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Research Paper

Developing an Algae Culturing System Using a Microcontroller Platform

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Abstract. Including *Spirulina platensis*, many microalgae have acquired an attention from a diverse field of research because of the highly applicable potentials on many global problems such as energy depletion and green house effects. Not only pharmaceutical or health related field, but also cosmetic science, petroleum engineering, electrical engineering, and other disciplinary fields showed vigorous attentions on this class of species. Because of this popularity, the consumption of the microalgae products rapidly increases and the necessity of the stable and efficient production of the microalgae arouse. However, the technical and financial limitations, stable mass production of microalgae are not easy tasks to solve. Precise control over the environmental conditions in the place where microalgae grow and timely supply of the necessary materials would be the most prerequisite requirements for the stable growth of the microalgae. This requirement might be sufficed by mass cultivation and automated microcontroller system. In this study, a microcontroller system of microalgae culture has been introduced with an Arduino. This microcontroller platform was applied for more effective culturing method, monitoring the multiple environmental conditions: temperature, light, carbon dioxide and monitoring pH change. Our result demonstrated that the algae concentration from the microcontroller group was 16.5% on average which was greater when compared to that from the algae group cultured in natural indoor conditions after 35 days of cultivation. The microcontroller system might be applied with more elaboration in the algae culturing technologies.

Keywords: Microalgae, growth control, Automated Growing System, *Spirulina platensis*, Environmental Control.

INTRODUCTION

At the reality of global problems in depletion of fuel sources and greenhouse effect, the algae industry has been gaining popularity these days. Among many species of algae, *Spirulina* was chosen to examine the performance of our microcontroller system. *Spirulina* is a unicellular and filamentous blue-green alga. Since ancient Chinese dynasty, the application of this aquatic algal and bacterial species has been used for various purposes, but mostly for the human health (Oshima, 2013). This traditional use has continued to relatively contemporary generation and, in the early 1950's, the upsurge in the world's population and calculations of a deficient protein supply led to an exploration for new innovative substitute protein reservoirs. Algal biomass emerged at that time as a good candidate for this purpose (Becker, 2004; Cornet, 1998). Meanwhile, the systematic examination of algae for biologically active substances, particularly antibiotics, began (Borowitzka, 1995). After people had discovered the possibility of usage for the improvement of antibiotic, countless pharmaceutical scientists and biochemists focused on this species as a novel reservoir of many medical applications. As a result, researchers found out the feasible antibacterial potentials from many cyanobacterial or algal species (Kulik, 1995; Schlegel *et al.*, 1998; Kumar *et al.*, 2009). Not only antibacterial

effect research but, algae also showed many different medicinal possibilities. Many species in the category of algae and cyanobacteria showed an anti-cancer effect in animal tests, and some of them are in the clinical trials currently. Especially *Spirulina platensis* which is the species we are focusing on this study showed antiviral, anti-epilepsy, and many other medically active performances (Singh *et al.*, 2011).

However, currently, the most popular application of *Spirulina platensis* is the dietary supplemental application (Belay *et al.*, 1996). No matter what the pharmacy store is, in the health supplement section, there are always the products with the name of "*Spirulina*". This is because of its high nutritional contents of the species (Tokuşoglu and Üunal, 2003). It contains many types of essential amino acids and minerals. Regarding mineral, this species possesses the extraordinary amount of iron. *Spirulina* contains 28.9mg of irons in 100g of the products, and this is 210% of the daily recommended intake. In addition, studies revealed the fact that *Spirulina platensis* possesses many types of vitamins. Especially it has a lot of vitamin B. The *Spirulina platensis* of 100 g can contain 207% of daily recommended intake amount of Thiamine (Vitamin B1) and 306% of daily suggested intake amount of Riboflavin (Vitamin B2) (Capelli and Cysewski, 2010). By these results of studies, many pharmaceutical or health supplemental companies highlighted the potential of *Spirulina platensis*, and currently, there are many goods that are available on the market.

