

DESIGNING A SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM FOR PHOTO-BIOREACTOR

*Submitted in partial fulfillment of the requirements for the award of Bachelor of
Technology degree in Biotechnology*

BY

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **HAVINESH KUMAR U (40230013)**, **YUVARAJA T (40230049)** who carried out Project entitled "**Designing a Supervisory Control and Data Acquisition (SCADA) System for Photo- Bioreactor**" under my supervision from September 2023 to April 2024.

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I, **Yuvaraja .T (40230049)**, hereby declare that the Project Report entitled **“Designing a Supervisory Control and Data Acquisition (SCADA) system for Photo- Bioreactor”** done by me under the guidance of **Dr.V.Ramesh Kumar** at the Centre for Bioresource Research and Development, Department of Biotechnology, Sathyabama Institute of Science and Technology, Chennai, is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Biotechnology.

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ABSTRACT

When SCADA (Supervisory Control and Data Acquisition) systems are incorporated into fully automated photobioreactors, they become pivotal components, essentially acting as the brains behind the operation. Their role is to oversee and regulate crucial parameters essential for the optimal cultivation of microalgae, such as temperature, pH levels, agitation, and other environmental factors. Through the utilization of a network of sensors strategically positioned within the photobioreactor, SCADA systems continuously collect real-time data, providing operators with comprehensive insights into the current state of the cultivation process. One of the primary functions of SCADA systems in this context is precise control. Operators can remotely adjust and fine-tune various parameters to ensure that the conditions within the photobioreactor remain within the ideal range for microalgae growth. For instance, if the temperature begins to deviate from the desired setpoint, the SCADA system can automatically trigger the activation of heating or cooling systems to swiftly restore optimal conditions. Similarly, adjustments to pH levels can be made through the control of CO₂ injection or nutrient dosing, ensuring that the microalgae are provided with an environment conducive to their growth and development. Moreover, SCADA systems play a critical role in managing agitation within the photobioreactor. Proper agitation is essential for maintaining uniform distribution of nutrients and preventing sedimentation of microalgae.

Keywords

Automated photobioreactor, *Chlorella vulgaris*, Sensors, Biomass concentration, Sustainability

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LIST OF ABBREVIATIONS

SCADA - Supervisory Control and Data Acquisition

PLC - Programmable Logic Controller

HMI - Human-Machine Interface

RTU - Remote Terminal Unit

PID - Proportional-Integral-Derivative (controller)

LED - Light-Emitting Diode

LDR - Light-Dependent Resistor

CO₂ - Carbon Dioxide

pH - Potential of Hydrogen

DO - Dissolved Oxygen

IoT - Internet of Things

GUI - Graphical User Interface

ADC - Analog-to-Digital Converter

DAC - Digital-to-Analog Converter

PWM - Pulse Width Modulation

OPC - OLE for Process Control

TCP - Transmission Control Protocol

SCADA RTU - SCADA Remote Terminal Unit

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CHAPTER-1

INTRODUCTION

1.1. Background of Photobioreactors

Photobioreactors are specialized bioreactors designed for the cultivation of photosynthetic organisms such as microalgae, cyanobacteria, and plants, using light as the primary energy source. They offer a controlled environment for optimizing growth conditions and are used in various applications, including biofuel production, wastewater treatment, and the production of high-value compounds (Chisti, 2007). The concept of photobioreactors emerged from the growing interest in renewable energy sources and the need for sustainable production methods. Researchers have explored various photobioreactor designs, ranging from open ponds to closed-loop systems, each with their advantages and limitations (Brennan and Owende, 2010). Efficient light utilization is a key factor in photobioreactor design, as it directly impacts the growth and productivity of photosynthetic organisms (Zhang et al., 2016). Factors such as reactor geometry, light distribution, and mixing play crucial roles in optimizing light utilization efficiency.

