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Research Article

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Solar Radiation Intensity Impact on Microalgae Growth Rate

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Abstract Biofuels produced from natural sources such as vegetable oils and animal fats are a promising alternative to biodiesel. As it have similar diesel combustion properties with fewer emissions. However, what is wrong is to rely on agricultural or animal sources, which affects the level of global food. Therefore, the production of biofuels from microalgae farms is a better alternative and more suitable in all the standards.
In this study, the effect of light intensity on the microalgae produced was investigated practically. the results clarifiedthat as the number of cell increased, the solution becomes increasingly cloudy because when light passing through it is scattered by the microalgae present. Also, the culturing of microalgae is available by using photo-bioreactor with different lights (red, green and blue).

Keywords Solar Radiation, Intensity, Microalgae

Introduction

The global warming caused by high CO_2 discharge rates, which has caused climate change for many parts of the world [1,2], and volatile oil prices [3], and many other problems that have emerged in recent years have led researchers and decision-makers to seriously consider the transition to renewable energy [4]. The fossil fuels will not last for long because of the permanent and escalating depletion of its resources because of the growing population in the world and the increasing need for transport and industry [5, 6]. It is therefore very important to explore renewable sources that are environmentally friendly and economic, such as: solar energy [7, 8], wind [9], and biofuels [10].
In recent decades, energy demand has grown exponentially and environmental problems have also increased [11]. These issues are of great importance to human health and life and must be taken care of [12]. So exploring renewable energy and low-energy pollution, such as wind power, solar power, and geothermal energy is essential [13]. Biodiesel is a renewable fuel and a good alternative to diesel fuel [14, 15]. For example, in the United States, biodiesel production reached 691 million gallons in 2008, although annual production fell to 490 million gallons in 2009, while overall higher production continues to escalate [16]. Several studies have shown that biodiesel has better advantages than fossil fuels and is an environmentally friendly energy source [17, 18].
The burning of biofuels produces less carbon dioxide and is less sulfur-free, because of its oxygen content, the emissions of carbon monoxide and unburned hydrocarbons are lower [19, 20]. Technically, 90% of air toxicity and 95% of cancers can be reduced by biodiesel. Making it a favorite for researchers, the biodiesel could be provided in a sustainable manner, so there was no need to cope with the shortage of supplies [22]. Biodiesel has great potential in the energy market [23]. High fossil fuel prices are high and volatile due to lack of supply and high demand. When biofuels are used as a renewable energy source, there will be no problem with the availability of supply or the fluctuation of its price [24].

Biodiesel produced from algae is one of the new and promising technologies in the field of biodiesel production [25]. Many researchers use micro algae in the production of chemicals, oils, and cosmetics [26, 27]. Several studies and research have shown that maize crops, soybeans, animal fats can produce biofuels, and use them as renewable diesel after treatment [28]. This biodiesel produced from these crops cannot meet the growing demand for energy as its production is very limited, as well as using these crops as fuel may affect the global food basket [29]. Micro algae absorb light and process photosynthesis to produce oil [30]. The production of micro-algae for biodiesel is much higher than the above-mentioned crops [31].

The land used for agriculture is also an important issue. Comparatively, microscopic algae can be extracted without the need for a large planting area such as that required by agricultural crops [32]. As an example, to meet the demand for 50% of the transportation fuel in the United States, the use of palm oil as a source of biofuels needs in this country additional areas are not available as 24% of the total area of the crop is less than 50% of demand. In the case of the use of micro-algae for the production of biodiesel, it requires an area of land that does not exceed 1% - 2.5% of the total agricultural land to meet the same demand for transport fuel [33].