Many nutritional and toxicological results have proved the suitability of algal biomass as the feed supplement (Spolaore *et al.*, 2006). *Spirulina platensis* is widely used in this area and concerns many types of animal: cats, dogs, aquarium fish, birds, horses, and breeding cows. Algae positively affect the physiology by providing an extensive profile of natural vitamins, minerals, and essential fatty acids; improved immune response and productivity; and better weight control and their external face resulting in clean skin and a lustrous coat of animals (Certik and Shimizu, 1999). In poultry divisions, algae up to a level of 5–10% can be used safely as the partial replacement for normal proteins. Prolonged feeding of algae at higher concentrations produces adverse effects. The yellow color of broiler skin and limbs as well as of egg center is the most important feature that can be influenced by feeding algae (Becker, 2004). Furthermore, the Institut für Getreideverarbeitung (Bergholz-Rehbrücke, Germany) provides a natural feed with the algae Chlorella and *Spirulina platensis* called "All Grow".

Although most of the studies had focused on the health-related projects, the field is not the only one application of *Spirulina platensis*. This species has been utilized for the source of the green energy (Rajvanshi & Sharma, 2012). Along with the upsurge of energy expense and the attention of environmental protection movement, petroleum engineers initiated using algae as a source of biofuel. Because of its containment of fatty acid, *Spirulina platensis* was one of the most potentate species for the application as a source of biofuel. Most of the algae for this application have grown up in the waste water, so the species has got attention as a solution to environmental problems in the contemporary generation (Abdel-Raouf, Al-Homaidan, and Ibraheem, 2012). In addition to this, electrical generation potential of this species also has studied a lot by the electrical engineers. Many of the studies related with this have conducted with the microbial fuel cells, and it also showed the great potential as a direct source of the electricity (Fraiwan and Choi, 2014)

Because of the many application of the species, the necessity of the growth control of the species has got attention from many scientists. For the many types of the studies using Spirulina platensis for the various applications, stable supply and fast growth of the species are needed. The purpose of our study is to develop a method to cultivate cyanobacteria using automatically controlled, closed system to achieve the goal of mass production of microalgae. Currently, many technical and economic obstacles prevent cultivation from scaling up from the laboratory to commercial operations (Rawat *et al.*, 2013). Since the commercially practical cyanobacteria culturing system has not been fully developed yet, the cost of biofuel from algae is higher than that of fossil-based petroleum fuels (Singh and Gu, 2010). Also, most of the algae culturing systems available today are structurally too complicated or rigorous to efficiently manage the algae. To effectively use algae as a primary source of biofuel, algae should be mass-cultivated under the optimal conditions (Ahmad *et al.*, 2011). Since an alga is an autotrophic organism, it requires sufficient amount of sunlight to produce biomass (Mata *et al.*, 2010). However, this has a relatively low biomass productivity since energy is required to convert carbon dioxide into biomass. Also, scientists are not clear yet whether closed or open system is best for commercial algae cultivation since there are advantages and disadvantages for both photo bioreactor and open ponds. If such problems are solved, then algae biofuel will be more commercially available. More people will be substituting a part of their fossil-based petroleum fuels with algae biofuel once the price of biofuel drops, becoming cost-competitive with fossil-based petroleum fuels (Olson, 2012). As more biofuel becomes available, some people might be able to be entirely dependent on biofuel only, eliminating the use of fossil-based oil fuel. The development of an efficient bioreactor for algae production is imperative to produce commercially viable fuel and create a healthier environment (Nigam and Singh, 2011).

Arduino is a microcontroller system that is applied here to control external conditions optimal for improved algal growth in coordination with peripheral sensors. The system is relatively easy to apply for actual engineering projects, compared to other software programs since anyone can have access to the knowledge of arduino, because it is born with an open source (Monk, 2012). Instructions can be sent to the Arduino board using the Arduino programming language, commanding it to sense temperature, light intensity, pH and carbon dioxide changes in the system and adjust the outputs for the control using the electric fan, heating lamp, or fluorescent bulb. This study was carried out to examine the growth pattern of spirulina in an isolated space for developing as a research-scale model under the microcontroller-controlled conditions. The objective of the present study was to introduce the arduino technology into the algae culturing field. Though, this paper was to examine first the possible application of the microcontroller platform into algae culture technology. Our research on more detailed parameters specific for growing algae should be continued for the following advancement.