Photobioreactor Design Considerations

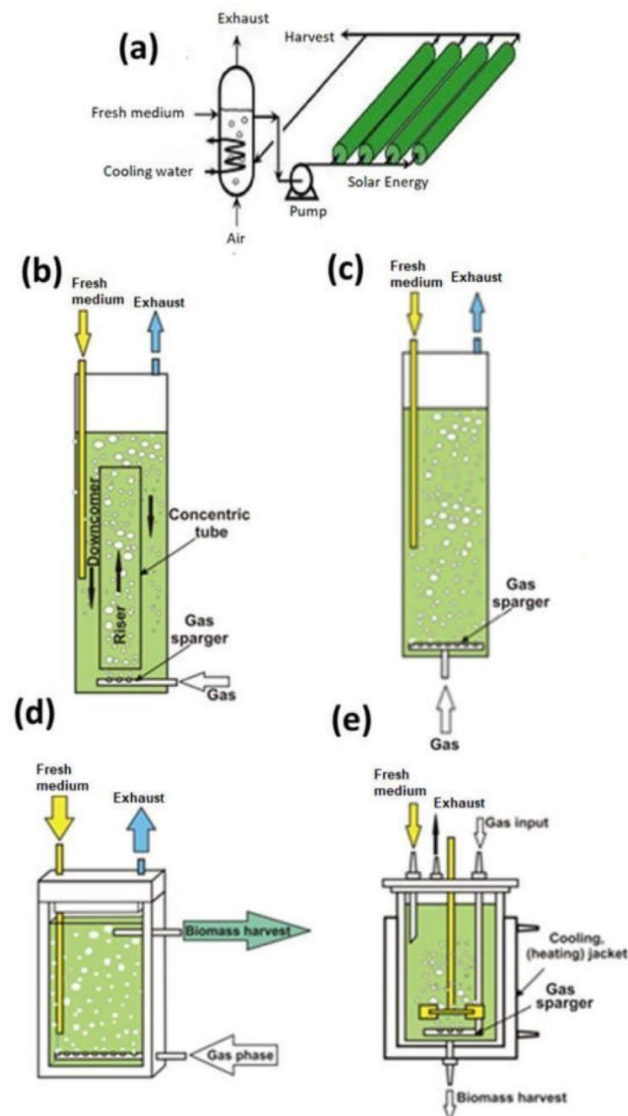


Fig: 1.1: Recent Developments on the Performance of Algal Bioreactors for CO₂ Removal: Focusing on the Light Intensity and Photoperiods (Zarook Shareefdeen, et al.,)

In recent years, there has been a growing interest in integrating monitoring and control systems into photobioreactors to enhance their performance and productivity. SCADA (Supervisory Control and Data Acquisition) systems have been used to monitor and control key parameters such as temperature, pH, and nutrient levels, enabling real-time adjustments and automation (Muñoz and Guzmán, 2017). Overall, photobioreactors represent a promising technology for sustainable bioproduction, with ongoing research focused on improving their efficiency, scalability, and cost-effectiveness.

1.2. Importance of SCADA Systems in Photobioreactors

SCADA systems offer a range of benefits for monitoring and controlling photobioreactors. Real-time monitoring capabilities allow operators to continuously track crucial parameters like temperature, pH, dissolved oxygen, and nutrient levels (Muñoz and Guzmán, 2017). This immediate feedback enables quick detection of deviations from optimal conditions, facilitating timely corrective actions to maintain the health and productivity of photosynthetic organisms.

The automation features of SCADA systems are particularly valuable, enabling the automated control of processes such as nutrient dosing, pH adjustment, and light intensity modulation. Automation not only reduces the need for manual intervention but also ensures that conditions are consistently maintained within the desired range, leading to enhanced efficiency and productivity of the photobioreactor.

Another key advantage of SCADA systems is their data logging and analysis capabilities. These systems can store vast amounts of data over time, allowing for in-depth analysis and optimization of photobioreactor operation (Chisti, 2007).

By analyzing historical data, operators can identify trends, patterns, and areas for improvement, ultimately leading to better performance and productivity.

Remote access and control are also significant benefits of SCADA systems. Operators can access and monitor the photobioreactor from anywhere with an internet connection, enabling greater flexibility and convenience. This remote accessibility is particularly useful for researchers and operators managing multiple photobioreactors or monitoring them from off-site locations.

Safety and security are paramount in photobioreactor operation, and SCADA systems incorporate several features to address these concerns (Muñoz and Guzmán, 2017). Built-in safety features such as alarms and emergency shutdown procedures help protect the photobioreactor from potential hazards. Additionally, SCADA systems implement robust security measures to prevent unauthorized access and ensure the integrity of data and control systems.

