OPEN ACCESS

1st World Sustainability Forum
1-30 November 2011

www. wsforum.org

Communication

An Electronic System for Monitoring Sunlight Intensity toward Optimal Growth of Microalgae for Sustainable Production of Biodiesel

Hooman Fatoorehchi [1] and Nadia Mahmoudi Khatir[2],*

[1] IDEA Engineering Company, No. 42, 17th Eastern All., Patris Lumumba St., Shahrara Ave., Tehran, Iran
[2] Low Dimensional Materials Research Centre (LDMRC), Department of Physics, Faculty of Science, University of Malaya, P.O. Box: 50603, Kuala Lumpur, Malaysia

E-Mails: hfatoorehchi@gmail.com ; mahmoudy_phy@siswa.um.edu.my

* Author to whom correspondence should be addressed; Tel.: +60-379-674-015; Fax: +60-379-674-146

Received: / Accepted: / Published:

Abstract: Production of biodiesel from microalgae is a promising step toward sustainability. The superiority of microalgae to their counterpart sources of biomass lies in many favorable characteristics of microalgae such as high biodiesel productivity, low land use and carbon dioxide biofixation. Sunlight as an effective parameter in growth and cultivation of various microalgae species is an aspect of concern in design and operation of photobioreactors. In this communication, we present a simple measuring system which can provide the effect of sunlight irradiance in photobioreactors qualitatively. The system is very low cost and can be connected to an ordinary personal computer to monitor sunlight intensity to a photobioreactor. Based on a set of experiments a calibration curve for the measuring system is also given. The proposed system can contribute to optimal growth of microalgae inside large scale photobioreactors as well as to lab scale research projects.

Keywords: microalgae; biodiesel; sustainable fuel sources; sunlight.

---

1. Introduction

Microalgae have proved to consume carbon dioxide and produce stored lipids, triglycerides, which can subsequently yield biodiesel through transesterification processes (see Fig. 1). Therefore, they are sometimes referred to as “sunlight-driven cellular factories” that provide potential bioenergy [1].

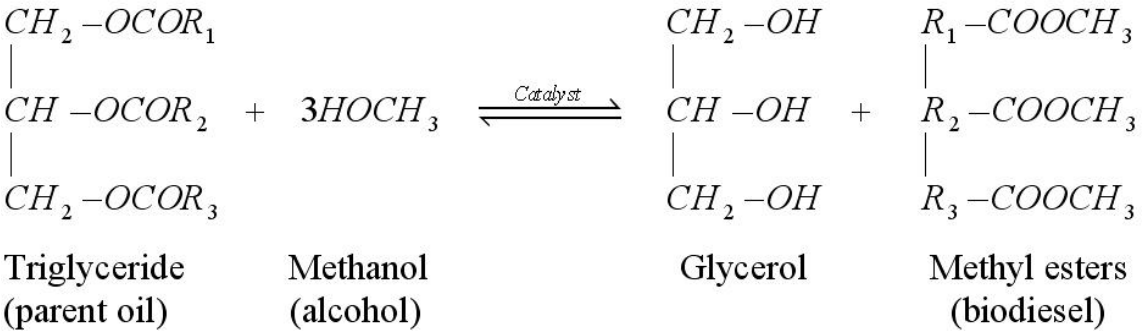

Figure 1. General reaction for synthesis of biodiesel from lipids

The recent literature abounds with articles pointing the advantages of biodiesel production from microalgae, e.g. see [2-4]. Here, we only suffice to briefly include a comparison of land use for extraction of biodiesel from different sources of feedstock (see Fig. 2) and productivity capacities of a set of microaglae in table 1.