EXPERIMENTAL METHODS

Materials and Reagents

The following materials have been purchased: Ultimate UNO R3 Arduino board with1602 LCD servo motor, relay, RTC, LED (China), Algae culturing kit (Algae Research Supply, Carlsbad, CA), Spirulina Culture (X System, CA), Chelated Iron for spirulina media (Spirulina System), CO2 Gas Sensor (Arduino compatible) SEN0159 (DFRobot, Shanghai, China), Analog pH Meter Pro (DFRobot, Shanghai, China), Tetra Whisper Air Pump, Water-proof DS18B20 Stainless steel encapsulated temperature sensor 1M cable (YourDuino.com), 100 nF of 50 Value 50V ceramic disc capacitor assortment kit (SKU092768, DFRobot), AM2302 DHT22 temperature and humidity sensor module for Arduino SCM (SKU146979, DFRobot), Light intensity sensor module 5528 photo resistor for AVR Arduino UNO R3 (China), Latex-free Super-soft vinyl gloves (CVS Pharmacy, NY), Research grade distilled water (CVS Pharmacy, NY), Power supply (Duracell, Bethel, CT), Digital Lux Meter EX10108B (China).

Preparation of Culture Vessel Cover Assembly

Two transparent acrylic plastic covers were created with the dimension of 25”x25”x18” for covering 10-gallon culture vessels (16.5”x12”x10.5”) in which *spirulina* was cultured. Therefore, there existed a chamber space between the culture vessel and plastic cover. Both of the covers were equipped with two electric fans each at opposite side that controlled air flow through a layer of antibacterial HEPA filter. One cover was assembled for the culture vessel that would be placed in the indoor bright room conditions, while the other was prepared for the culture vessel with microcontroller system in a cool and dark area. The cover was painted green to protect unwanted leakage of the light beam from outside into the controlled chamber space.

Microcontroller System Assembly

A rectangular acrylic panel (23”x16”) was obtained and reinforced with couples of 20 inch aluminum brackets for creating the structure to be rigid. Electronic parts and sensors were arranged on the panel, and fixed with screws and glues. And, all the parts were connected with electric wires according to a circuit diagram prepared before the assembly. The algae culturing system could control the temperature, light, carbon dioxide and pH by the microcontroller system. Briefly, when it sensed that the temperature in the chamber was higher than a specified range, then the system turned on the electric fan to decrease the temperature. On the other hand, when the system detected that the light intensity went down below the specified range, then it could make the fluorescent bulb brighter. The pH electrode was connected to the microcontroller system board that detected pH changes in the system and adjusted the pH levels manually according to a buzzer alarm along with a warning LED light on. In a descriptive manner of the microcontroller system, it might be explained as follows; The microcontroller board consisted of columns of analog pins and digital pins. The number of the analog pins started from A0 and A5, with which the system sensed its peripheral conditions, for example, A0 was used for CO_2 sensor, A1 for light intensity from algae growing monitor, A2 for temperature monitoring in the culture medium, A3 for temperature monitoring in the chamber space, A4 for light intensity monitoring in the chamber and A5 for light sensor from algae growing monitor, and A6 for pH monitoring, respectively. On the other hand, the number of digital pins were utilized from pin 6 to pin 12, with which the system executed the commands given by software sketch in response to the information from the analog pins as follows; digital pin 6 was used for pH alert with a warning LED light and buzzer sound, pin 7 for the light LED light and buzzer alert, pin 10 for operating the electric fan to cool down the system, pin 11 for the heating bulb to warm up the chamber, pin 12 for the LED and buzzer warning when the culturing medium temperature was out of range, and pin 13 for alarm for low CO_2 concentration, and for powering on the electric fan to increase the CO_2 concentration in the chamber. The microcontroller system monitored, executed the

computer code commands and gave off alarm sound along with LED lights accordingly.

Temperature-controlled System

The culturing medium temperature and the chamber space temperature were monitored simultaneously with two different sensors. The first sensor was the water-proof stainless steel encapsulated temperature sensor that sensed the culturing medium temperature and set off an alarm when it was out of range. The core functionality included its direct-to digital temperature sensor. The resolution of the temperature sensor was adjustable to 9, 10, 11, or 12 bits, corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively. The default resolution at power-up was 12-bit. The sensor was powered up in a low power idle state. To initiate a temperature measurement and A-to-D conversion, the master must issue a convert T command. Following the conversion, the resulting thermal data was stored in the 2-byte temperature register in the scratchpad memory, and the sensor returned to its idle state. When the sensor was powered by an external supply, the master could issue “read time slots” after the convert T command and the sensor would respond by transmitting 0 while the temperature conversion was in progress and 1 when the conversion was completed. When the sensor was controlled with parasite power, this notification technique could not be used because the bus must be pulled high by a strong pull-up during the complete temperature conversion.