1.3. Algal biomass production in a photobioreactor

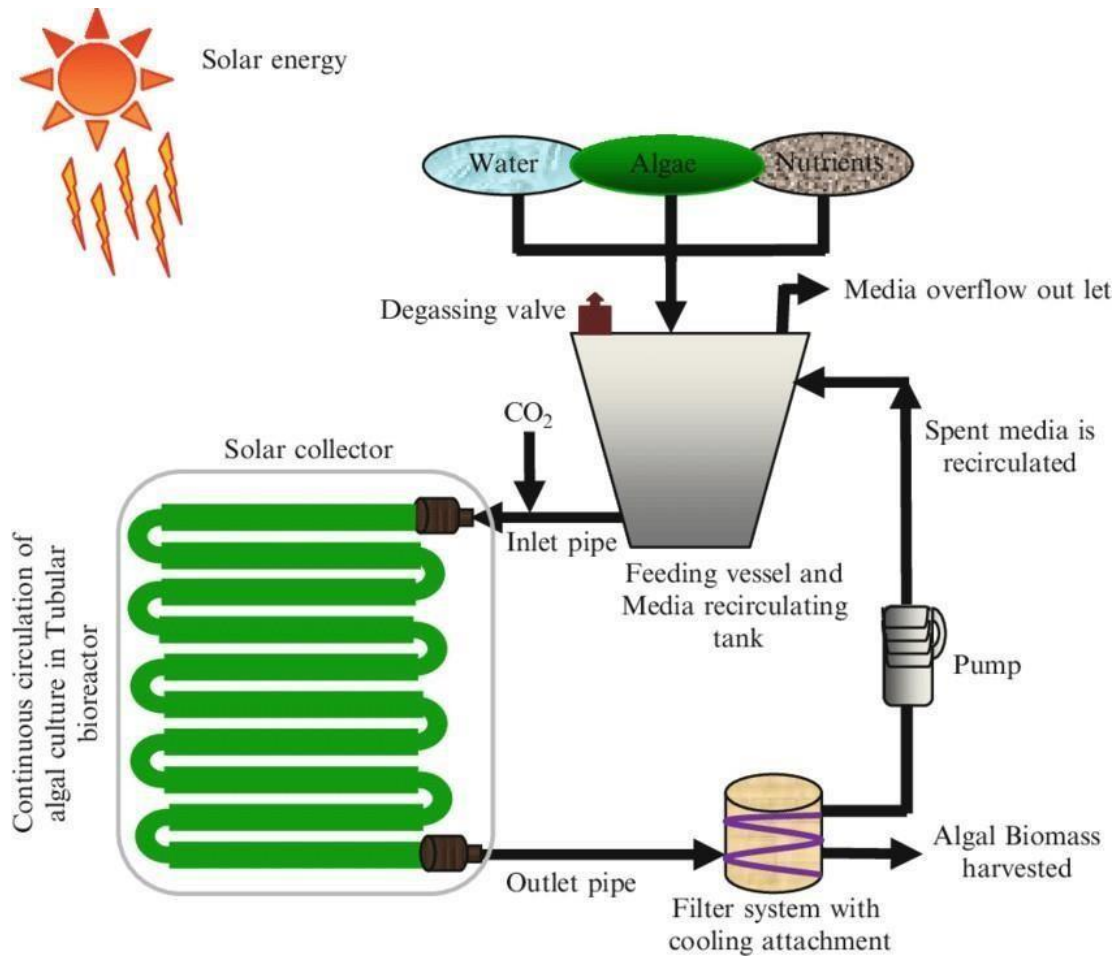


Fig: 1.2: Approaches and Prospectives for Algal Fuel (Brennan and Owende, 2010).

Algal Strain Selection: The choice of algal strain is a critical factor influencing biomass productivity in photobioreactors. Different strains have varying growth rates, lipid contents, and environmental tolerances (Chisti, 2007). For example, *Chlorella vulgaris* is often favored for its rapid growth and high lipid content,

making it suitable for biofuel production. Other strains, such as *Spirulina* and *Nannochloropsis*, are preferred for their high protein content, making them valuable for food and feed applications. The selection of the most appropriate strain depends on the specific goals of the cultivation project, such as maximizing biomass yield or optimizing product quality.

Optimal Growth Conditions: Algae require specific environmental conditions to thrive and maximize their growth potential. These conditions include appropriate light intensity, temperature, pH, and nutrient levels. Light intensity affects photosynthesis rates, with different strains having varying light requirements. Temperature influences metabolic rates and growth rates, with most algae species thriving in temperatures ranging from 20 to 30°C (Chisti, 2007). pH levels need to be maintained within a specific range (typically between 6.5 and 8.5) to ensure optimal growth and nutrient uptake. Additionally, algae require nutrients such as nitrogen, phosphorus, and micronutrients, which are supplied in the form of fertilizers or specialized growth media.

Light Source: The choice of light source is crucial for providing the necessary energy for photosynthesis. Light-emitting diode (LED) lights are often preferred for their energy efficiency and ability to emit specific wavelengths of light that are optimal for photosynthesis. LED lights can be tailored to emit wavelengths that correspond to the absorption peaks of chlorophyll a and b, maximizing light absorption by the algae. Additionally, LEDs generate less heat compared to other light sources, reducing the need for cooling systems in the photobioreactor.

Nutrient Supply: Algae require nutrients for growth, including macronutrients such as nitrogen, phosphorus, and potassium, as well as micronutrients such as iron, manganese, and zinc. These nutrients are typically supplied in the form of fertilizers or specialized growth media. The composition and concentration of nutrients in the growth medium need to be carefully controlled to avoid nutrient imbalances or deficiencies, which can inhibit algal growth.

Harvesting Methods: Harvesting algae from the photobioreactor can be challenging due to their small size and low settling rates (Brennan and Owende, 2010). Common harvesting methods include centrifugation, which uses centrifugal force to separate algae from the growth medium, filtration, which uses filters to

capture algae, and flocculation, which involves the addition of chemicals to clump algae together for easier separation. Each method has its advantages and disadvantages, and the choice of harvesting method depends on factors such as the size of the operation, the desired purity of the harvested biomass, and the cost of the method.

Biomass Monitoring: Monitoring the growth of algae is essential for optimizing productivity and ensuring the health of the culture. Various techniques can be used to monitor biomass growth, including optical density measurements, which estimate biomass concentration based on the scattering of light by algae cells, chlorophyll fluorescence, which measures the fluorescence emitted by chlorophyll molecules and is proportional to photosynthetic activity, and cell counting, which involves manually counting algae cells under a microscope (Brennan and Owende, 2010). These monitoring techniques provide valuable insights into the growth dynamics of the culture and help identify any issues that may arise during cultivation.

CO₂ Supply: Carbon dioxide (CO₂) is essential for algal growth, as it is a key substrate for photosynthesis. CO₂ can be supplied to the photobioreactor from various sources, including industrial emissions, fermentation processes, or CO₂ cylinders. The availability of CO₂ can significantly influence algal growth rates and biomass productivity, making it important to ensure a stable and adequate supply of CO₂ to the culture.

