International Journal of Research in Engineering, Science and Management
Volume 7, Issue 12, December 2024
https://www.ijresm.com | ISSN (Online): 2581-5792

Remote Web and IoT-Based Growth Chamber Monitoring System for in Vitro Microalga Optimation

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***Abstract*: Based on the Strategic Plan of the Institut Teknologi Sepuluh Nopember, the proposed field of research excellence is related to innovation, namely the growth chamber for in vitro microalgae culture that can be controlled remotely. The objective of this project is to design and develop a smart incubator grow system for plants by developing the open source hardware and software platforms for sensor-controlled systems. Inside of this smart incubator, climate variables such as carbon dioxide, air temperature, pH, salinity can be controlled and monitored, through wireless connectivity technology. The system can be monitor and control through wireless connectivity technology, which is I/O port technology to build a software control platform, displaying data from the sensors in real time through data acquisition to the host computer. Data from the three sensors are collected to the sensor node, then sent to the gateway via websocket, then forwarded to firebase which will be displayed on the web interface. On the computer, a graphical interface will appear in real time to control the system in the growth chamber in order to achieve a conditioned growth environment. The results showed that this tool can be used to grow microalgae cultures according to the required conditions, and can be used for researchers who need accurate and remote data.**

***Keywords*: innovation, growth chamber, microalgae, real time, web interface.**

1. Introduction

Microalgae is photosynthetic organisms that have various potentials and important applications in various fields, including biological sciences, renewable energy, biotechnology, and the environment [1]. Microalgae has become one of the research concerns due to their biomass potential for renewable energy sources and bioproducts. However, until now, large-scale microalgae development is still constrained, mainly due to high culture costs. The efficiency of large-scale cultivation of microalgae is essential to save costs and successfully utilize microalgal biomass as a candidate for renewable energy. The culture method is the most commonly used method that aims to obtain the highest abundance of algae cells with optimal nutrient content [2]. Algae culture requires careful maintenance and monitoring, as well as adjusting the culture environment according to the cultured microalgae species.

Microalgae growth is influenced by several external (environmental) factors that greatly affect the rate of growth and metabolism [3]. According to [4], factors that affect microalgae growth include light intensity, temperature, nutrients, aeration, dissolved oxygen, pH, and salinity, which in turn affect the amount of biomass and products produced. These are some external factors that influenced microalga growth, such as:

a. *Lighting:* Different light intensities can affect microalgae growth. Some studies have shown that microalgae growth can be enhanced by the use of high-intensity lighting at certain spectra.
b. *Temperature*: Temperature also affects microalgae growth. Research shows that higher temperatures can increase the growth rate of microalgae, but only to a certain extent before growth begins to decline.
c. *Nutrients*: Nutrients such as nitrogen, phosphorus, and carbon also affect microalgae growth. The addition of nutrients can increase microalgae growth, but only to a certain extent before growth begins to decline.
d. *Population Density*: The population density of microalgae in the growth chamber can also affect growth. Too high a population density can inhibit microalgae growth.
e. *Environmental Conditions*: Environmental factors such as pH, salinity, and the presence of chemicals also affect microalgae growth.

This requires specialized equipment that can better control environmental parameters [5], [6], and [7]. Growth chamber is like a designed container to assist plant growth with some special features to modify the microclimate in the chamber. Microclimate elements can be adjusted to the needs of the microalgae culture, so that it can grow well without having to be planted in a certain area [6]. An embedded system is a computer system with a specific function to integrate with all the sensors, hardware and mechanical parts with real-time computing constraints. The smart growth chamber has sensors to combine with the hardware inclusive of temperature, salinity,

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and mild intensity. Those sensors, led and hardware are connecting with microcontroller or board computer. There are several unique I/O features found on present microcontrollers [8]. The advantage of smart incubator grow system for plants can be monitored and handled via cell phone through the application. The system will monitor everything that your plants need to grow, including light, temperature, salinity nutrient levels and pH of the alga's growth mediums.

2. Material and Methods

A. Specifications of Smart Growth Chamber

The components of the smart growth chamber are as follows

a. The first part, as a tool control system with dimensions of 40x40x95 cm^3, which contains a CO2 gas cylinder, mini CPU, temperature control components, humidity, pH, nutrient pump, water pump, moist generator, power supply, and power LED, which is made of hardplex wood.
b. The second part, made of glass, with dimensions of 80x50x40 cm3, which functions as a growth chamber, where micro algae containers will be observed for the growth process until the harvest period arrives under certain environmental conditions.