Oil produced from microalgae has many advantages, including: the chemical composition of microalgae is very similar to vegetable oils, since the organic composition of them is very close [34]. When using a concentrated process control method, the production of oils from algae can reach 85% of its dry weight [35]. The need to renew the life cycle of micro algae is less [36]. From here, if we take into account the growing demand for energy and the need to cultivate the land required for man first, it seems that the use of microalgae to produce renewable biodiesel is the most appropriate option [37]. The issue of the use of microalgae to produce biodiesel is a hot topic and is attracting great attention these days [38]. However, the use of microalgae to produce biodiesel, accompanied by defects including: the oil produced from microalgae has a heating value less than fossil diesel. Also, the production processes of oils from microalgae in which there are many economic challenges as the harvest price is high and dewatering, and extract microalgae oils technology is mature and still need further tests [39, 40].

Nitrogen is an essential element for the growth of microalgae. Nitrogen is presented in the air by more than 78%, making it a large source. Many algae species use nitrogen gas in the air to fix it for their own use. Increasing nitrogen content in the growth field will increase the growth rate of microalgae. Nitrogen is a beneficial nutrient for micro algae [41, 42].

Light is the key element in the growth of microalgae. Light is used in photosynthesis, but light energy cannot be stored by microalgae and must be provided sustainably. Microalgae cannot use all incoming light energy because they cannot absorb all photons of energy, and increased optical radiation causes inhibition of the surface layer of micro algae. Light does not reach the inner part of the algae due to the lack of photons. In photosynthesis, algae are fed by converting carbon dioxide into the air into organic compounds, and visible light is used as a major source of energy since chlorophylles, vicublins and carotenoids in micro algae can be absorbed into visible light range [43].

When the light intensity rises above a certain limit and its survival at this level will reduce the rate of growth of microalgae. This phenomenon is called discourage the photon. The photon height inhibits the growth rate and determines when the light intensity is slightly higher than the required light intensity. The excessive light source and the photo-inhibition cause damage as opposed to photosynthesis [44]. So avoiding photon inhibition can help increase the daily growth rate of algal biomass [45].

As the light intensity changes, the temperature becomes an environmental factor indirectly affecting the growth of micro algae [46]. According to a study on the effects of temperature on the maximum rate of photosynthesis of micro algae in Lake Casomigora, the results showed that when the water temperature was less than 4°C, photosynthesis of algae is completely inhibited. When the temperature is between 4°C and 11°C, photosynthesis is strongly inhibited. At temperatures above 11°C, the relationship between temperature and the growth of microalgae becomes linear [47]. Water temperature determines the activity and reaction rates of enzymes inside cells, which in turn will affect algae photosynthesis, respiration, microalgae growth, and reduction of its distribution [48].

The pH of water affects the growth of micro algae through photosynthesis, as the change of pH will also affect the growth rate of microalgae. For microalgae, it is easier to interact with carbon dioxide in the atmosphere when the growth state is alkaline, and then more biomass will be produced [49, 50]. When the pH is increased, CO_2 in the water turns into HCO^{3-} a weak alkaline substance that is used by big algae. However, studies have shown that chlorophyll content in microalgae is low when the pH value is 8.5 to 9.5 [51, 52].

Algae have their own system to adjust the salinity of water. Microalgae found in seawater are usually tolerated higher than freshwater algae [53]. Studies have shown that micro algae have a salinity system associated with their optimal growth, and when water salinity is higher or lower it will damage the growth rate of algae [54]. In the case of salinity decrease, algae growth will be beneficial for the addition of sodium chloride and Na_2SO_4, but when salinity is higher than 6g/l the micro algae growth rate will be halted [55].

Shading is an impediment to the growth of microalgae. As it prevents the light from reaching the microalgae and absorbing it effectively that affects the biomass produced. Microalgae grow well in the lake or stream due to water dynamics [56]. When designing a microalgae farm, the dynamics of light, water, and temperature are important factors for micro algae growth [57].

Man uses algae as a food, to produce useful compounds, biological filters used to remove nutrients, and other contaminants from waste water, water quality measurement, environmental change indicators, and space technology and laboratory research systems. Commercialized algae are used for pharmaceuticals, cosmetics and for aquaculture purposes.