The second temperature sensor was the temperature and humidity-combined sensor module which kept measuring the chamber temperature of the space between the culture tank and acrylic plastic cover. The sensor triggered the electric fans powered on to cool down the chamber space, while a heating lamp heated up the temperature in the space when it was out of range. The relative humidity module RHT03 output calibrated the digital signal. It applied exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability. Its sensing elements were connected with an 8-bit single-chip computer. Every sensor of this model was temperature compensated and calibrated in accurate calibration chamber, and the calibration-coefficient was saved in type of program in OTP memory when the sensor was detecting, it would cite coefficient from memory. The model RHT03 power supply should fall between 3.3 ~ 6V DC, and its output signal was digital signal via MaxDetect 1-wire bus sensing element polymer humidity capacitor. Its operating range moisture 0 ~ 100%RH; temperature –40 ~ 80 ºC with the accuracy humidity±2%; temperature ±0.5 ºC resolution or sensitivity humidity 0.1%; temperature 0.1 ºC. Our microcontroller software sketch was written to report the humidity on the serial monitor connected to a computer.

Control of Heating Bulb Control

The heating bulb was controlled with a relay and a fuse safety system. The relay system with a fuse box was harnessed to isolate high electrical power from the microcontroller system. Inside the relay were two paddles consisted of metal. One paddle was made of a ferrous material like steel and was free to move. The other paddle was made of copper, and it was stationary. When these paddles touched, they were capable of allowing a large amount of power to flow like 120 alternating current voltage with 30A.

The other half relay was called the coil. This coil was a small electro-magnet. When an electric current was flown through the coil, a magnetic force was created, which pulled on the iron paddle causing it to flip and touch the copper paddle as if you flipped a light switch. The coil required a small amount of power usually at 5 VDC with its current of 80mA.

In contrast to the function of the heating bulb, an electric fan was employed for cooling down the chamber space. The internal temperature in the algae culturing chamber could be warmed up by the heating bulb responded by a command of a temperature sensor TM35, installed with a combination with a transistor 1N4004. When the chamber temperature was higher than that of limitation defined in the microcontroller sketch, the electric fan was turned on to cool down the system. This assembly was operated with a temperature sensor, and the DC Motor turned on the fan when the temperature in the culturing chamber was higher than 35℃ degrees and off when the temperature was lower than 30 ℃ degrees. Therefore, the cooling system lowered the temperature down to the favorable range for the growth of the algae.

pH Monitoring System

A sensitive glass membrane with low impedance was allowed to make this industrial pH electrode. It could be applied in a variety of pH measurements with fast response and excellent thermal stability. It had good reproducibility and, it was hard to hydrolysis, and could remove basic alkali error. In pH 0.0 to pH 14.0 range, the output voltage was highly linear. The reference system which consisted of the Ag/AgCl gel electrolyte salt bridge had a stable half-cell potential and excellent anti-pollution performance. The ring PTFE membrane was resistant to be clogged, so the electrode was optimized for long-term online detection. It was used with a module power of 5.00Vwith the dimension of module size of 43mmx32mm （1.70"x1.26"). The measuring range fell within pH 0.0 to pH 14.0 under the temperature of 0 ~ 60℃. It had the accuracy of pH±0.1 at 25℃ with response time of less than 1.0 minute. The module was equipped with the industry pH electrode with BNC connector and pH 2.0 interface,

gain adjustment potentiometer and power indicator LED.

Before the electrode in continuous use, the unit should be calibrated by the standard solution to obtain more accurate results. The best environment temperature was about 10 - 50℃, and the pH value was known and reliable, close to the measured value. When the acidic sample was measured, the pH value of the standard solution should be 4.01. When the alkaline sample was measured, the pH value of the standard solution should be 10.0. Subsection calibration, was to get a better accuracy. According to the linear characteristics of the pH electrode itself, after the calibration, the unit could directly estimate the pH value of the alkaline solution. Alkaline calibration used the standard solution whose pH value was 10.0. Also, adjust the potential gain device; let the value stabilize at around 10.0. After this calibration, the pH electrode could measure the pH value of the alkaline solution for a long-term basis.