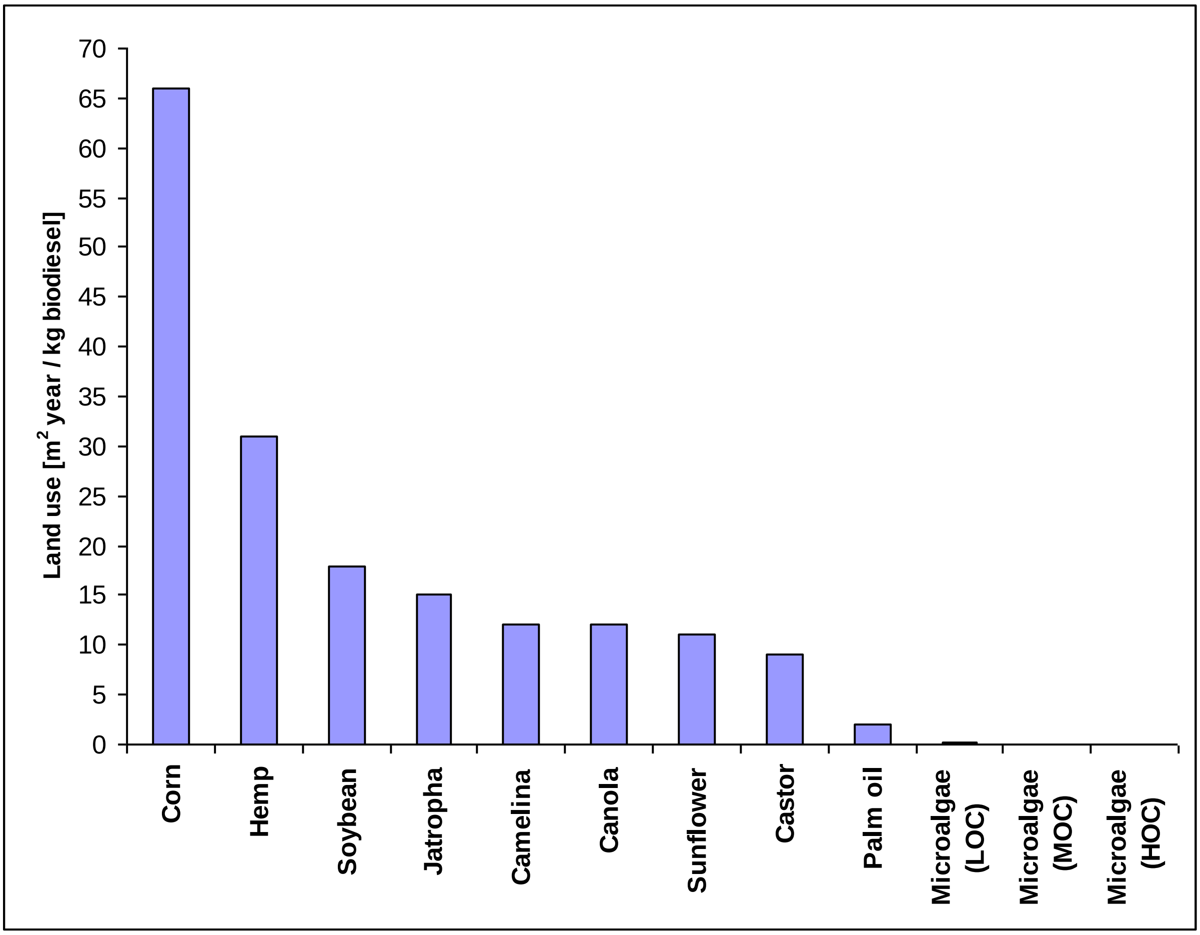

Figure 2. Land use of different feedstock for production of biodiesel [5]

Photobioreactors, from a simplified point of view, are vessels in which the growth of microalgae is promoted photosynthetically. They have been subject of intense attention during recent years and many technologies have emerged in this field [6-8].

Table 1. Biomass productivity, lipid content and lipid productivity of various microalgal strains (cultivated in 250mL flasks) [9]

