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MODIFIED OPEN PLATE SYSTEM FOR OPEN DOOR PRODUCTION OF ALGAL BIOMASS

Mohamed M. El-Fouly, Fouad E. Abdalla and Abo El-Khair B. El-Sayed

Botany Department, NRC, Dokki-Cairo, Egypt

Abstract

This work was conducted using two different open plate systems, mainly used as inoculum unit, to study the effect of culture volume, growth surface and flow rate on growth of the alga *Scenedesmus sp.*

For inoculum preparation, laboratory growth was performed using N8 macronutrients solution with PAZ trace elements mixture. Out door production was heterotrophically achieved using a mixture of 0.3 $g.l^{-1}$ urea (46.5%), 0.05 $g.l^{-1}$ SoulPotas (mini.50.0%K_2O & 46.0% SO_3), 0.1$ml.l^{-1}$ phosphoric acid (85%) and 6mM acetic acid (5%) under continuous illumination.

The first unit, of 1000 L capacity, exposed area of 8.78m^2, pumping power of *2.0 hp* through out 45 mm polyethylene pipe system, 54-60$m^3.h^{-1}$ of follow rate and fueling valve of 63 mm was compared with the modified unit. The modification was operated based on increasing volume capacity to 2000 L, 19.0-36 $m^3.h^{-1}$ of flow rate with large exposed area of 13.73 m^2 and higher pumping power (*2.5 hp*) through 63 mm polyethylene pipe system. The out let was also modified using total width outlet instead of whole outlet of 63 mm diameter.

The modifications done increased growth of alga in terms of dry weight or total chlorophyll. The increment of growth, about 33.0% of dry weight and about 25.0% of total chlorophyll, recorded the variation of growth among two units. Growth characteristics represented variable results.

Introduction

Factors affecting the mass production of microalgae were early studied. Most advanced studies were concentrated to overcome production problems, which in turn minimized the production costs. Inoculum size was considered as one of the most limiting factors of cultivation technique and capacity. It was advised that 10% of inoculum is required at least at the beginning of cultivation, however it may also started by more than 30% for the production of non green pigments. In contrast, to avoid self-shading, a dilute cultures were employed, Boussiba and Vonshak (1991). The objective of the current work is to improve the volume capacity, pumping system and their effects on growth expressed as dry weight and total chlorophyll of the locally isolated alga *Scenedesmus sp.*

Materials and Methods

Scenedesmus sp. isolated from El-Rayan Valley, El-Fayoum Governorate, Egypt was used to study the effect of two-inoculum units on growth. For pre-cultivation, alga was incubated using El-Rayan drainage water after sterilization and enrichment by 10% of N8 macronutrients solution (Soeder *et al.*, 1967). When cells reached their maximum growth, cultures were centrifuged at 5000-rpm cooling centrifuge, washed two times by bidistilled water and re-centrifuged. Cells after then were incubated with NSI

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macronutrient solution with PAZ trace elements stock solution (Payer and Trultzsch 1972). Growth conditions were adjusted at 100 μ.*e* of continuous light intensity (Gossen, PANLUX electric, Germany), 25±1°C and aerated by compressed air. Acetate was added at a concentration of 6 mM (Kobayashi *et al.*, 1993, 1992 and 1991). Out door production was heterotrophically achieved using a mixture of 0.3 $g.l^{-1}$ urea (46.5%), 0.05 g. l^{-1} SoulPotas (mini.50.0%K_2O & 46.0% SO_3), 0.1ml.l^{-1} phosphoric acid (85%) and 6mM acetic acid (5%) under continuous illumination.

Measurements:

Dry weight:

Five ml of algae suspension were filtered through pre-weighted dried membrane filters (0.45μm, white grade). Filters were dried before filtration at 105°C for two hours, cooled over anhydrous calcium chloride and re-weighted. The biomass production is the result of variation of the biomass content in alga growth .

Pigments:

Chlorophyll of fresh cultures was extracted by DMSO (95%) according to Burnison (1980). The extract was measured at 666 nm according to Seely *et al.* (1972).

