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Preliminary Economic Estimation for Microcystis Aeruginosa Cultivated in Two Closed Cultivation Systems.

Samar A El-Mekkawi[1]*, NN El-Ibiari[1], Ola A El-Ardy[1], Nabil M Abelmonem[2], Ahmed H. Elahwany[2]

[1]Chemical Engineering and Pilot Plant Department, National Research Centre, Dokki, Egypt.
[2]Chemical Engineering Department, Faculty of Engineering, Cairo University.

ABSTRACT

In recent years, cyanobacterial cultivation has paid much attention and investments. Since cyanobacteria can be used for biodiesel production. It also has abundant bio-refinery products. The cultivation technique using photobioreactor is mandatory to ensure production of specific products with high purity. In this research, the cultivation process requirements to cultivate *Microcystis aeruginosa* and an economic estimation of the designed system of cultivation are discussed in details. Comparing the economic benefit of cultivation in flat plate photobioreactor with that of cultivation in bubble column photobioreactor; the results revealed that in spite of the validity of bubble column system on bench scale this system is not applicable on scaling up cultivation. Scaling up Flat Plate photobioreactor recorded positive return on investment (ROI).

Keywords: Economic estimation; *Microcystis aeruginosa;* Photobioreactor; Bubble column; Flat plat; Bio-refinery

Corresponding author

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INTRODUCTION

Algae belong to plant kingdom. They are divided into macroalgae as seaweed of size over 50 µm that are classified as Eukaryotic, and microalgae that are divided into Prokaryotic blue-green algae (cyanobacteria) and Eukaryotic algae of size up to 50 µm. [1, 2]. Nowadays Cyanobacterial biodiesel is an attractive alternative source of energy [3]. No doubts renewable fuels are necessary for environmental and economic sustainability. Thus the proper selection of algal strain is considered the key of successful and economic biotechnology process. Moreover bio-refineries and valuable co-products enhance this process [4].

Algal cells can be used in several bio-refinery industries since they consist of lipids, proteins, carbohydrates, vitamins and pigments. Lipids are commonly classified as polar and non-polar lipids. Non-polar lipids include triglycerides (TAG) that are used in biodiesel and/or bio-jet production. While free fatty acids (FFA) are not desirable in biodiesel or bio-jet [5, 6]. The carbohydrates are valuable in bio-alcohol production via fermentation. Fermentation process simply is based on converting starch of the biomass into alcohol using enzymes or using mechanical means as ultrasonic or mechanical shear. Research recorded significant amounts of sugar in microalgae that can be utilized as feed stock for bio-alcohol production [7-9]. Microalgae accommodate cellulose which can be fermented to bio-ethanol [10] while the solid residue can be used as cattle-feed [11]. Bio-alcohols are used as a petrol additive or substitute; however alcohols can be readily ignited by hot surface. Thus the pre-ignition and knocking in engines that use alcohol makes alcohol engines more dangerous than other engines [12]

Algal biomass can be used also for biogas production [13, 14]. Anaerobic digestion of carbohydrates produces hydrogen and carbon dioxide [15]. Bio-hydrogen production can be also synthesized from mixed culture of photosynthetic anaerobic bacteria [16]

Nevertheless the fast growing beneficial strains optimized for domestic climatic conditions is necessary to the success of any algal mass culture, the suitable cultivation system is mandatory to increase the income [17]. The aim of this research is to perform an economic study about two designed system for cultivation on full scale with annual production 2 .21 ton dry algae.

MATERIALS AND METHOD

INOCULUM PREPARATION

In this research the algal strain "*Microcystis aeruginosa"* is cultivated using modified BG 11 medium of composition illustrated in Table (1). The inoculum that is fed to the cultivation system is prepared at controlled conditions; temperature 20±2°C, irradiance 1500 lx (20.3 µmol m^{-2} s^{-1}) of white cool fluorescent, light duration 24 hr for 7 days and inoculum concentration about 25 µg chlorophyll/L (2 mg biomass/L).