Scale-up Considerations: Scaling up algal biomass production from a lab-scale photobioreactor to a commercial scale requires careful planning and consideration of various factors. These factors include reactor design, nutrient supply, harvesting methods, and overall process efficiency. The design of the commercial-scale photobioreactor needs to take into account factors such as scalability, efficiency, and cost-effectiveness. Additionally, nutrient supply needs to be optimized for the larger scale of operation, and harvesting methods need to be efficient and cost-effective. Overall, scaling up algal biomass production requires a systematic approach and close attention to detail to ensure a successful transition from lab to commercial-scale production.

1.4. Algal Biomass Used in Various Sectors:

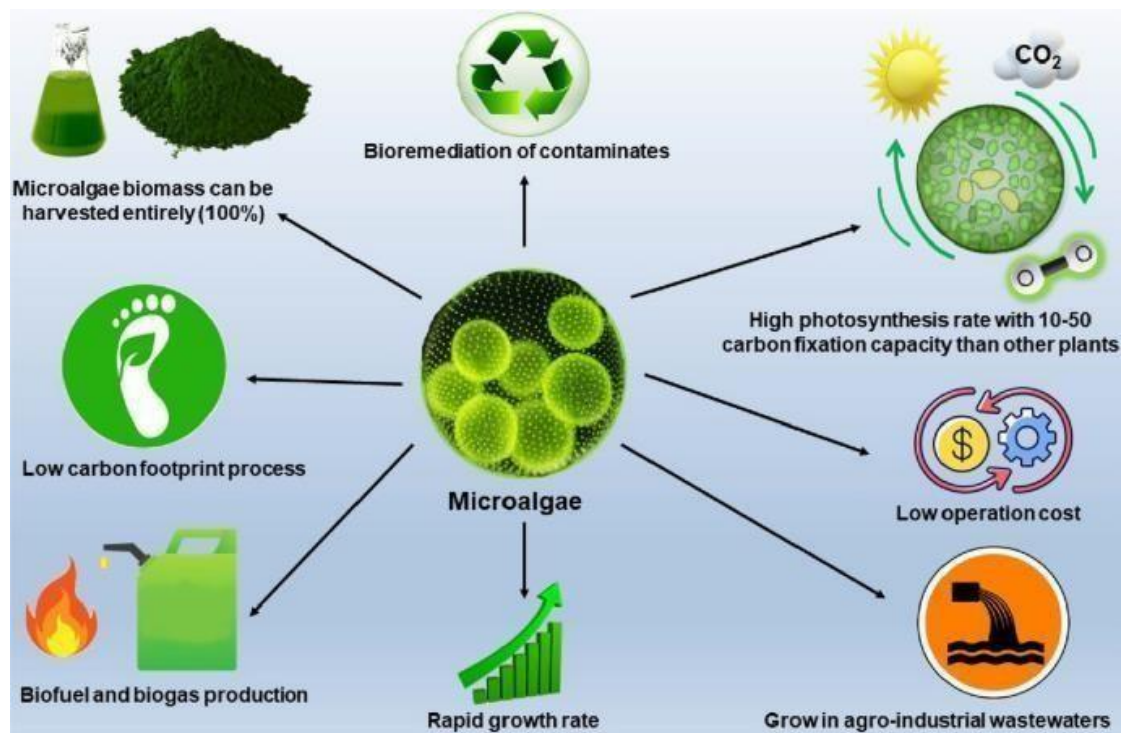


Fig:1.3: Algal biomass valorization for biofuel production and carbon sequestration: a review (Chisti, 2007).

Biofuels:

Algal biomass can be converted into various types of biofuels, including biodiesel, bioethanol, and biogas. These biofuels are considered sustainable and environmentally friendly alternatives to fossil fuels. Algae can produce high yields of biomass and can be grown in a wide range of environments, making them a promising source of renewable energy.

Animal Feed:

Algal biomass is rich in proteins, lipids, vitamins, and minerals, making it a nutritious feed supplement for livestock and aquaculture. Algae can be used to enhance the nutritional content of animal feed, improve animal health, and reduce the environmental impact of livestock production.

Food and Nutraceuticals:

Some algae species are edible and can be used as food sources for humans. Algae are rich in essential nutrients such as omega-3 fatty acids, antioxidants, and vitamins, making them valuable for functional foods and nutraceuticals. Algal-derived products are used in dietary supplements, health foods, and food additives.

Pharmaceuticals:

Algae produce a variety of bioactive compounds with potential pharmaceutical applications. These include antibiotics, antiviral agents, anti-inflammatory compounds, and anticancer drugs. Algal-derived pharmaceuticals are used in the treatment of various diseases and disorders.

Cosmetics:

Algal extracts are used in cosmetics and personal care products for their moisturizing, antioxidant, and anti-aging properties. Algae-derived compounds are also used in skincare products for their beneficial effects on the skin. Algal extracts can improve skin hydration, reduce inflammation, and protect against environmental damage.

Bioremediation:

Algae can be used for bioremediation purposes to remove pollutants such as heavy metals, nitrogen, and phosphorus from wastewater and industrial effluents. Algae can also be used to capture CO₂ from industrial flue gases, helping to mitigate climate change. Algal-based bioremediation technologies are environmentally friendly and cost-effective.