Growth parameters:

Growth as dry weight and total chlorophyll was evaluated by the calculated values of growth rate on the maximum ($\mu_{max.}$) and on the average($\mu_{avr.}$), doubling time(g), degree of multiplication (n) and percentage increase (%), Pirt (1973).

Growth development:

For outdoor cultivation and to compare the growth within two units, scaling up was started using 100ml glass tubes followed by 1, 2, and 5 L round flasks. An adequate volume of 5L cultures was transferred to Plexiglas of 200L. When growth reached the maximum, cultures were transferred to the original unit of 1000L (Fig. 1a). When growth reached the maximum, about 2/3 volume of the health culture (*ca* 650L) were transferred to the modified unit (Fig. 1b) and the sequential dilution was followed it. Dilution was done using tape water to 1000 and 2000 L for original and modified unit, respectively.

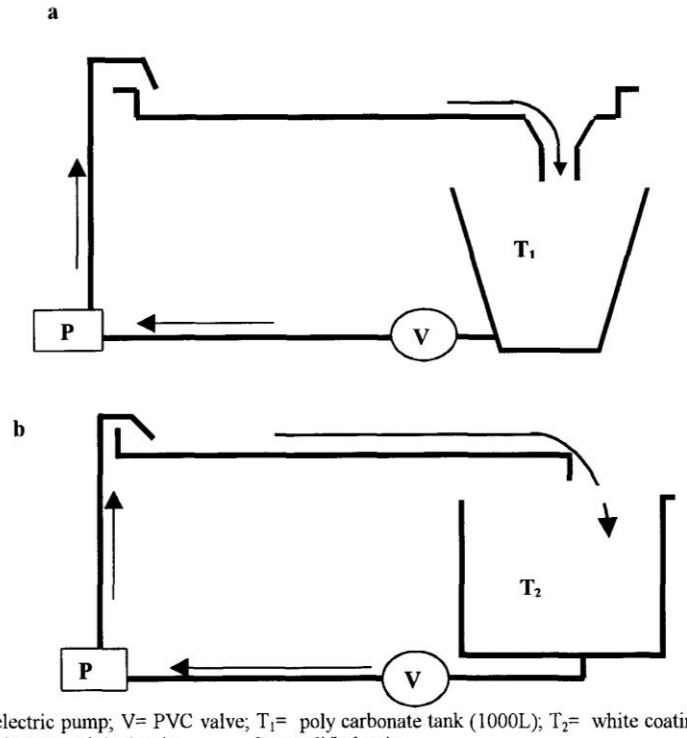
Growth units construction:

As listed in Table (1), the unit was modified to reach the volume capacity to 2000L with increasing the exposed area to 13.73m^2 instead of 8.78 m^2 of the original unit. To increase the photic layer, which considered as the actually growth area, the end less basin was operated to allow the high fueling potential. In addition, increasing the pumping power to 2.5*hp* with three outlet wholes.

Table 1. Technical data of original and modified unit

Unit	V (L)	Plat area (m^2)	Tank surface (m^2)	Out let (cm)	*Total exposed area (m^2)	Pump power (*hp*)	Pip system (mm)	Flow rate $m^3.h^{-1}$	Suspe-nsion height (cm)
Orig.	1000	7.42	1.36	0.63 diameter	8.78	2.0	45	60.0	5-10
Mod.	2000	10.56	2.05	70 x160	13.73	2.5	63	27.5	10-15

• Tank surface area (m^2) =Plate surface + Tank surface + Outlet surface



P= electric pump; V= PVC valve; T_1= poly carbonate tank (1000L); T_2= white coating steel tank (2000L); **a**= original unit **b**= modified unit

Fig.1: Schematic diagram of experimental growth unit

Results and discussion:

During outdoor cultivation, the original unit resulted maximum dry weight after 23 days of incubation (1.27 $g.l^{-1}$). By such time, the modified unit gave 1.76 $g.l^{-1}$ of dry weight. With respect to the dilution rate during the whole cultivation period, growth could minimize to less than 15 days, where cultures required 7 days to reach the net studied

volume; *i.e* 1000 and 2000 L of original and modified units; respectively. Concerning growth surface, it was calculated as 8.78 and 13.73 m^2 for both original and modified units; respectively resulted in 0.14 and 0.13$g.m^{-2}$ of the growth surface during the whole culture by the aforementioned respect. The growth enhancement not only referred to different exposed area, but also depending upon the thickness of photic layer as well as fueling potential.