Algal group	Microalgae strains	Habitat	Biomass productivity (g/I/day)	Lipid content (% biomass)	Lipid productivity (mg/l/day)
Diatoms	Chaetoceros muelleri F&M-M43	Marine	0.07	33.6	21.8
	Chaetoceros calcitrans CS 178	Marine	0.04	39.8	17.6
	P. tricornutum F&M-M40	Marine	0.24	18.7	44.8
	Skeletonema costatum CS 181	Marine	0.08	21.0	17.4
	Skeletonema sp. CS 252	Marine	0.09	31.8	27.3
	Thalassiosira pseudonana CS 173	Marine	0.08	20.6	17.4
	Chlorella sp. F&M-M48	Freshwater	0.23	18.7	42.1
	Chlorella sorokiniana IAM-212	Freshwater	0.23	19.3	44.7
	Chlorella vulgaris CCAP 211/11b	Freshwater	0.17	19.2	32.6
	C. vulgaris F&M-M49	Freshwater	0.20	18.4	36.9
Green algae	Chlorococcum sp. UMACC 112	Freshwater	0.28	19.3	53.7
	Scenedesmus quadricauda	Freshwater	0.19	18.4	35.1
	Scenedesmus F&M-M19	Freshwater	0.21	19.6	40.8
	Scenedesmus sp. DM	Freshwater	0.26	21.1	53.9
	Tetraselmis suecica F&M-M33	Marine	0.32	8.5	27.0
	Tetraselmis sp. F&M-M34	Marine	0.30	14.7	43.4
	T. suecica F&M-M35	Marine	0.28	12.9	36.4
	Ellipsoidion sp. F&M-M31	Marine	0.17	27.4	47.3
	Monodus subterraneus UTEX 151	Freshwater	0.19	16.1	30.4
	Nannochloropsis sp. CS 246	Marine	0.17	29.2	49.7
Eustigmatophytes	Nannochloropsis sp. F&M-M26	Marine	0.21	29.6	61.0
	Nannochloropsis sp. F&M-M27	Marine	0.20	24.4	48.2
	Nannochloropsis sp. F&M-M24	Marine	0.18	30.9	54.8
	Nannochloropsis sp. F&M-M29	Marine	0.17	21.6	37.6
	Nannochloropsis sp. F&M-M28	Marine	0.17	35.7	60.9
	Isochrysis sp. (T-ISO) CS 177	Marine	0.17	22.4	37.7
	Isochrysis sp. F&M-M37	Marine	0.14	27.4	37.8
Prymnesiophytes	Pavlova salina CS 49	Marine	0.16	30.9	49.4
	Pavlova lutheri CS 182	Marine	0.14	35.5	50.2
Red algae	Porphyridium cruentum	Marine	0.37	9.5	34.8

Figure 3. Different types of photobioreactors used in growing microalgae: (**a**) raceway pond, (**b**) flat-plate type, (**c**) inclined tubular type and (**d**) horizontal/continuous type [10]

Along with CO_2 level, pH, temperature, mixing and other design aspects, light is of prominent significance in performance of these reactors. Therefore, a tool for quantitatively assessment of light intensity might highly be helpful in research and operation of photobioreactors.

It is the objective of this communication to introduce a very low cost sunlight intensity meter to be equipped with photobioreactors for optimal production of microalgae. The proposed device is comprised of a hardware package (a simple electronic circuit) along with a short computer code, the software, to measure the sunlight radiation parameter in design of photobioreactors. Based on the feedback the computer receives from the measuring system, operating parameters such as flow rates can be controlled in microalgae production units.

2. The Sunlight Measuring System

The essence of the proposed sunlight measurement system is in capacitance measurement of an *RC* circuit. The circuit, whose schematic view is given in Fig. 4, consists of a number of electronic pieces, namely, an NPN transistor, resistors, an Op-Amp (Operational Amplifier) IC, and a voltage regulator IC and a photoresistor. The software is mainly an LPT programming code in Visual Basic.