In addition, there is a series of sensors to monitor conditions in the growth chamber in real time consisting of:

1) Relay Module 4 Channel

A 4-channel relay module is a device used to control electrical devices by using signals from a microcontroller or other automation system. This relay module allows users to turn on or off electrical devices such as lights, motors, and other electronic devices by using signals from a microcontroller (e.g. Arduino). Relays can be used in timer applications, where devices can be turned on or off automatically after a certain period. These relays are connected to motor pumps, gas switches, and LED lights [9].

Fig. 1. Relay module 4 channel

2) ESP32 WIFI Controller

The ESP32 is a Wi-Fi and Bluetooth microcontroller used in various IoT (Internet of Things) projects and other applications. This component is connected to various types of sensors and I/Os (Input/Output) that connect various additional devices such as temperature sensors, humidity sensors, LEDs, and others. Furthermore, this component is connected to the internet which is integrated with a database [10]. Wifi ESP32 is a chip and includes a processor, memory and access to GPIO. So, the ESP32 Wifi Module can replace Arduino and can support wifi networks directly [11].

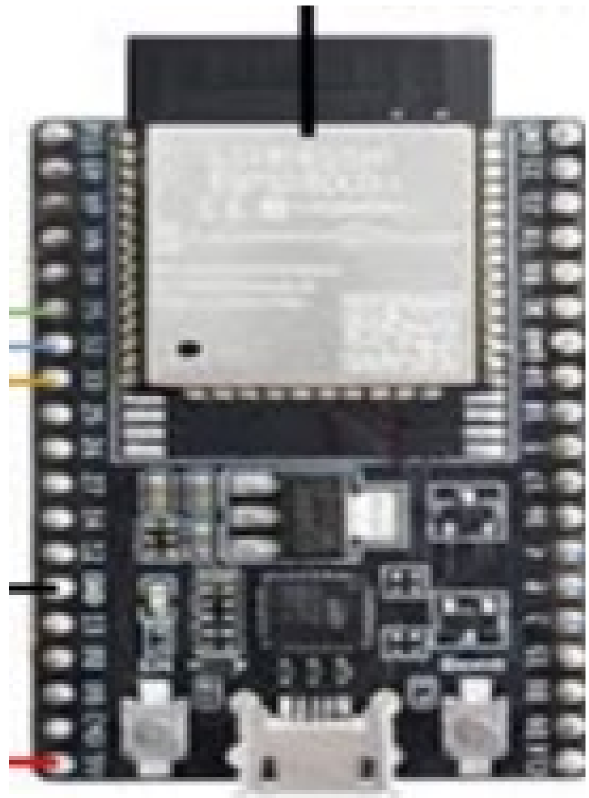

Fig. 2. ESP32 WIFI controller

3) 4502C pH Meter Sensor

Fig. 3. 4502C pH meter sensor

The 4502C pH meter sensor is a device used to measure the acidity or basicity of a solution, and has high accuracy, with some studies showing that accuracy can reach 98% or more. (pH sensors are often used with microcontrollers such as

Arduino to convert analog signals from sensors into digital data that can be further processed. The water pH meter sensor is a sensor used to measure the pH level in water which affects the life in the water. The indication of the pH meter itself is pollutants, if the pH is abnormal then there are pollutants indicated by pH values ranging from 1 to 5, and the H + activity of water is greater than OH- and is considered acidic. Conversely, a water pH greater than 7, the OH- activity of water is higher than H + and is considered basic [12].

4) DS18820 Temperature Sensor

The DS18B20 temperature sensor is a digital temperature sensor used in various applications, including IoT system development and temperature measurement. It has a very high temperature resolution of 0.5°C, and can measure temperatures from -55°C to 125°C. This sensor uses the One-Wire protocol, which allows communication with the microcontroller through a single cable [13]. Furthermore, the DS18B20 sensor has a unique 64-bit serial code, which functions to make it easier to control the sensor in a very large area [14].