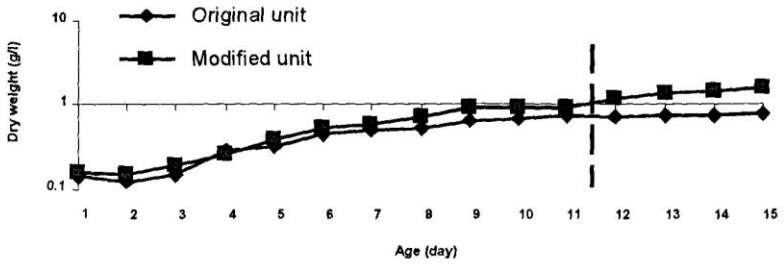


Fig.2 Growth measurements as dry weight ($g.l^{-1}$) of *Scenedesmus sp.* as affected by growth unit

It was early mentioned that increasing of growth surface, solar collectors extend the growth period while causes overheating in summer. Here, such problem could be avoided by maintaining the depth of algal broth with high fueling potential. Also, an increasing of atmospheric gaseous penetration could be consumed. Evidence showed that the most promising way to increase *Chlorella* yield in light was to supply the bright light to the individual cells in short flashes which are followed by longer periods of darkness. At such period other cells enter the intensity illuminated photic period. The most practical way to achieve this was judged by Davis and Milner (1953), to create turbulence. They showed that the yield of *Chlorella* could be increased at least 70% and perhaps even 300%, clearly depending on the population density.

Increasing of darken layer, collector tank, might be enhanced the growth of the studied alga. In addition, between 0.7 and 1.0 $g.l^{-1}$ of dried biomass were required for the next production processes on the large scale, thus scaling up could be done after 11 and 9 days for original and modified units; respectively. However, it was more useful to do such steps by lack time to get more concentrated inoculum.

Total chlorophyll

Chlorophyll accumulation rate was slightly contrasted with that found with dry weight. Among the two examined units, the differences might be attributed to the variation during the whole growth, and also, to the variation of the initial chlorophyll content at zero time (after 7 days of incubation). In addition, the later variation might be due to dilution rate.

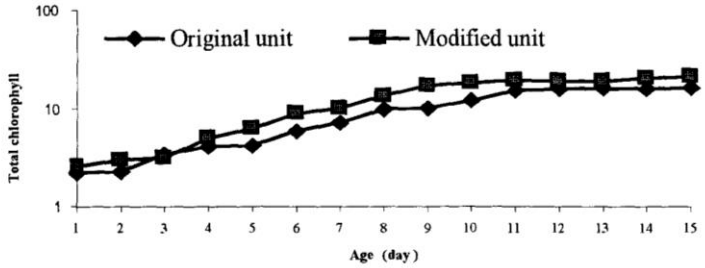


Fig.3 Growth measurements as total chlorophyll (mg.l^{-1}) of *Scenedesmus sp.* as affected by growth unit

Cells are stimulated to their highest capacity at the beginning of dark phase. If the alga can produce sufficient cell materials during this period, they are triggered by the beginning of the following light phase to release auto spores, Becker(1994).

As shown in Fig. (3), after 12 days of the actual growth or 19 days of whole cultivation it was also observed that increasing of nitrogen supplemented as urea; up to 0.3 g.l^{-1} could increase chlorophyll concentration. A high flow rate shearing forces may damage the algal cells, especially filamentous cyanobacteria, Becker, 1995. A high flow rate is necessary to prevent settling of the growing algae, increased gas exchange by CO_2 supplementation and eliminates the formed oxygen. However, such high flow rate shearing forces may damage the algal cells, especially filamentous cyanobacteria, Becker (1994).