Table 1: Composition of modified BG11medium

Nutrient Solution	Stock Weight (g/L)
K_2HPO_4	40
$NaNO_3$	1500
$MgSO_4.7H_2O$	75
$CaCl_2$ anhydrous	330.98
Citric acid	6
Na_2CO_3	20
Na_2EDTA	1
Ferric ammonium citrate	6
Trace elements*	

*Trace elements were prepared by dissolving (2.86 g) of H_3BO_3, (1.81 g) of $MnCl_2.4H_2O$, (0.222 g) $ZnSO_4.7H_2O$, (0.39 g) of $Na_2MoO_4.2H_2O$, (0.079 g) of $CuSO_4.5H_2O$ and (0.0494 g) of $Co(NO_3)_2.6H_2O$ in 1L of distillate water.

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SYSTEM DESCRIPTION

The cultivation process is illustrated in the block flow diagram Fig (1). It consists of mixing the nutrients with fresh water in EW5329VNS- Belgium mixer then is fed into the photobioreactors, while the inoculum is injected directly into the PBR. Two types of PBRs are compared; air lift bubble column and flat plate PBR (Photosynthetic Instruments- Czech Republic). Each of capacity 15.36 m^3 supplied with air compressor, water pump, pH sensors, chlorometers, and temperature controllers. The bubble column PBR unit is composed of eight columns; 600 units occupy 500m^2. The flat plate PBRs is composed of 307 photo-bioreactors each of volume 50 L. Cultivation process spends 10 days as batch process run alternately. Harvesting process composed of settling using settler tank EW5173VNS- Belgium with capacity 90 L, the collected thick culture is centrifuged in rate of 1.0 L/min using Basic Algal Centrifuge -China. The biomass is dried using air freezing dryer HRD-8F; China; with rate 1.5 m^3/min; while the decanted solution is filtrated using micro ultra-filtration EWUF-1 China with rate 1.0 m^3/h to be recycled to the mixer.

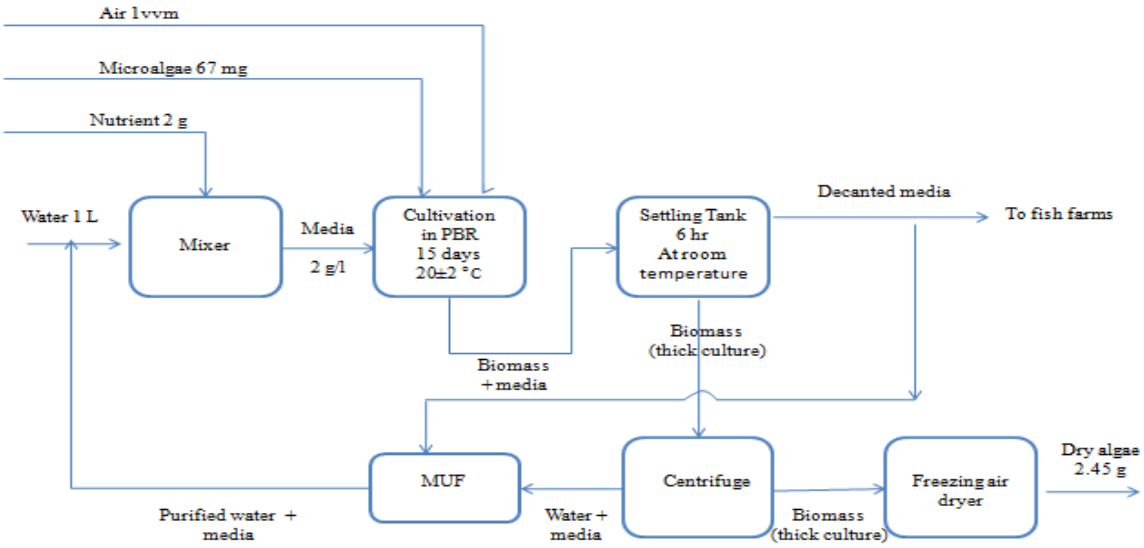

Figure (1) Block Flow diagram for the cultivation and harvesting process

The cultivation conditions applied are: Photon flux density PFD 81 µmol m^{-2} s^{-1} and initial inoculum concentration is 67 mg/L. The light used for cultivation is white LED. In this system mixing is applied by air bubbling that is 1.0 vvm [17]. In this work a cost estimation of the cultivation process is applied for bubble column PBR and Flat plate PBR, the capital investment and the return on investment are calculated.

RESULTS AND DISCUSSION

The target of annual production is 2 ton dry algae. This target can be achieved using the above described system operated by 14 labors through 330 working days. The cost of the purchased equipments is illustrated in Table 2.