CO_2 Controlled System

The CO2 sensor should display the CO2 concentration in the chamber and turned on the electric fan when its value was lower than 360 ppm in the container. The CO2 sensor worked as follows: The output voltage of the module fell as the concentration of the CO2 increased. The potentiometer on board was designed to set the threshold of voltage. As long as the CO2 concentration was high enough, a digital signal should be released. It equipped with MG-811 sensor module onboard which was highly sensitive to CO2 and less susceptible to alcohol and CO, low humidity and temperature dependency. On board heating circuit brought the best temperature for the sensor to function. Internal power boosting to 6V for heating sensor best performance. This sensor had an onboard conditioning circuit for the amplifying output signal. The CO2 sensor had its dedicated 5V 2A power supply, and it could be read in a steady output voltage of 4.1V. The voltage was required to trigger any response above 350 ppm according to the formula was around 2.75V. To get the sensor to read anything the ppm should be above 350 ppm. The CO_2 electrode was not calibrated after purchased, because it was applied as the values as set in factory default.

The Summary of Completed Culturing System

The completed microcontroller system was leaned and taped carefully on the back side of the culture vessel in a closed acrylic plastic cover chamber that was equipped with antibacterial HEPA filters and electric fans. The system could sense multiple parameters and responded accordingly. For example, when the chamber space was higher than 35℃, it turned on an electric fan to cool down the climatic temperature. On the other hand, when it sensed lower than 30℃, it turned on the heating bulb. It also sensed pH, water temperature, light intensity. On the other hand, a sound alerts and a warning LED light was activated when the parameters moved out of a specified range in the software sketch. The CO2 sensor displayed the CO2 concentration in the chamber and turned on the electric fan when its value was lower than 360 ppm in the chamber, until it reached back to 400 ppm.

The algae culturing system monitored the conditions of ambient environment for 24 hours with 12/12 light and dark cycle. It sensed the temperature in water and air, humidity, pH, light intensity and acts as coded in the microcontroller system. The system might be able to culture the *spirulina* more efficient way in a bench-sized research scale.

Algae Culturing Procedures

Alter all the microcontroller platform was completed along with its software development and placed as intended, the culturing *spirulina* used in this study was purchased from Spirulina Systems (CA) with culture medium formulated with a series of minerals including salt petre, sea salt, Epsom salt, iron chelate, sea mineral, potash, and ammonium phosphate. The five gallon of original *spirulina* medium was poured into the two culture vessels 2.5 gallon each. By the recommendation of the *spirulina* suppliers, the ready-made culturing medium that dissolved in distilled water by 1:2 dilutions, was added up to 5 gallons of initiation culturing condition into the culture vessels. One of the culture vessel was left in the dark area for controlling the optimal culturing conditions with the microcontroller system, while other culture vessel was placed in the bright indoor conditions. Ant, both of the culture tanks were covered with the acrylic plastic assemblies described previously.

RESULTS AND DISCUSSION

The algae culture was maintained in two 10-gallon culture vessels either with or without a microcontroller system that was equipped with multiple sensors such as temperature, humidity, light, CO2 and pH. The microcontroller system controlled the peripheral activators according to the magnitude of the sensing variables. Because this preliminary study was mainly focused on the application of the microcontroller platform, the calibration data deemed important. The devices were calibrated according to the manufacturer's recommendations, before they were harnessed, if required.

