A Review of Effect of Light on Microalgae Growth

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Abstract—**Algae-organisms are unicellular or simple multicellular body plant that is able to manufacture their own food material by photosynthesis. Algae can be cultivated under certain conditions of temperature, light and sufficient nutrients to produce biodiesel. Many researchers worked to increase the efficiency of the production rate in both indoor and outdoor cultivating systems and by designing special photobioreactors (PBRs) to increase the rate of photosynthesis. Light conditions affect directly the growing and photosynthesis of microalgae. (Duration and intensity).Microalgae needs a light/dark regime for productive photosynthesis, it needs light for a photochemical phase to produce (ATP, NADPH) and also needs dark for biochemical phase synthesize essential molecules for growth. This article critically reviews research under taken to date to study the effect of light on the microalgae growth.**

Index Terms— **microalgae, biomass, photosynthetic, photo bioreactor, light intensity, algal growth, biomass concentration, chlorophyll**

I. Introduction

Global warming, CO_2 discharge, expensive petrofuels and many other problems that appear in the last years persuades us to think thoroughly for green future , renewable energy and enhance public awareness .It's well known that fossil fuels will not survive for long time because of the dangerous accumulation of "green house gas" CO_2 and due to depleting resources, depending on that it's very important to explore renewable energy source that's eco-friendly and economical, such as; solar energy , wind and biofuels[13].

Algae-organisms with unicellular or simple multicellular body plan that is able to manufacture their own food material by photosynthesis. Algae are used in food industries and cosmetics. Also, algae have the ability to absorb metals in biotreatment. On other hand many investigations were made recently to extract biodiesel from biomass, the extracted biodiesel does not increase the CO_2 amount in the atmosphere when burned like fossil fuels [11].

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Algae show high efficiency in converting solar energy to produce biodiesel than other crops. That's because algae need less area for cultivation in case of indoor or outdoor system in comparative with crops. To produce a certain amount of biodiesel in indoor system algae needs 1000 times water less than crops.

Table 1 Comparison of crop-dependent biodiesel production from plant oils [15]

Plant source	Biodiesel (L/ha/year)	Area to produce global oil demand (hectares x 106)	Area as percent global arable land
Cotton	325	15,002	756.9
Soybean	446	10,932	551,6
Mustard seed	572	8,524	430,1
Sunflower	952	5,121	258,4
Rapeseed/canola	1,190	4.097	206,7
Jatropha	1,892	2,577	130 (0[a])
Oil palm	5,950	819	41,3
Algae (10 g m^{-2} day -1 at 30%TAG	12,000	406	20,5 (0[a])
Algae(50 g m $^{-2}$ day -1 at 50%TAG)	98,500	49	25 (0[a])

[a] algal ponds and bioreactors are situated on non-arable land

II. Literature review

Light conditions affect directly the growing and photosynthesis of microalgae (Duration and intensity). Microalgae needs a light/dark regime for productive photosynthesis, it needs light for a photochemical phase to produce (ATP) Adenosine triphosphate (NADPH) Nicotinamide adenine dinucleotide phosphate-oxidase) and also needs dark for biochemical phase synthesize essential molecules for growth [3].

Experimental investigations reveal that the increase in light duration is directly proportion to increase in number of cultivated microalgae as well as the increase in the light intensity.

Khoeyi Z., et. al., 2011, used three algae samples placed in different light conditions (photoperiod, intensity), there was a huge difference in the growing concentration between them as the maximum biomass was recorded between 0.1 g and 2.05 g when the algae culture exposed to 62.5 µmol photons m^{-1} s^{-1} for a 16:8 h light/dark photoperiod duration, while the maximum percentage of total saturated fatty acids (SFA) was 33.38 % at 100 µmol photons $m^{-2}s^{-1}$ for a 16:8 h light/dark photoperiod duration.

Carvalho A., et. al., 2010, studied light requirements in microalgal photoreactors. They noticed that cultivating microalgae in photobioreactors (PBRs) should be provided with appropriate light duration, intensity and wavelength. Insufficient light may lead to growth limiting or photo-oxidation and inhibition.

Posten C., 2009, reviewed the different parameters for designing photobioreactors that effect the growth of algal mass. There are several suggestions to increase light distribution along with sufficient agitation, aeration and energy demand for higher performance. The suggested way to increase light rather than increasing the transparent surface and bringing the algal growth to the light is to use alternative ways to bring light to the biomass layers by using milli and micro scaled multi structures – fleece of glass fibers can be used – or a build in light conductive structure can be used to guide light into a compact closed reactor. Another way is to use lenses effect or LEDs light to distribute the light uniformly inside the reactor.

Belcher H., et. al., 1982, illustrated a lab scale manual for culturing algal; in additional to the medium preparation and other cultivating factors lightning has been taken in consideration. It's advisable to place the culture vessels near a north facing window, and take in care that a direct sunlight never falls on the tubes another window direction been used. Extra florescent tubes can be used but the culture temperature should be monitored to avoid elevation in temperature inside the tubes.

Ifeanyi V., et. al, 2011, the researchers examined the effect of light and salt concentrations on Aphanocapsa algal population. They worked on an isolated Aphanocapsa from a water sample collected from Shell petrol station and found that the effect of 5000, 3500 and 2000 lux light intensity on the growth was very high and a noticeable increase in the in the biomass density recorded on the 9th date of cultivation.

Janssen M., 2002, studied light/dark cycles to examine the efficiency of light utilization in (PBRs). A medium frequency light/dark cycles –from few seconds to 1000s- lauded to higher photosynthetic efficiency in the PBRs in comparison to constant light levels.