Fig. 4. 4502C pH meter sensor

5) Salinity Sensor

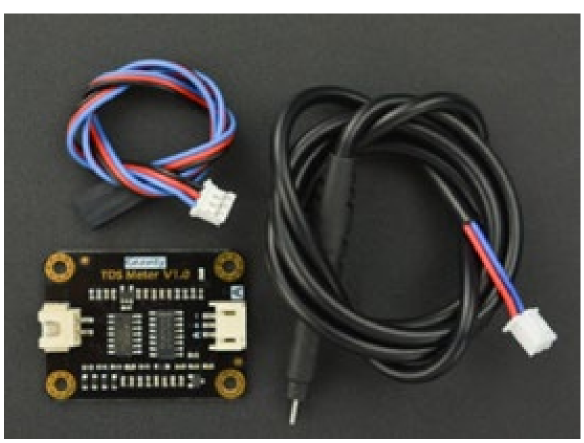

Fig. 5. Analog TDS/Salinity Sensor

The Analog TDS Sensor/Meter is a device used to measure the purity and mineral content contained in water or salinity levels. Two probes are immersed in a liquid or solution then the signal processing circuit will produce an output showing the conductivity value of the solution in units of Part Per Million (PPM). The device is compatible with Arduino, allowing users to integrate it with IoT projects or water monitoring systems, via analog pins, allowing TDS data to be sent to the microcontroller and further processed [15].

B. Smart Growth Chamber System Design

In the general design of the smart growth chamber system includes the design of the sensor node gateway itself which functions in collecting all data from each sensor node. There is also a gateway design with a database, then between the database to the client which functions to store all the data collected from the gateway and can be observed in real time.

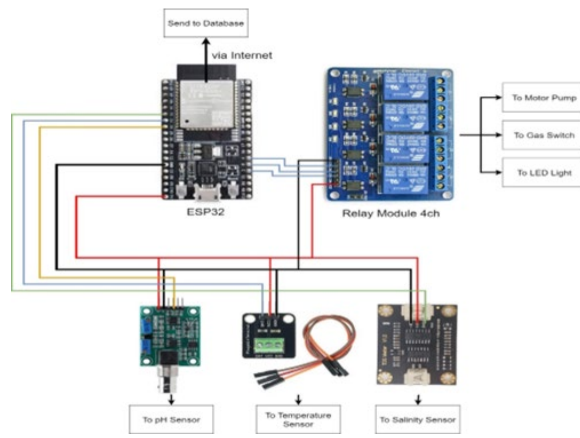

Fig. 6. Smart growth chamber system design

The figure above shows communication can occur in a system. Communication between the ESP32 gateway requests data from the ESP32 sensor node, then from the ESP32 sensor node will send data to the ESP32 Gateway, which is obtained from each sensor node, namely temperature, pH and salinity. Furthermore, communication occurs between the ESP32 gateway to the database. The database functions to request data to be stored and display the output results to the web.

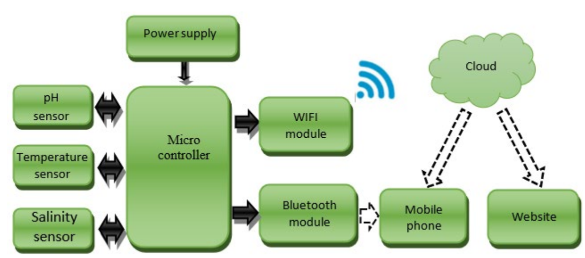

Fig. 7. Block diagram of the system design

Block diagram of the smart growth chamber system in the above figure shows three sensors that have been integrated in this work that are supposed to monitor certain parameters in the chamber, such as temperature, salinity, and pH. These parameters are vital and need to be monitored and controlled in order to ensure that microalga in the chamber are well-kept.

The information and signal that obtain from the system will trigger actuator to manage the sensors and LED rays inside the smart growth chamber. Furthermore, it collected the pH, temperature and salinity data on the database through the communication device. Moreover, the embedded server has the interface application for the system which connect to the single board computer and hand phone through wireless. As a result, the environment inside the incubator available to be monitor via mobile phone and website.

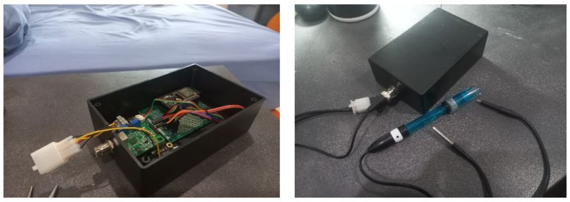

Fig. 8. Integration all sensors and components in the communication device

Fig. 9. Graphical user interface (GUI) system

The smart monitoring system utilizes a microprocessor (ESP32 Wifi controller) to process the commands and tasks that are programmed in it to use the connected sensors such as 4502C pH meter sensor to monitor the pH levels of the nutrient treated water inside the reservoir, DS18820 temperature sensor, and analog TDS/salinity sensor, which is the fed to a Graphical User Interface (GUI) that can be accessed and monitored by the researchers at anytime and anywhere. GUI is a user interface that uses images and symbols to interact with a computer. A GUI allows users to monitor, operate and control computer or network software and operating systems in a more interactive way, compared to a text interface (CLI) that uses only text commands. GUI monitor systems can usually display data in real-time, allowing users to identify problems immediately. The data collected on the database, obtained from the previous sensor nodes, will be received and displayed by the GUI as shown in Figure 9.