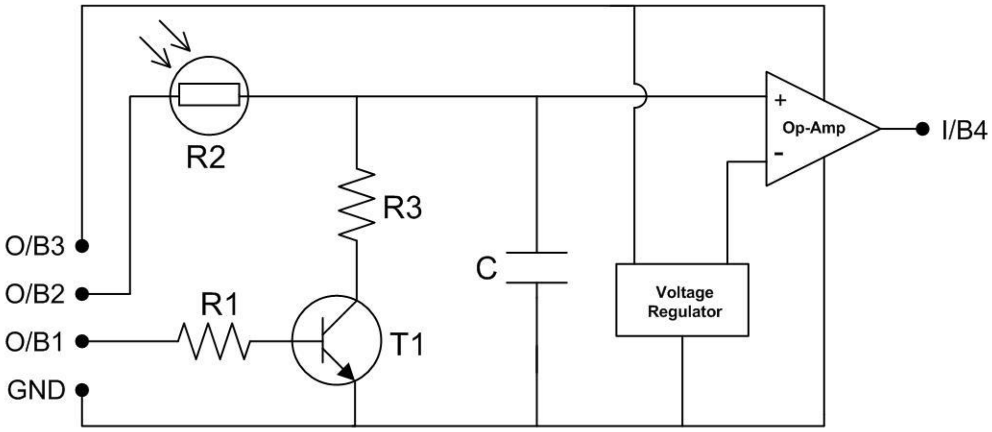

Figure 4. Schematic view of the electronic circuit

3. Circuit Analysis

Look at the circuit diagram. At the beginning of any sunlight intensity assessment, it is essential to zero the electric charge of the subject capacitor. For this end, an electric signal is sent via output pin of P1 to switch the transistor T1 on, for a specific sufficient period of time. As a consequence, the capacitor is discharged through the R3 resistor within a very short duration. During this discharging step, the voltage across the capacitor reads as:

$$\frac{V}{V_0} = e^{\frac{-t}{R_3C}} \tag{1}$$

where V denotes dynamic voltage across the capacitor, V_0 the initial potential difference between two plates of the capacitor, C the capacitance, t the elapsed time, and R_3 the electric resistance of the resistor R3. Immediately after, the software triggers a 5 volts signal via O/P2 pin, and simultaneously activates a high precision time counter, increasing the voltage across the plates of the subject capacitor gradually. The voltage increment in the subject capacitor is expressed by the equation:

$$\frac{V}{V_s} = \left(1 - e^{\frac{-t}{R_3C}}\right) \tag{2}$$

where V is the in time voltage of the capacitor and V_s is the exerted signal amplitude. As soon as V exceeds that amount provided by the voltage regulator (Vref), the Op-Amp chip switches its voltage supply to its output (i.e. the Op-Amp chip acts as a voltage comparator). This signal is sent back to an input pin of the LPT port (I/P4), informing the computer program that the capacitor is charged just as to Vref and to stop the time-counting process. Thus, the elapsed time period (θ) needed to charge the subject capacitor from 0 up to Vref is measured and recorded. Afterwards, the resistance of the photoresistor (R_2) is easily reverted by the computer program according to the following formula:

$$R_2 = \frac{\theta}{C \ln\left(\frac{V_S}{V_S - V_{ref}}\right)} \tag{3}$$

To increase the measurement precision, it is recommended that the capacitance value of Capacitor C be chosen large enough, relative to the order of magnitude of R_2, so that time constant for the RC circuit (during the charging step) would be much larger than the program's timer clock.

To guarantee the measurement accuracy and be assured of the reproducibility of the output data, the software code can easily repeat the procedure as many times as the user wishes.

In order to calibrate the proposed light measuring system, a set of experimental tests was conducted in outdoor daylight by an illumination meter TES-1339 (TES Electrical Electronic Co.) and a linear relation between the charging elapsed period θ and sunlight illuminance IL was found as follows (also depicted in Fig. 5):