Agrochemicals:

Algae-derived bioactive compounds can be used in the production of environmentally friendly pesticides, herbicides, and fertilizers. These compounds can help to improve crop yields, reduce the use of synthetic chemicals, and promote sustainable agriculture practices.

Bioplastics:

Algal biomass can be used to produce biodegradable plastics as a sustainable alternative to conventional plastics derived from fossil fuels. Algal-based bioplastics are biodegradable, renewable, and have a lower environmental impact compared to traditional plastics.

Reactor Type: The selection of the appropriate reactor type is a critical decision that depends on various factors such as the type of organisms being cultured, the desired production scale, and the available space. Common types of photobioreactors include tubular, flat-panel, column, and airlift reactors, each offering unique advantages and limitations. Tubular reactors, for example, are well-suited for large-scale production due to their high surface area-to-volume ratio, while flat-panel reactors are more compact and easier to scale up. Column reactors provide efficient light exposure and are suitable for high-density cultures, while airlift reactors offer good mixing and aeration capabilities. The choice of reactor type can significantly impact the overall efficiency and productivity of the algal cultivation process.

Reactor Volume and Geometry: The design of the photobioreactor should carefully consider the optimal volume and geometry to maximize the surface area exposed to light while ensuring efficient mixing and nutrient distribution. Factors such as the aspect ratio, surface area-to-volume ratio, and light path length should be taken into account to optimize light penetration and nutrient uptake by the algae. A well-designed reactor geometry can enhance light utilization efficiency and promote uniform algal growth throughout the culture medium.

Material Selection: Selecting the right materials for constructing the photobioreactor is crucial for ensuring its performance and longevity. Materials such as glass, acrylic, and polycarbonate are commonly used due to their transparency, durability, and compatibility with the culture medium. These

materials allow for adequate light transmission while providing protection against corrosion and contamination. The choice of material should also consider factors such as cost, availability, and ease of fabrication, ensuring that the photobioreactor meets the specific requirements of the algal cultivation process.

Mixing and Aeration: Efficient mixing and aeration are essential for maintaining uniform nutrient distribution and preventing cell settling in the photobioreactor. Various mixing systems, such as bubbling, stirring, or recirculation, can be employed to achieve the desired level of mixing and aeration. The selection of the mixing system should consider factors such as energy efficiency, scalability, and the ability to maintain optimal growth conditions for the algae. A well- designed mixing and aeration system can improve nutrient uptake by the algae and enhance overall productivity.

Light Source: The selection and positioning of the light source are critical for providing the required light intensity and spectrum for photosynthesis. Factors such as light source efficiency, heat generation, and scalability should be considered when choosing a light source for the photobioreactor. LED lights are commonly used due to their high efficiency and controllability, allowing for precise control over the light conditions in the reactor. The light source should be positioned to ensure uniform light distribution throughout the reactor and to minimize shading effects, ensuring that all algae receive adequate light for photosynthesis.

Temperature Control: Maintaining optimal temperature is crucial for the growth of photosynthetic organisms in the photobioreactor. The design should include provisions for temperature control, such as heating and cooling systems, to ensure a stable and conducive environment for algal growth. Temperature control is particularly important in outdoor photobioreactors, where temperature fluctuations can occur due to environmental factors. A well-designed temperature control system can help optimize algal growth rates and improve overall productivity.

Contamination Control: Preventing contamination of the algal culture is essential for maintaining the purity and viability of the culture. This can be achieved through the use of sterile culture media, aseptic techniques, and the

implementation of a closed-loop system to minimize the risk of contamination. Contamination control measures should be integrated into the design of the photobioreactor to ensure that the culture remains free from unwanted organisms throughout the cultivation process.

1.5. Selection of Sensors and Actuators

Temperature Sensors: Monitoring and controlling temperature is crucial for the growth of photosynthetic organisms in a photobioreactor. Sensors such as thermocouples or resistance temperature detectors (RTDs) are commonly used to measure the temperature of the culture medium. These sensors provide real-time data on temperature, allowing for precise control of the environmental conditions inside the reactor. By maintaining the optimal temperature range for algal growth, the sensors help maximize productivity and ensure the health of the culture.

pH Sensors: pH is a critical parameter that can significantly impact the growth and metabolism of photosynthetic organisms. pH sensors, such as glass electrodes or ion-selective electrodes, are used to monitor the acidity or alkalinity of the culture medium. These sensors provide accurate and reliable pH measurements, enabling operators to maintain the pH within the optimal range for algal growth. By controlling the pH, the sensors help prevent fluctuations that can be detrimental to the health of the culture and ensure consistent growth rates.

Dissolved Oxygen Sensors: Adequate oxygen supply is essential for the respiration of photosynthetic organisms and the maintenance of aerobic conditions in the culture. Dissolved oxygen sensors, such as optical probes or electrochemical sensors, are used to monitor the concentration of dissolved oxygen in the culture medium. These sensors provide real-time data on oxygen levels, allowing for adjustments to the aeration rate to ensure optimal oxygenation of the culture. By maintaining the dissolved oxygen concentration within the desired range, the sensors help prevent oxygen limitation and promote healthy algal growth.