Calibration of the pH Electrode

Before using the pH electrode, its calibration was carried

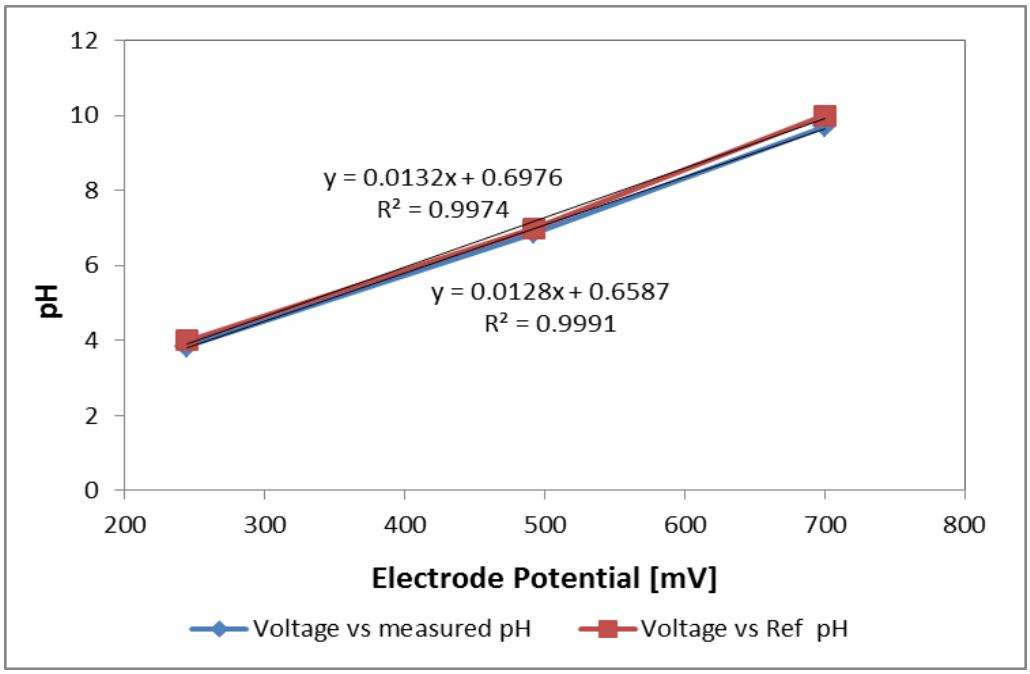

Figure 1. The electrode potential was measured with reference pH solution which showed high correlations (Mean of n=6).

out with three pH standard solutions, pH 4.0, pH 7.0 and pH 10.0. Figure. 1 below shows the pH output when the electrode immersed into the standard solutions. The graph illustrated the high linearity for the relations between pH and electrode potential. As seen in the figure, the voltage dimension could be understood as a relative number from the sensor simply according to the pH of the solution. The initial electrode output was obtained when measured before the calibration with the regression coefficient R^2 equal to 0.9974, which confirmed the high performance of our pH electrode. On the other hand, the squared line was drawn with the pH after offset with the pH calibration. And, it showed a minor increase of the linearity coefficient up to R^2 0.9991. This industrial quality of pH electrode did not need to perform a frequent calibration, and had the capability to remain in the culture medium during the period of the whole study. The pH variation in this study was recorded with a range of pH 9.5 to pH 10.5.

Calibration of Light Sensor

The correct measurement of the light intensity should be carried out for algae culture to survive on the light. Despite the fact that the light intensity should be constant mostly in the culturing tank, any perturbation on the light intensity should be getting attention through an alarm. A lux meter was used to evaluate the linearity of the light sensor output according to the light intensity. There existed a linear relation between sensor value and light intensity with regression coefficient R^2 of 0.9965 as shown in Figure. 2. For the unit conversion from the sensor value to light intensity, the linear function was incorporated into the software sketch. The light to the algae might be the same to be a food for any animal. Therefore, its intensity was assumed to be an important factor to be monitored. However, the intensity of bulb light was not changed significantly, and there was no buzzer sound during the study.

In the study, the light intensity in the bright room conditions were changed with the range of 400 luces to 3800 lux which was changed by the natural light near the window. The variation in light intensity was greater, compared to the group of controlling microcontroller system. In contrast, the light intensity in the controlled system was changed relatively less on 2400±150 lux on average.

Algae Concentration with a Light Sensor

The method used in this study could be seen as a spectrophotometry. An algae meter was created with an opaque-painted plastic tube with the length of 10 cm (4.0 cm O.D.). Inside of the tube, an LED light was installed on the wall in the middle and glued waterproof, while a light sensor was placed just opposite side of the LED for reading the light intensity from the LED, assuming that the light intensity should be proportionally decreased by the concentration of the algae which would block the light. The output of light