C. Trial Test Procedure

Trial test of the smart growth chamber was conducted by placing a container of microalga in the chamber area. There are several steps to use the tool and connect it to the web system. The following is a flowchart of the smart growth chamber trial procedure:

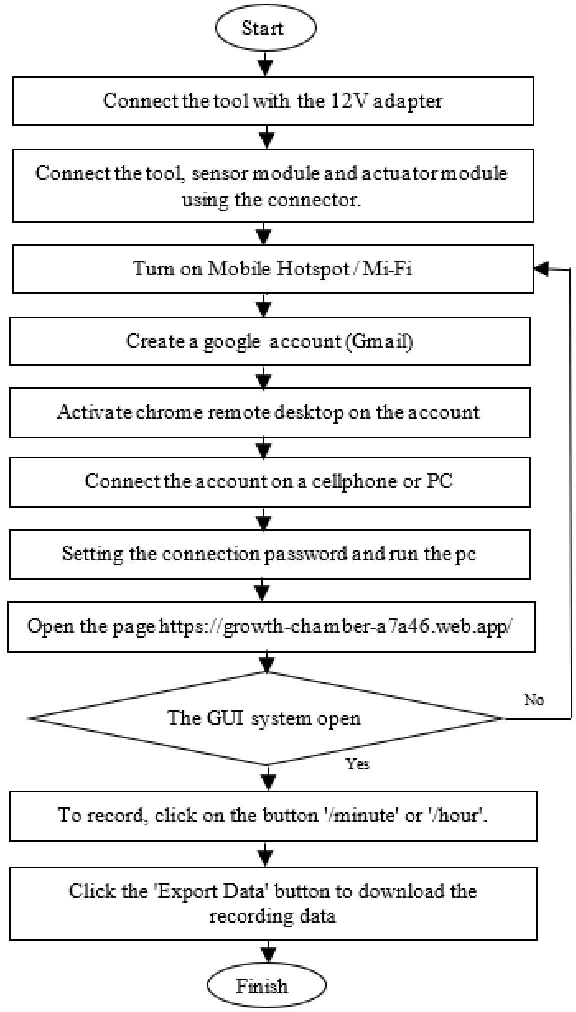

Fig. 10. The smart growth chamber trial test flowchart

3. Results and Discussion

The smart growth chamber is installed and LED strips are deployed on the indoor system in order to control the light ray which act like sunlight at the outdoor environment. Below is the design of the smart growth chamber.

Fig. 11. The smart growth chambers

Remote control system is used to monitor the microalga growth in the smart growth chamber, that can be access both form PC web or phone web. Following is the remote-control system that is accessed from PC Web.

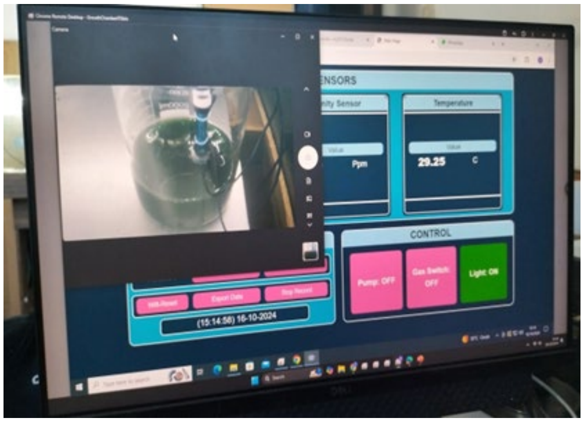

Fig. 12. Remote control system using PC web

A. *Testing of Sensors*

The three sensors installed in the smart growth chamber were tested on the microalga sample in the beaker glass. The test results show that all three sensors can function and generate data. From each sensor node sends data to the gateway, and the gateway is forwarded by Firebase and displayed both on the PC web and the mobile web. Testing was carried out by inserting all sensors such as temperature sensor, pH sensors, and turbidity sensor, into a beaker glass containing microalgae samples then left for a while. The table 1 shows the results from the testing sensors nodes.