Rochet M., et. al., 1986, studied certain conditions in southern Hudson Bay (Canadian Arctic) from March to May 1983 to observe the response of sea-ice microalgae to different changes in light intensity and quality. When algal growth was incubated under blue light it doubled as compared to the growth under white light. According to the availability of blue green light environment ice algae had adaptive response to it and showed high concentration of chlorophyll. On the other hand the same algae responded to light spectrum when in incubated under white illumination by increasing their chlorophyll. "The ability to chromatically adapt may become a critical factor in species competition".

Jacob-lopes E., et. al., 2009, evaluated growing algae under different light cycles, and 24:0 (night: day) respectively. A reduction in biomass production was observed in parallel with the reduction in light period duration.

Kitaya Y., et. al., 2005, investigated the effects of temperature; CO_2/O_2 concentrations and light intensity were examined on cellular multiplication of microalgae. Microalgae were cultured under five levels of temperatures from 25˚C to 33˚C, three levels of CO_2 concentrations from 10% to 30 %, and six levels of photosynthetic photon flux from 20 to 200 µ mol m^{-2} s^{-1}.The results demonstrated that the highest multiplication rate of the microalgae cells was at temperature of 27-31˚C, CO_2 concentration of 4%, O_2 concentration of 20% and light flux of about 100 µ mol m^{-2} s^{-1}.

Mata T., et. al., 2012, analyzed the factors that may affect the production of biomass and the treatment of brewery waste water. Many parameters were studied to reach the highest biomass production and the most suitable conditions for cultivating algae. Those conditions were in an aerated culture and exposing the growth to a 12 h period of day light at 12000 lux intensity. The maximum biomass obtained was 0.9 g of dry biomass per liter of growth on the 9th day.

Cheirsilp B., et. al., 2012, investigated chlorella sp.and Nannochloropsis sp. to be the best algae species for production of biodiesel. For the production of higher biomass amount with high lipid content the growth was cultivated under stepwise increasing intensity as a fed-batch. This procedure insured approximately twice lipid production than conventional batch cultivation. The composition of the main fatty acid was appropriate for biodiesel production.

Chen X., et. al., 2011, performed cultivation of micro algae Chlorella sp. in draft-tube PBR. The best growth performance was detected under alight intensity range of 82-590µ mol / m^{-2} s^{-1}. A lumostatic strategy was applied, based on the light distribution profiles detected by image analysis and chlorophyll content. This strategy allowed for a high biomass dry weight of 5.78 g /l and productivity of 1.29 g/l d, which were 25.7% and 74.3% higher than constant light intensity.

Hsieh C., et. al., 2009, developed an open PBR tank with rectangular transparent chambers to increase the photosynthetic efficiency of micro algal growth. The transparent rectangular chambers (TRCs) made of high light conducting transparent acrylic. This structure allows deeper light conductance into PBR even at high cell concentration. The (TRCs) provides a high effective utilization of light for the growth with high rate production. The biomass obtained using this design was 56% higher than PBRs without (TRCs).

III. RESULTS AND DISCUSSION

Microalgae needs a light/dark regime for productive photosynthesis, it needs light for a photochemical phase to produce (ATP) Adenosine triphosphate, coenzyme used as an energy carrier in the cells of all known organisms,(NADPH) nicotinamide adenine dinucleotide phosphate-oxidase) is a membrane-bound enzyme complex. And also needs dark for biochemical phase synthesize essential molecules for growth [1].

The experimental results also showed that the increased levels of light intensity and light duration was associated with increased saturated fatty acids (SFA), decreased monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA)[17].

Also, with the development of new PBRs a higher multiplication of the growth could be reached under controlled conditions such as: temperature, CO_2/O_2 concentrations and light intensity [7]. Flashing light had an obvious effect on the photosynthetic efficiency(PE) because of the ability of reaching the opaque medium at irregular efficiency in addition a turbulent flow can applied in a high density algal mass in PBRs.

Algal pigments and photosynthetic operations have the ability to adapt to environmental condition. Sea-ice micro algae showed chromatic adaption when incubated under white light spectrum although it responded to their blue-green light environment. This ability for adaption may become an important factor in species competition [13].

Improved PBRs designs can play an important role in biomass productivity. Light guidance fibers, transparent rectangular chambers or build in reflecting lenses can increase (PE) and reach a high biomass concentration [3].The multiplication rate of algal cells was highest at temperatures between 27-31˚C, with photon flux of 100 µmol $m^{-2}s^{-1}$. Algal biomass could convert CO_2 to O_2 more efficiently under such conditions [16].

The productivity of microalgae can be enhanced by cultivating the culture under light emitting diodes (LEDs) with peak emittance of 680 nm, this will result in doubling the number of cells produced without changing the cell volume then the culture is exposed to white light in order to enlarge the cells size so the overall biomass will increase [1].

IV. CONCLUSION

It is beneficial to cultivate microalgae with high (PE), however, the culture needs to be exposed to light/dark period with certain light intensity.

The (16:8 h light/dark photoperiod) method is suitable for outdoor cultivation in Oman because of enough solar energy throughout the year, also artificial lights can be used in cloudy winter days if it's necessary. Slow deep stirring or small pumps can be used to mix the culture so the deeper layers have the chance to contact directly to sun light [17].

PBRs method is more expensive due to the expensive artificial light sources that should match cultivation conditions. Also the PBRs should be designed as narrow reactor channels with short light/dark cycles or strong stirring should applied to the dense microalgae culture to enhance light flux tolerance and improve productivity.

Microalgae cultivation with controlled conditions will provide a constant and high yield of biomass but further researches should carry on making it economically worth and applicable worldwide.

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