Light Sensors: Light is a key factor in photosynthesis, providing the energy necessary for algal growth. Light sensors, such as photodiodes or light- dependent resistors (LDRs), are used to measure the intensity of light inside the photobioreactor. These sensors provide feedback on the light conditions, allowing operators to adjust the light source to maintain the optimal light intensity for photosynthesis. By optimizing the light conditions, the sensors help maximize the photosynthetic efficiency of the culture and promote higher growth rates.

Actuators for pH Adjustment: To control the pH of the culture medium, actuators such as valves or pumps are used to dose pH-adjusting chemicals into the reactor. The actuators are controlled based on the readings from the pH sensors, ensuring that the pH remains within the desired range. By automating the pH adjustment process, the actuators help maintain a stable pH environment for the culture, promoting consistent growth rates and minimizing the risk of pH-related stress.

Actuators for Light Intensity Control: To control the intensity and duration of light exposure, actuators such as dimmable light sources or motorized shades are used. These actuators are controlled based on the readings from the light sensors, allowing operators to adjust the light conditions to meet the needs of the culture. By providing precise control over the light intensity, the actuators help optimize the photosynthetic efficiency of the culture and promote healthy growth.

1.6. SCADA System Architecture

Supervisory Control and Data Acquisition (SCADA) Software: The SCADA software serves as the central component of the system, providing the user interface for monitoring and controlling the photobioreactor. It includes features for data visualization, alarm management, and data logging.

Programmable Logic Controllers (PLCs) or Remote Terminal Units (RTUs): PLCs or RTUs serve as the interface between the SCADA software and the photobioreactor hardware. They collect data from sensors and actuators and execute control commands based on the instructions from the SCADA software.

Communication Infrastructure: The communication infrastructure connects the SCADA software to the PLCs or RTUs and enables real-time data exchange. This

can include Ethernet, Modbus, Profibus, or other industrial communication.

Data Acquisition Modules: Data acquisition modules interface with sensors and actuators to collect real-time data and transmit it to the PLCs or RTUs. They may include analog-to-digital converters, digital I/O modules, and communication interfaces.

Human Machine Interface (HMI): The HMI provides the operator with a graphical interface to interact with the SCADA system. It displays real-time data, alarm notifications, and allows the operator to send control commands to the photobioreactor.

Historian Database: The historian database stores historical data collected by the SCADA system, allowing for trend analysis, performance monitoring, and report generation.

Alarm System: The alarm system notifies operators of any abnormal conditions or system failures. It can include audible alarms, visual alarms, and notifications sent to mobile devices or email.

CHAPTER-2

LITERATURE SURVEY

2.1. *Chlorella vulgaris* Cultivation in a photo-bioreactor:

Studies have shown that *Chlorella vulgaris* exhibits optimal growth at moderate light intensities, typically in the range of 100 to 200 $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$. Higher light intensities can lead to photoinhibition, while lower intensities can limit growth (Converti *et al.*, 2009). The optimal temperature for *Chlorella vulgaris* growth is typically in the range of 25 to 30°C. Temperatures outside this range can reduce growth rates and biomass productivity (Converti *et al.*, 2009). *Chlorella vulgaris* thrives in slightly alkaline conditions, with an optimal pH range of 7.5 to 9.0. Deviations from this range can affect nutrient uptake and metabolic processes, leading to reduced growth rates (Richmond, 2004). Studies have shown that *Chlorella vulgaris* requires specific nutrient concentrations for optimal growth, including nitrogen, phosphorus, and trace elements. Nutrient limitation or excess can negatively impact growth and biomass productivity (Converti *et al.*, 2009). Providing a suitable light/dark cycle is essential for *Chlorella vulgaris* growth. Studies have shown that a 16:8 light/dark cycle is optimal for maximizing biomass productivity (Rasoul-Amini *et al.*, 2019). Proper mixing and aeration of the cultivation medium are important for maintaining uniform growth conditions and ensuring adequate nutrient supply to the algae. Insufficient mixing or aeration can lead to nutrient depletion and reduced growth rates (Mata *et al.*, 2010). *Chlorella vulgaris* requires carbon dioxide for photosynthesis and biomass production. Studies have shown that supplementing the cultivation medium with CO₂ can enhance growth rates and biomass productivity (Hu *et al.*, 2008). The quality of the water used for cultivation can also impact *Chlorella vulgaris* growth. Studies have shown that using high-quality water with low levels of contaminants is important for maximizing biomass productivity (Zhang *et al.*, 2016).

Open pond systems are the most common and cost-effective method for cultivating *Chlorella vulgaris*. These systems rely on natural sunlight and can be simple to construct and operate. However, they are susceptible to contamination and require large land areas (Richmond, 2004). Closed photobioreactor systems offer more control over cultivation conditions, including light intensity, temperature,

and nutrient supply. These systems can achieve higher biomass productivity and reduce the risk of contamination. However, they are more expensive to construct and operate compared to open ponds (Rasoul-Amini *et al.*, 2019). Hybrid cultivation systems combine features of open ponds and closed photobioreactors. For example, a closed photobioreactor may be used for seed culture production, which is then transferred to open ponds for large-scale cultivation. This approach can optimize biomass productivity and reduce costs (Converti *et al.*, 2009). Several studies have compared the performance of different cultivation systems for *Chlorella vulgaris*. These studies have evaluated biomass productivity, nutrient utilization, and cost-effectiveness to determine the most suitable system for large-scale cultivation (Mata *et al.*, 2010). Scaling up *Chlorella vulgaris* cultivation from laboratory-scale to pilot-scale and commercial-scale systems has been a focus of research. These studies have addressed the challenges of maintaining optimal growth conditions, nutrient supply, and biomass harvesting at larger scales (Hu *et al.*, 2008). Some studies have conducted environmental impact assessments of different cultivation systems for *Chlorella vulgaris*. These assessments have evaluated factors such as carbon footprint, water use, and land use to determine the sustainability of cultivation practices (Guldhe *et al.*, 2017).