$$IL = -248.02\theta + 43259; \quad R^2 = 0.9783 \tag{4}$$

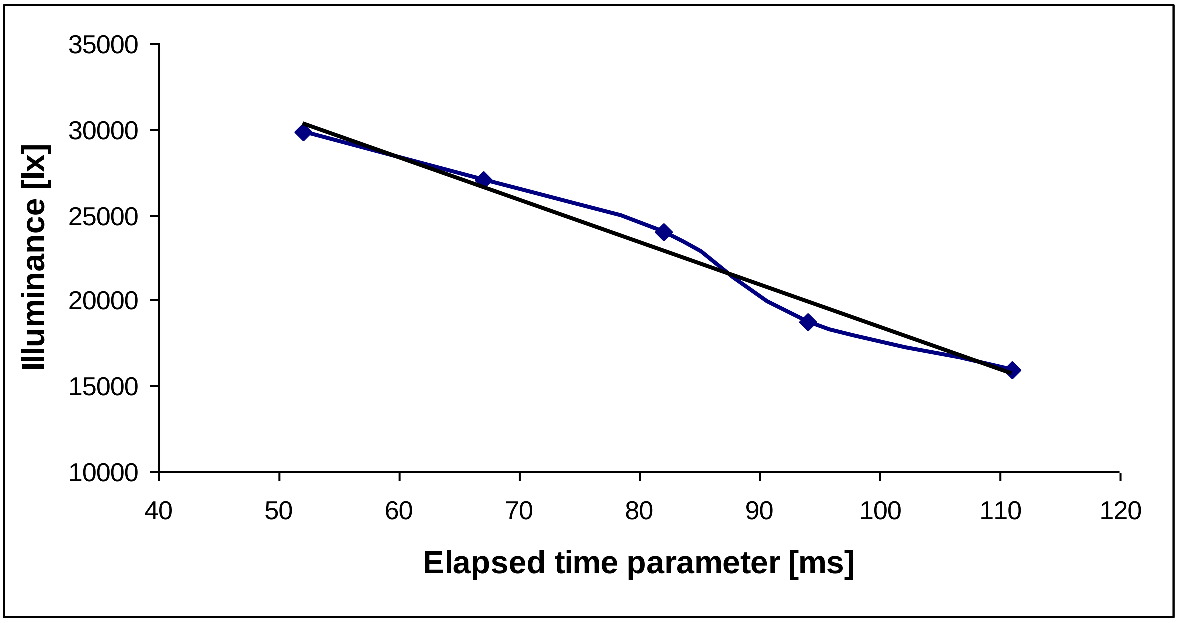

Figure 5. Relation between the elapsed period parameter θ and sunlight intensity

4. Conclusion

Light intensity as a key parameter in growth of microalgae for production of biodiesel has been emphasized in this work. Accordingly, a simple but effective system for measuring sunlight irradiance to photobioreactors or other microalgae cultivation media was proposed. The metering device mainly exploits capacitance measurement inside an *RC* electronic circuit. By establishment of a bijection between charging period of a known capacitor (named above as elapsed time parameter) and the resistance of a photoresistor, an LPT programmed computer code was made to sense sunlight intensity. The proposed system was calibrated by a commercial luxmeter and its calibration curve was found to be almost linear. The findings of this communication may contribute to research or operational works in the topic of sustainable production of biodiesels.

References and Notes

1. Chisti, Y. Biodiesel from microalgae. *Biotechnology Advances* **2007**, *25*, 294-306.
2. Malcata, F.X. Microalgae and biofuels: A promising partnership. *Trends in Biotechnology* **2011**, *29*, 542-549.
3. Amaro, H.M.; Guedes, A.C.; Malcata, F.X. Advances and perspectives in using microalgae to produce biodiesel. *Applied Energy*, **2011**, *88*, 3402-3410.
4. Lee, D.H. Algal biodiesel economy and competition among bio-fuels. *Bioresource Technology*, **2011**, *102*, 43-49.
5. Mata, T.M.; Martins, A.A.; Caetano, N.S. Microalgae for biodiesel production and other applications: A review. *Renewable and Sustainable Energy Reviews* **2010**, *14*, 217-232.

6. Rodolfi, L.; Zittelli, G.C.; Bassi, N.; Padovani, G.; Biondi, N.; Bonini, G.; Tredici, M.R. Microalgae for oil: Strain selection, induction of lipid synthesis and outdoor mass cultivation in a low-cost photobioreactor. *Biotechnology and Bioengineering,* **2009**, *102*, 100-112.
7. Sierra, E.; Acién, F.G.; Fernández, J.M.; García, J.L.; González, C.; Molina, E. Characterization of a flat plate photobioreactor for the production of microalgae. *Chemical Engineering Journal*, **2008**, *138*, 136-147.4.
8. Hsieh, C.-H.; Wu, W.-T. A novel photobioreactor with transparent rectangular chambers for cultivation of microalgae. *Biochemical Engineering Journal*, **2009**, *46*, 300-305.
9. Ahmad, A.L.; Mat Yasin, N.H.; Derek, C.J.C.; Lim, J.K. Microalgae as a sustainable energy source for biodiesel production: A review. *Renewable and Sustainable Energy Reviews* **2011**, *15*, 584-593.
10. Bitog, J.P.; Lee, I.-B.; Lee, C.-G.; Kim, K.-S.; Hwang, H.-S.; Hong, S.-W.; Seo, I.-H.; Kwon, K.-S.; Mostafa, E. Application of computational fluid dynamics for modeling and designing photobioreactors for microalgae production: A review. *Computers and Electronics in Agriculture* **2011**, *76*, 131-147.