mg $CaCO_3$/L)	7.15	6.45–8.05	46.39	27.27–74.67
NH_4^+–N (mg N/L)	1.32	0.00–5.61	0.59	0.00–2.32
NO_3^-–N (mg N/L)	3.00	0.00–8.87	0.38	0.00–2.16
NO_2^-–N (mg N/L)	1.35	0.00–6.51	0.08	0.00–0.52
Org–N (mg N/L)	1.14	0.00–5.73	0.93	0.06–5.73
TKN (mg N/L)	2.55	0.00–8.50	1.54	0.38–6.89
TSS (g/L)	–	–	0.14	0.09–0.26
FSS (g/L)	–	–	0.08	0.04–0.15
VSS (g/L)	–	–	0.06	0.03–0.11

Table 2
Simple linear regressions of algal biomass on physicochemical factors.

Independent Variables	Dependent Variables			
	TSS	TSS	VSS	VSS
	Feed	Reactor	Feed	Reactor
COD	×	✓	×	✓
TN	×	×	×	×
TP	×	×	×	×
pH	✓	×	✓	×
DO	✓	×	✓	×
Alkalinity	×	✓	×	×
NH_4^+–N	×	×	×	×
NO_3^-–N	×	×	×	×
NO_2^-–N	×	×	×	×
Org–N	×	×	×	×
TKN	×	×	×	×

Remark: ✓: statistically same under 5% significant level; ×: statistically different under 5% significant level.

This study chose the simple/multiple regressions with SAS software [14] to select the most crucial factors of growth condition to form a statistical modeling for the algal biomass production.

3. Results and discussion

3.1. Microalgal growth and culture conditions

The most important parameters regulating algal growth are nutrient quantity/quality, light, temperature and pH [15–18]. The microalgal growth conditions of this study are summarized in Table 1. The average biomass was 0.14 and 0.08 g/L by TSS and VSS, respectively. The study showed that the carbon, nitrogen and phosphorous (CNP) ratio, 9:27:1, of the supplied carbon–limited (unsupplemented) natural water medium could support microalgae growth, according to the Redfield ratio [19]. In the culture, the efficient microalgal utilization of macro nutrients of nitrogen and phosphorus led to effective removal of nitrogen and phosphorus up to 69% and 84% from the respective pools. In other words, the present system imitated natural microalgal growth and produced significant biomass.