B. *Results Research*

Table 1
Sensors monitoring system result's test

Time	pH Value	Salinity Value (‰)	Temperature (°C)
11:21:56	8.35	33.64	25.5
11:22:56	8.25	33.64	25.5
11:23:56	8.24	33.5	25.5
11:24:56	8.21	33.5	25.5
11:25:56	8.36	33.65	25.5
11:26:56	8.24	33.65	25.5
11:27:56	8.29	33.5	25.5
11:28:56	8.29	33.5	25.44
11:29:56	8.27	33.67	25.5
11:30:56	8.32	33.67	25.44
11:31:56	8.17	33.66	25.44
11:32:56	8.35	33.66	25.44
11:33:56	8.31	33.5	25.44
11:34:56	8.41	33.5	25.44
11:35:56	8.37	33.67	25.44
11:36:56	8.36	33.67	25.44
11:37:56	8.29	33.67	25.37
11:38:56	8.33	33.5	25.37

Environmental factors are very determined in the culture or cultivation of microalgae. One of the environmental factors that needs attention is pH (degree of acidity) so that the metabolism of microalgae cells are not disturbed. Degree acidity or pH is described as the presence of hydrogen ions. The degree of acidity (pH) affects the solubility and availability of mineral ions thus affecting nutrient uptake by cells. Changes in pH value values can significantly affect enzyme work and inhibit the process of photosynthesis and microalgae growth [16]. pH is an important factor affecting microalgae growth. Microalgae generally show optimal growth at neutral or slightly alkaline pH (around 7-8). The table above shows that microalga can grow well in alkaline water and photosynthesis rates are optimal to make microalga grow in the smart growth chamber. pH affects the metabolism and growth of microalgae cultures by altering the inorganic carbon balance, changing nutrient availability and affecting cell physiology. In an alkaline environment, CO_2 is in a free form so that it can diffuse easily into microalgae cells This causes CO_2 as the main carbon source for the photosynthesis process of microalgae to be sufficiently available so that metabolic processes can take place quickly and cell density increases [17].

Environmental temperature is one of the important factors affecting microalgae growth. Generally, microalgae grow well at temperatures between 15°C and 35°C, and some microalgae species can even tolerate a wider range of temperatures [18]. Research above shows that microalgae grow well at temperatures around 25°C. Temperature has a direct influence on the effectiveness of photosynthesis. Increasing temperature can increase the activity of photosynthetic enzymes, but too high a temperature can cause chloroplast degradation and cellular structure loss. Appropriate temperature helps maintain the conformational stability of hydrophobic and hydrosoluble enzymes cooperating in the metabolic process of microalgae, so that they can effectively perform functional functions. Proper temperature makes the lipids of membrane components flexible, so that membrane permeability functions well in absorbing essential ions and nutrient molecules, which are necessary for microalgae to grow optimally [19].

Salinity is one of the significant environmental factors that affect microalgae growth and productivity. Microalgae can be found in a variety of environments, ranging from freshwater to seawater, and each species has a different salinity tolerance [20]. The results showed that the algae belonged to the Halophilic Microalgae class, which is this species can survive and grow at high salinities (20-50‰). The effect of salinity on microalgae growth includes maintaining osmotic balance, so that the water balance in microalgae cells is maintained. The right salinity can increase the production of biomass and secondary metabolites, such as lipids and carotenoids. in addition, salinity affects microalgae cell morphology. Some species may experience changes in cell size or shape in response to changes in salinity [21].

The last factor that also important for microalga growth is light. Light is the main source of energy for microalgae through the process of photosynthesis. Sufficient light intensity is essential to support growth. Microalgae typically require light intensities between 100 to 500 µmol m^-2 s^-1 for optimal growth. However, too much light can cause photoinhibition, where chlorophyll is damaged by excess radiation. In addition, light quality (wavelength) also affects photosynthetic efficiency; blue and red light are generally more effective than green light [22].

4. Conclusion

The smart growth chamber that has been made is capable of growing microalga until optimum. It uses a remote monitor web system that can display data in real time, allowing users to identify problems immediately.

Acknowledgments

The researcher would like to thank all those who have helped the completion of this research. Directorate of Research and Community Service, Special Research for Non-Educational Staff 2024, In Accordance With The Research Implementation Agreement Letter No: 1290/PKS/ITS/2024, as well as other parties that cannot be mentioned one by one.