Algae can be used to produce biodiesel, ethanol, and bio-butanol, and some brands can produce large amounts of oils compared to crops grown for the same purpose. Hydrogen can also be produced from algae. In 1939, Hans Gavron noted that the green algae studied (Clamidomonas Reinhart) sometimes turned from oxygen production to hydrogen production.

This paper aims to study the effect of light intensity on the production rate of microalgae.

Materials and Methods

The following materials and equipment were used in the experiments: fresh water, microalgae solution, photo-bioreactor, microscope, and air pump. The tests were conducted by take 30% microalgae sample (30 ml) and 70% water (70 ml). These two substances were mixed in flask of 100 ml solution. A fertilizer was added to the solution in a rate of 0.37 ml of fertilizer for each 1litre of solution. The solution was fixed in the photo-bioreactor and the light intensity was adjusted at its maximum value (1500-the red color). The number of cells was counted using microscope every day. This process took 4 days.

After keeping sample 1 for a period of four days, 333 ml of water and microalgae solution (233 ml of fresh water in the solution) was added. Extra fertilizer was added also. The sample was left for four days in the photo-bioreactor. Then, the number of cells was counted again by using microscope every day.

In the third part of the tests, which started after Sample 2 was left for four days in the photo-bioreactor, 1000 ml fresh water was added (total =1333 ml of water and microalgae solution). Another extra fertilizer will be added. The sample will be left for extra four days in photo-bioreactor in the red color light intensity. Again, the number of cells must be accounted using microscope every day. Fig.1 represents the microalgae and fresh water in the red colored light intensity. Fig. 2 shows the resulted microalgae after the third round (12 days).

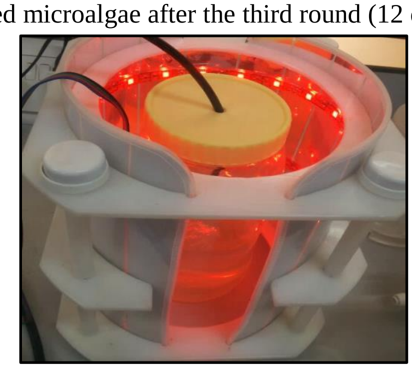

Figure 1: Sample (microalgae and fresh water) in red colored light intensity

Figure 2: The microalgae sample after 12 days (three rounds)

In the fourth round of experiments started and it extended for five days. In this round two samples from the last part 30% microalgae sample (30 ml) and70% water (70 ml) used and extra fertilizer was added to it. The two samples were left to culture by putting each in separate photo-bioreactor. Sample No. 1 in blue color light intensity (light intensity = 1000 Lux), and Sample No. 2 in green color light intensity (light intensity = 2450 Lux). The number of cells was counted using microscope daily.

The method used to count the cells number using a microscope was conducted using the procedure of counting the number of cells (only which are green (live cells)). The number of algae cells counted only in the five quadrants. The microalgae sample calculation was conducted using the following steps:

1. Put small sample of microalgae culture in a thin transparent slice under the microscope. We will see the five squares (quadrants)
2. After counting up the number of cells (total number in five quadrants). the density $\left(\frac{cells}{ml}\right)$was calculated using :

$$density\ \left(\frac{cells}{ml}\right) = \frac{total\ number\ of\ cells\ counted}{5 \times 10 \times 10^{-6}}$$

3. Draw graphs to predict the relation between time and the number of cells, and between the number of cells and cell density.
4. Table 1 shows the number of cells counted using the microscope.