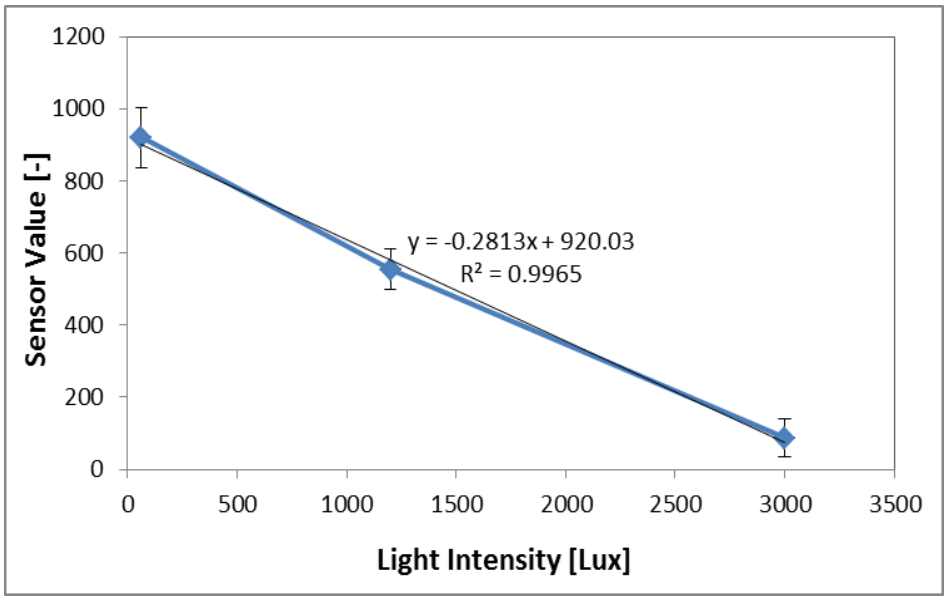

Figure 2. The Calibration of our Light Sensor (Mean±STD, n=6)

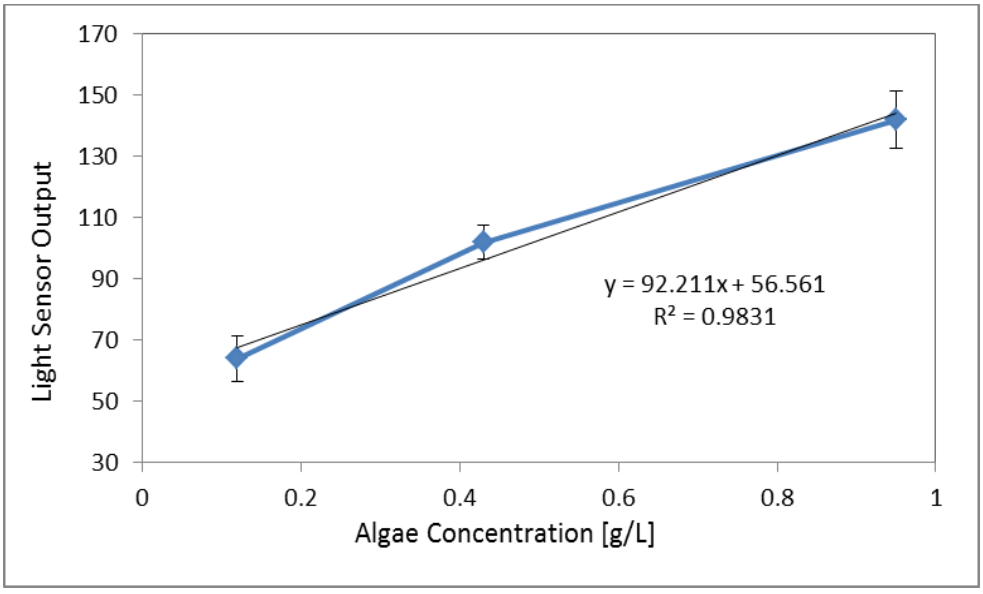

Figure 3. The relation of light sensor output and algae concentration was highly linear with the regression coefficient R^2 was equal to 0.9831 (Mean±STD, n=6).

sensor was proportional to the algae density as illustrated in Figure. 3. Technically, the LED was lighted on first, and light sensor measured the light intensity through the green water (N=6). For the calibration, 300 mL of well-grown culture water was obtained and it was serially diluted 2 times. By immersing our algae meter into each solution, the light sensor value was obtained from the serial monitor and plotted as seen below. With a filtering method through a coffee filter, the algae concentrations of the three diluted solution were evaluated.