References

[1] Budiman, A. 2019. Mikroalga, Kultivasi, Pemanenan, Ekstraksi, dan Konversi Energi. UPT. Perpustakaan Politeknik Negeri Banjarmasin. Gadjah Mada University Press.
[2] Buwono, N. R., & Nurhasanah, R. Q. 2018. Studi Pertumbuhan Populasi Spirulina sp. Pada Skala Kultur yang Berbeda. Jurnal Ilmiah Perikanan Dan Kelautan, 10(1), Article 1.
[3] Fachrullah, M.R. 2011. Laju pertumbuhan mikroalga penghasil biofuel jenis Chlorella sp. dan Nannochloropsis sp. yang dikultivasi menggunakan air limbah hasil penambangan timah di Pulau Bangka. (Skripsi). Fakultas Perikanan dan Ilmu Kelautan. IPB, pp. 3-11.
[4] Hadiyanto, & Azim, M. (2012). Mikroalga: Sumber Pangan & Energi Masa Depan (1st Ed.). Undip
[5] K. Gray, "MIT's incubator-grown plants might hold key to food crisis," Wired magazine, Oct. 2014.
[6] D. Dik, E. Polyakova, A. Chelovechkova, V. Moskvin, and T. Nikiforova, "The System of Environment Control of Botanic Garden Greenhouses," in 2018 International MultiConference on Industrial Engineering and Modern Technologies (FarEastCon), 2018, pp.1–7.
[7] Darkó, P. Heydarizadeh, B. Schoefs, and M. Sabzalian, "Photosynthesis under artificial light: The shift in primary and secondary metabolism," Philos. Trans. R. Soc. Lond. B. Biol. Sci., vol. 369, p. 20130243, Mar. 2014.
[8] Y. Zhou, Y. Xie, and L. Shao, "Simulation of the core technology of a greenhouse-monitoring system based on a wireless sensor network," Int. J. Online Eng., vol. 12, no. 5, pp. 43–47, 2016
[9] Irmayani, A., Asrul, Muh., dan Kaliky, N. 2020. Desain Bangun Ayakan Alat Mesin Tanaman Perkebunan. Jutkel: Jurnal Telekomunikasi, Kendali Dan Listrik. Vol. 2, No.1, pp. 12-22, 2020.
[10] Rifky, I. 2021. Miktokontroler ESP32. Universitas Raharja. https://raharja.ac.id/2021/11/16/mikrokontroler-esp32-2/
[11] Arafat, 2016. Sistem Pengamanan Pintu Rumah Berbasis Internet of Things (IoT) Dengan ESP8266. Technologia. 7(4), pp. 262-268.
[12] Patil, K., Patil, S., Patil, S. & Patil, V. 2015. Monitoring of Turbidity, PH & Temperature of Water Based on GSM. International Journal for Research in Emerging Science and Technology, 2(3).
[13] Anonymous. 2021. Menggunakan Sensor Suhu DS18B20 pada Arduino. Universitas Medan Area.
[14] Maximintegrated, 2019. Programmable Resolution 1-Wire Digital Thermometer. Washington: Maxim Integrated Products, Inc.
[15] Y. Irawan, A. Febriani, R. Wahyuni, and Y. Devis, "Water quality measurement and filtering tools using Arduino Uno, PH sensor and TDS meter sensor," J. Robot. Control, vol. 2, no. 5, pp. 357–362, 2021.
[16] Gunawan. 2012. Pengaruh Perbedaan pH Pada Pertumbuhan Mikroalga Klas Chlorophyta. Universitas lambaung mangkurat. Kalimantan Selatan. BIOSCIENTIAE Volume 9, No. 2, 62-65, 2012.
[17] Reynolds C.S. 1984. The Ecology of Freshwater Phytoplankton, Cambridge University Press, Cambridge.
[18] Belay et al., (2019) "Optimization of Temperature for Growth and Lipid Production by Microalgae" *Journal of Algal Research*, Vol. 11(12): pp. 101032.
[19] Zhang et al., (2018), "Temperature Effects on Cellular Structure and Functionality of Green Algae" *Frontiers in Plant Science*.
[20] Gómez et al., (2018) "Effect of Salinity on Growth and Lipid Production of Microalgae" *Journal of Applied Phycology*, Vol. 30(4): pp. 2231-2240.
[21] Renaud et al., (2016) "Salinity Effects on the Growth and Biochemical Composition of Microalgae" *Aquaculture Research*, Vol. 47(6): pp. 1823-1834.
[22] Khan et al., (2018) "Effects of Light Intensity and Quality on the Growth and Photosynthetic Efficiency of Microalgae" *Journal of Applied Phycology*, Vol. 30(4): pp. 2231-2240.