Figure 3: photo-bioreactor in blue and green color

Table 1: counting cells number (culturing of microalgae) with time

Periods No.		day	light		Total number of cells	Density $\left(\frac{cells}{ml}\right)$
			Type of color	Intensity (Lux)		
Period 1		1	Red	1500	86	4300000
		2	Red	1500	181	9050000
		3	Red	1500	355	17750000
		4	Red	1500	1146	57300000
Period 2		1	Red	1500	312	15600000
		2	Red	1500	718	35900000
		3	Red	1500	868	43400000
		4	Red	1500	1050	52500000
Period3		1	Red	1500	74	3700000
		2	Red	1500	350	17500000
		3	Red	1500	888	44400000
		4	Red	1500	1300	65000000
Period 4	Sample 1	1	Blue	1000	243	12150000
		2	Blue	1000	400	20000000
		3	Blue	1000	630	31500000
		4	Blue	1000	995	49750000
	Sample 2	1	Green	2450	100	5000000
		2	Green	2450	360	18000000
		3	Green	2450	798	39900000
		4	Green	2450	1000	50000000

Results and Discussions

Culturing of microalgae by using photo-bioreactor (measure of the increase in biomass over time) is depending on light absorption, when the cells absorb most of the incoming irradiation (by chosen different colors: red, green and blue), the number of cells will increase by direct proportional. Also, the time effect on microalgae growth, as time increase (number of days) the total numbers of cells increase.

Fig. 4 represents the total number of cell calculated as mentioned in the previous section for the first round of experiments. The microalgae number and density increased with time advancing to reach its highest values on the fourth day. The algae needs light and time to grow and both were available in this case.

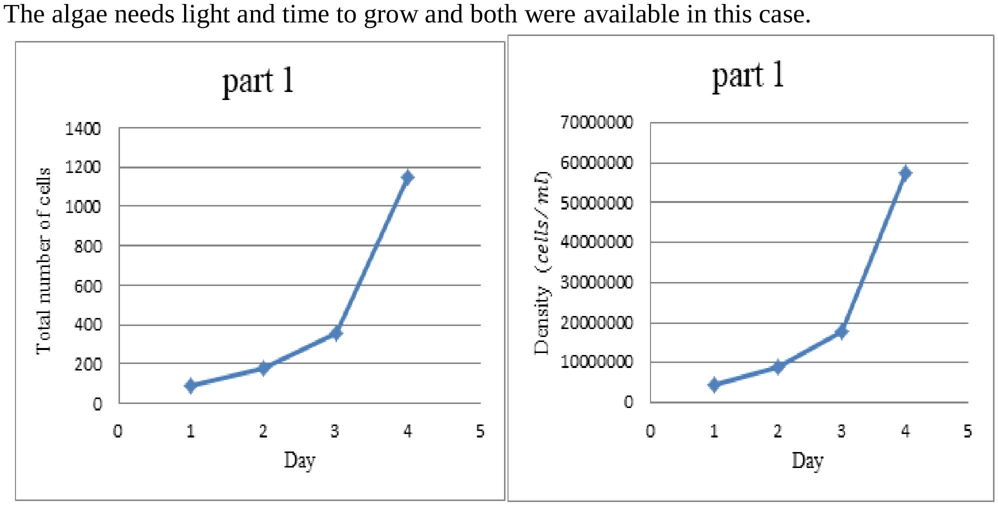

Figure 4: relation between time and density of cells and the total number of cells inthe first round of experiments

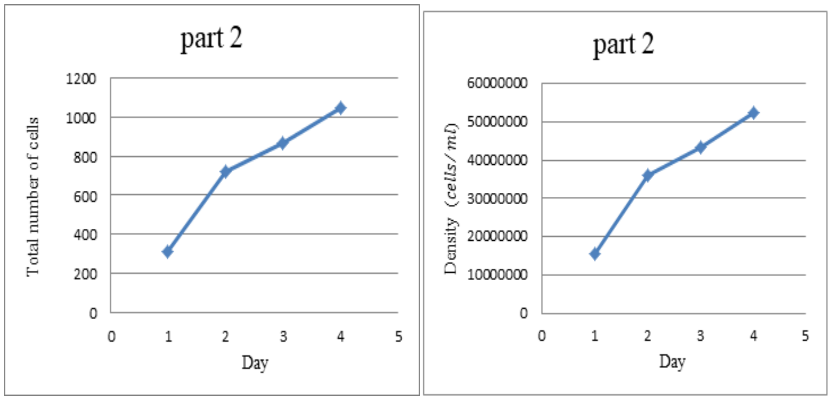

Figure 5: relation between time and density of cells and the total number of cells the second round of experiments