Table 2: Cost of purchased equipments

Equipment	Size	Cost $
Mixer	90 L	1280
Bubble column PBR	15.36 m^3	600'000
Flat Plate PBR	15.36 m^3	60'000
Settling tank	90 L	100
Centrifuge	1.0 L/min	1200
Micro Ultra-filtration	1.0 m^3/h	2300
Drying	1.5 m^3/min	300

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The purchased equipment cost of system based on bubble column PBR is $2,901,600 while that of system based on flat plate PBR is $312,700. The percentage of fixed capital investment for direct and indirect cost is detailed in Table 3.

The individual components as percentage of the total product cost -based on raw materials-are summarized in Table 4. The annual nutrient consumption cost is $31,000. The operating labor represent 5% of the total product cost, the direct supervisory is 10% of operating labor as same as the laboratory charges. While the utilities, royalties, local taxes and insurance are considered 10%, 1%, 1% and 0.4% of total product cost respectively. The operating supplies are evaluated as 10% of cost of maintenance and repairs. The sum of direct production cost, fixed charges, and plant cost represent the manufacturing cost.

Table 3: Cost % of fixed capital investment

Components	Cost of Flat Plat system $	Cost of bubble column system $	Cost % of fixed capital investment
Direct Cost			
Purchased equipment	65,200	605,000	22.94
Purchased equipment installation	23,500	217,800	8.26
Instrumentation	18,300	169,400	6.42
Piping	20,900	193,600	7.34
Electrical	13,000	121,000	4.59
Building	13,000	121,000	4.59
Yard improvement	5,200	48,400	1.83
Service facilities	39,120	363,000	13.76
Land	2,600	24,200	0.92
Total direct cost	200,800	1,863,400	
Indirect Cost			
Engineering and supervision	26,100	242,000	9.17
Construction expense	31,300	290,400	11.01
Contractor's fee	5,200	48,400	1.83
Contingency	20,900	193,600	7.34
Total indirect cost	83,500	774,400	
Fixed capital investment	284,300	2,637,800	**100**
Working capital	28,400	263,800	
Total capital investment	312,700	2,901,600	

General expenses are taken into consideration as sum of administration costs, distribution and selling costs, and research and development cost as 2%, 0.5%, and 3% of total product cost respectively. The sum of manufacturing cost and general expenses is the total product cost that gives positive net profit in case of flat plate PBR system while the net profit is negative in the case of bubble column PBR system.

Table 4: The individual components of total product cost.

Individual component	Bubble column system cost $	Flat plate system cost $
Operating labor	31,000	31,000
Direct supervisory	3,100	3,100
Utilities	62,000	62,000
Maintenance and repairs	58,000	6,300
Operating supplies	5,800	630
Laboratory charges	3,100	3,100
Patents and royalties	6,200	6,200
Direct production cost	200,200	143,330
Depreciation	2,400	300
Local taxes	26,400	2,800
Insurance	10,600	1,100
Fixed charges	39,400	4,200
Plant-overhead costs	31,000	31,000
Manufacturing cost	270,600	178,530

Administration cost	12,400	12,400
Distribution and selling cost	3,100	3,100
General expenses	15,500	15,500
Total product cost	286,100	194,000
Total income	221,200	221,200
Net Profit	-ve	27,200
ROI%	-2.24	8.70

The Return on investment is calculated according to the equation

$$ROI\% = \frac{P}{TCI} \times 100$$

Where; P= Net Profit and TCI= total capital investment.

The results revealed that negative ROI for the bubble column. This may refer to the high cost of the photobioreactor which require higher maintenance cost and utilities since the columns are fabricated of Plexiglas materials in relatively smaller volumes. While the flat plate PBR is fabricated with cheaper materials (plastic supported with nets of stainless steel) that require cheaper maintenance and utilities.

CONCLUSIONS AND PROSPECTIVE

The main target of this work is to compare between two closed systems: the bubble column PBR and the flat plate PBR to increase the biomass productivity with minimum cost. The former is not recommended for large scale production while the latter is applicable due to the positive net profit and return on investment. Nevertheless more research should be applied to increase the biomass productivity and decrease the manufacturing cost, research on bio-refinery products are important to increase the economic income of the whole process. The protein could be used as animal nutrition as the toxicity analysis of *Microcystis aeruginosa* shows negative results of toxicity. The carbohydrates content enhances the production of bio-alcohol by fermentation or biogas via anaerobic digestion.

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