Algae Growth Curve

The algae meter was lowered into the algae culturing medium. Using the calibrated algae meter as above, the density of *spirulina* was measured on the same day for both fish tanks. We could monitor the growth pattern for six weeks after starting culturing with the *spirulina* solution received from the company. Through the experiments, the instruction of the *spirulina* culture from the manufacturing company was followed. As seen in Figure. 4 below, the growing pattern with respect to the

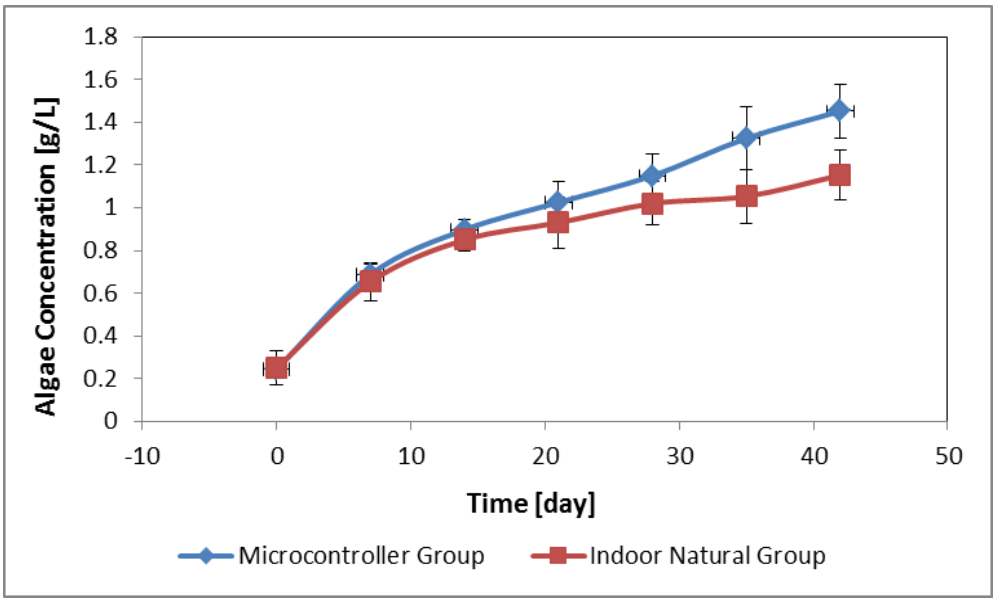

Figure 4. The data showed the growth speed difference between the automatic system and natural control with the room temperature in the laboratory. Automatic control system shows better performance in raising Spirulina (Mean±STD, n=6).

algae concentration demonstrated the similar growing curves published from other groups (Mahrouqu *et al.*, 2015; Walter *et al.*, 2011). When compared to our two study groups, the result demonstrated that the algae biomass from the microcontroller group was 16.5% on average which was greater when compared to that from the algae group cultured in natural indoor conditions after 35 days of cultivation. The microcontroller system might be applied with more elaboration in the *spirulina* culturing technologies.

This study has been done as a first step for fine-tuning this method for further in-depth study. In the future, more attention will be paid for better growing the algae with greater biomass.

In summary, we cultured *Spirulina* in two culture vessels with plastic covers with and without the microcontroller system. The culture vessels were placed at comparable places; one at sunny indoor room condition, while the other at a controlling system at a dark place.

For both cases, culture medium pH was monitored during the study, and it usually changed from 9.5 to 10.5. The electrical heater controlled the medium temperature. Therefore, its temperature was mostly constant from 30ºC to 35 ºC as controlled by the system. Light intensity was 2400 lux±150 with 12/12 light/dark cycle, while the room temperature group was under the fluorescent light near the window with a blinder that was open in a half-way. No direct light was beamed on the culturing tank directly. The microcontroller system reported CO2 concentration from 350 ppm to 400 ppm as oscillated by the activation of electric fan.

CONCLUSION

We assembled an automatically controlled system for efficient culturing of *spirulina*. We could monitor the growth pattern for five weeks after starting culturing with the *Spirulina* solution received from the company. Using the calibrated algae meter as above, we could successfully measure the density of *spirulina* on the same day for both fish tanks. The data showed that the algae concentration from the microcontroller-controlled group was 16.5% higher than that from no control group in room conditions after 35 days of incubation. More study might be necessary for the confirmation of culturing conditions maintained by the microcontroller platform in future research. According to the advancement of sensor technologies and coding skills, it might come a prime time to adapt the burgeoning microcontroller systems for culturing algae more efficiently in bench-scaled research laboratory.

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