Fig. 5 represents the total number of cell and its densities for the second round of experiments. Here, the total number of cells started to increase more than the first round. The algae adapted to her environment and with the required water and fertilizer availability its growth became steady with almost linear relation between the days and total number of cells as well as the algae density.

Fig. 6 shows the total number of cell and its density with time. The relation describes a linear relation approximately. The time advancing resulted in more algae and higher density.

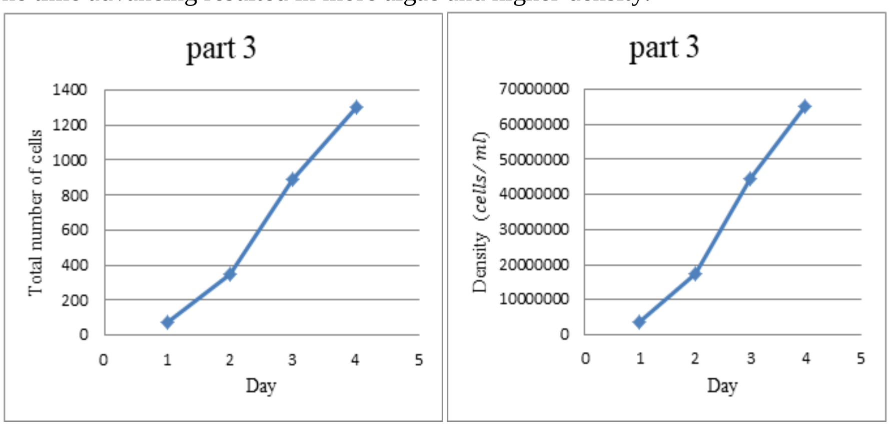

Figure 6: relation between time and density of cells and the total number of cells in the third round of experiments

Fig. 7 represents the relation between time and number of cells and cells density. The use of green light gave more algae numbers and density at the third day. However, at the end of the fourth day the algae numbers and densities were equal.

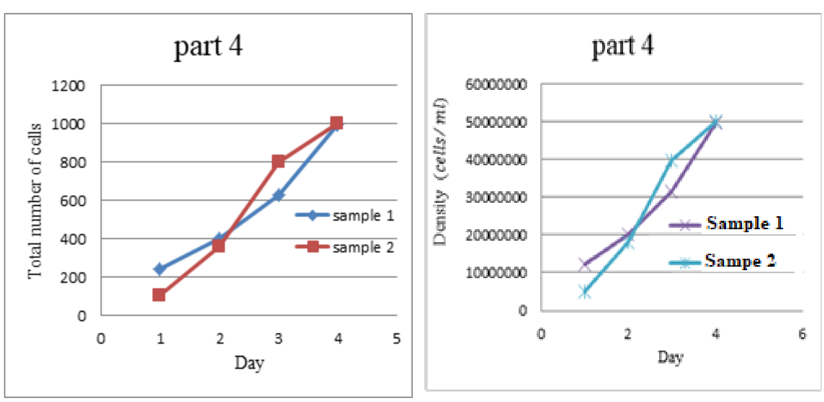

Figure 7: the relation between time and density of cells and the total number of cells in the fourth round of experiments

Conclusion

The study results indicated that as the number of cell increase, the solution becomes increasingly cloudy because when light passing through it is scattered by the microalgae present.

From the readings (from the figures and table), the relationship between density of microalgae and number of microalgae cells verses time are direct proportional, that's mean the culturing of microalgae is available by using photo-bioreactor with different lights (red, green and blue).

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