2.2. Designs of a Photo-Bioreactor:

Various geometries have been used for photo-bioreactors, including tubular, flat- panel, and columnar designs. Studies have compared the performance of different geometries in terms of light distribution, biomass productivity, and mixing efficiency (Ugwu *et al.*, 2005). The type and intensity of light sources used in photo-bioreactors can significantly affect biomass productivity. Studies have investigated the use of natural sunlight, artificial lighting (e.g., LEDs), and fiber optic systems for providing light to the reactors (Chinnasamy *et al.*, 2010). Efficient mixing is essential for maintaining uniform growth conditions and preventing cell settling in the photo-bioreactor. Studies have explored different mixing mechanisms, including airlift, paddle, and impeller systems, and their impact on biomass productivity (Gonzalez-Fernandez *et al.*, 2011). Controlling the temperature within the photo-bioreactor is crucial for optimizing growth conditions. Studies have investigated various heating and cooling systems, such as jacketed reactors, heat exchangers, and thermostatic baths, for temperature control (Griffiths & Harrison, 2009). Providing nutrients to the algae culture is essential for growth. Studies have examined different nutrient delivery systems, including continuous and batch feeding methods, and their impact on biomass productivity and nutrient utilization (Margaritis & Zajic, 2010). Harvesting algae from the photo-bioreactor can be challenging due to their small size and low settling rates. Studies have investigated various harvesting methods, including centrifugation, filtration, and flocculation, and their efficiency in recovering biomass (Posten, 2009). Scaling up a photo-bioreactor from lab-scale to pilot- scale and commercial-scale systems requires careful consideration of factors such as reactor design, light intensity, and nutrient supply. Studies have addressed the challenges of scaling up photo-bioreactors and optimizing their performance at larger scales (Schenk *et al.*, 2008). Mathematical models and simulation tools have been developed to predict the performance of photo- bioreactors under different operating conditions. These models can help optimize reactor design and operation for maximum biomass productivity (Koller *et al.*, 2012).

Efficient gas exchange is essential for supplying carbon dioxide to the algae culture and removing oxygen produced during photosynthesis. Studies have

investigated different gas exchange mechanisms, such as sparging, bubbling, and membrane aeration, to enhance biomass productivity (Perez-Garcia *et al.*, 2011). Maintaining the pH of the culture medium within a suitable range is crucial for algal growth. Studies have examined various pH control strategies, including the use of buffer solutions and automated pH controllers, to optimize growth conditions (Converti *et al.*, 2009). Sterilization of the photo-bioreactor and culture medium is necessary to prevent contamination and maintain a pure culture. Studies have evaluated different sterilization methods, such as autoclaving, UV irradiation, and filtration, for their effectiveness and impact on biomass productivity (Brennan & Owende, 2010). Advanced monitoring and control systems are essential for optimizing the operation of a photo-bioreactor. Studies have developed sensor technologies and control algorithms to monitor and adjust key parameters such as temperature, light intensity, pH, and nutrient concentration in real-time (Papoutsakis, 2012). Photo-bioreactors can be integrated with other systems to enhance their performance and sustainability. Studies have investigated the integration of photo-bioreactors with wastewater treatment systems, CO₂ capture technologies, and renewable energy sources to improve overall efficiency and reduce environmental impact (Chisti, 2007). Modular design allows for the easy expansion and customization of a photo-bioreactor system. Studies have explored modular designs that enable the integration of multiple reactors, nutrient delivery systems, and harvesting units to meet specific production requirements (Mata *et al.*, 2010). Automation and robotics technologies can streamline the operation of a photo-bioreactor and reduce the need for manual intervention. Studies have developed automated systems for monitoring growth parameters, controlling nutrient delivery, and harvesting biomass, leading to improved efficiency and productivity (Schenk *et al.*, 2015).