Growth characteristics

As listed in Table 2, in term of dry weight; 0.17 and 0.27 of $\mu_{avr.}$ characterized growth for original and modified unit; respectively. The same pattern was observed with $\mu_{avr.}$ values indicated the stability of growth within two unites; however the high differences between the two determined parameters (μ_{max} and $\mu_{avr.}$) showed the variation in growth during the whole cultivation period. Growth increment was found to be closely associated with other parameters, where it raise both the degree of multiplication (n) and the percentage increase and vice versa. By these, cells reached their maximum percentage increase from 879% of original unite to 975 % of the modified.

Table. 2. Growth characteristics of *Scenedesmus sp.* as affected by growth type

Dry weight					Total chlorophyll				
$\mu_{max.}$	$\mu_{avr.}$	g	n	%	$\mu_{max.}$	$\mu_{avr.}$	g	n	%
0.42	0.17	4.98	3.13	879	0.42	0.14	4.95	1.70	742
0.61	0.27	4.04	3.28	975	0.46	0.15	4.56	1.83	829

$\mu_{max.}$ = maximum growth rate $\mu_{avr.}$ = relative growth rate g= doubling time
n = degree of multiplication % = percentage increase
As for total chlorophyll, such pattern was observed, but the growth was slightly differed.

Conclusion:

Growth of algae was found to be depended up on the net growth surface and the following dark period rather than the fueling or power potential. The long dark period which suggested by increasing of tank volume beside the low pumping rate might be increased the consumption efficiency of the accumulated carbohydrate to other cell component like protein and other constituents.

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أستخدام وحدة الزراعة المفتوحة المعدلة للإنتاج الكمى للطحلب بالجو الخارجى

محمد مصطفى الفولى ، فؤاد السيد عبدالله ، أبوالخير بدوى السيد

المركز القومى للبحوث – قسم النبات

تم تعديل وحدة الزراعة المسطحة الى حجم ٢٠٠٠ لتر وقد اشتمل التعديل زيادة مساحة السطح المعرض للضوء من ٨,٧٨ إلى ١٣,٧٣م^{٣} وزيادة قطر أنابيب السحب والضخ من ٥٠ إلى ٦٣ مم وزيادة قوة الدفع الكهربية من ٢,٠ إلى ٢,٥ حصان ميكانيكى مع خفض معدل التدفق من ٦٠إلى ٢٧,٥ م^{٣}/ساعة و استخدمت لزراعة الطحلب الأخضر من جنس سنيدزموس المعزول من مياه وادى الريان بمحافظة الفيوم لقياس درجة النمو ٠ ولتحضير البادئ من الطحلب المعزول تم استخدام مياه وادى الريان بعد التعقيم وإضافة ١٠% من بيئة N 8) كمصدر للعناصر الكبرى نقل الطحلب بعد ذلك إلى بيئة العناصر الكبرى (NSI) مع مخلوط (PAZ) للعناصر الصغرى حتى حجم ٥٠٠٠سم^{٣} ثم ٢٠٠لتر وبعدها نقلت المزارع إلى خارج المعمل بالوحدة الأصلية (٢٠٠٠لتر) والوحدة المعدلة (٢٠٠٠لتر) وكانت بيئة النمو مكونة من اليوريا (٠,٣جم/لتر) ومركب سولوبوتاس (٠,٠٥حم/لتر) وحمض الفوسفوريك التجارى (٠,١سم^{٣}/لتر) وحمض الخليك (٠,٦ ملليمول)٠

تم الحصول على وزن جاف ١,٢٧-١,٧٦جم/لتر بعد٢٣ يوم من بداية الزراعة للوحدتين على التوالى مما يمكن من خفض فترة التحضين للمزارع المفتوحة (٩-١١ يوم)٠ وبالنظر إلى اختلافات النمو المقدرة يمكن القول بأن الاختلاف فى النمو بين الوحدتين يعتمد على النسبة بين مساحة السطح المعرض للضوء وفترة الظلام التالية فى الخزان الذى يعد المرحلة البنائية للضخ