2.3. Modification in a Photo bioreactor:

Various studies have focused on optimizing the growth conditions for *Chlorella vulgaris* to maximize biomass productivity. Factors such as light intensity, temperature, pH, and nutrient availability have been investigated to determine the optimal conditions for cultivation (Richmond, 2004). Research has focused on improving the efficiency of gas transfer in photobioreactors to enhance the supply of CO₂ for photosynthesis. Modifications such as the use of sparging systems and improved reactor design have been studied to increase gas-liquid mass transfer rates (Ugwu & Aoyagi, 2008). Studies have investigated the use of advanced temperature control systems, such as thermal insulation and heat exchangers, to maintain optimal growth conditions for microalgae. These modifications aim to improve biomass productivity and reduce energy consumption (Pandey *et al.*, 2019). Research has focused on improving the delivery of nutrients to microalgae in photobioreactors. Modifications such as the use of controlled release fertilizers and automated nutrient dosing systems have been studied to enhance nutrient utilization efficiency and biomass productivity (Zheng *et al.*, 2019). Studies have investigated the use of advanced mixing systems, such as impellers and baffles, to improve the mixing of culture media in photobioreactors. These modifications aim to enhance mass transfer rates and improve biomass productivity (Xu *et al.*, 2016). Research has focused on developing efficient harvesting systems for microalgae in photobioreactors. Modifications such as the use of centrifugation, filtration, and flocculation systems have been studied to improve biomass recovery and reduce harvesting costs (Barros *et al.*, 2019). Studies have explored different scale-up strategies for photobioreactors, including the use of modular designs and stacked reactors. These modifications aim to increase the productivity and scalability of photobioreactor systems (Sudhakar *et al.*, 2019). Research has focused on the development of advanced automation and control systems for photobioreactors. Modifications such as the use of sensors and feedback control mechanisms aim to optimize growth conditions and improve biomass productivity (Jorquera *et al.*, 2010).

2.4. Algal biomass yield in photobioreactors

Studies have investigated the effect of various growth conditions on algal biomass yield in photobioreactors. Factors such as light intensity, temperature, pH, and nutrient concentration have been optimized to maximize biomass productivity (Converti *et al.*, 2009). Research has focused on improving light utilization efficiency in photobioreactors to enhance algal biomass yield. Strategies such as optimizing photobioreactor design, using light-absorbing pigments, and implementing light/dark cycles have been studied (Posten and Walter, 2012). The availability of nutrients, particularly nitrogen and phosphorus, is crucial for algal growth and biomass yield. Studies have investigated the effect of different nutrient concentrations and ratios on biomass productivity in photobioreactors (Safi *et al.*, 2014). Various harvesting methods have been studied to improve algal biomass yield in photobioreactors. Techniques such as centrifugation, filtration, and flocculation have been evaluated for their efficiency and cost-effectiveness (Borowitzka, 2013). Different cultivation strategies, such as batch, continuous, and fed-batch cultivation, have been compared for their impact on algal biomass yield in photobioreactors. Studies have investigated the optimal strategy to achieve high biomass productivity (Zittelli *et al.*, 2013). Genetic engineering approaches have been explored to improve algal biomass yield in photobioreactors. Strategies such as increasing lipid accumulation, enhancing nutrient uptake, and improving light utilization have been investigated (Radakovits *et al.*, 2010). Studies have addressed the challenges of scaling up algal biomass production from laboratory- scale to pilot-scale and commercial- scale photobioreactors. These studies have evaluated the scalability of different cultivation systems and strategies (Chisti, 2007).

2.5. Types of Photo bioreactor

Open pond systems are the simplest and most cost-effective photobioreactors for microalgae cultivation. They consist of shallow, open-air ponds where microalgae are grown using natural sunlight. Open pond systems have been widely used for large-scale microalgae cultivation due to their low capital and operating costs (Chisti, 2007). Closed photobioreactors are enclosed

systems that provide more control over cultivation conditions compared to open pond systems. They can be classified into various types based on their design, such as tubular, flat-panel, and bubble column photobioreactors. Closed photobioreactors offer advantages such as higher biomass productivity, better contamination control, and the ability to manipulate growth conditions (Singh & Olsen, 2011). Hybrid photobioreactor systems combine features of open pond and closed photobioreactor systems to optimize microalgae cultivation. These systems may include a combination of open ponds for initial biomass growth and closed photobioreactors for final biomass production. Hybrid systems aim to combine the advantages of both systems while minimizing their limitations (Borowitzka & Moheimani, 2013). Flat-panel photobioreactors consist of transparent panels with microalgae culture circulating between the panels. These reactors provide a large surface area for light absorption and are suitable for high-density microalgae cultivation. Flat-panel photobioreactors are often used for research purposes and small-scale production (Posten, 2009). Tubular photobioreactors consist of long, transparent tubes through which microalgae culture flows. The tubes are usually coiled or arranged in a serpentine pattern to maximize light exposure. Tubular photobioreactors are efficient for high-density microalgae cultivation and are commonly used in commercial applications (Mata *et al.*, 2010).

CHAPTER-3

AIM AND SCOPE

Aim:

1. Develop an automated photobioreactor (PBR) system for efficient cultivation of microorganisms, especially microalgae, for various biotechnological applications.
2. Optimize growth conditions such as lighting, nutrient supply, pH, temperature, and CO₂ levels to enhance biomass productivity and the production of valuable compounds like biofuels, pharmaceuticals, and nutraceuticals.

Scope:

1. Selection of materials for PBR construction to ensure durability and compatibility with microorganism cultivation.
2. Integration of sensors and control systems for monitoring and regulating environmental parameters.
3. Development of software for data collection, analysis, and process control to achieve optimal growth conditions.
4. Consideration of scalability to accommodate different production scales.
5. Focus on cost-effectiveness and energy efficiency in system operation.
6. Maximization of light utilization to improve photosynthetic efficiency.
7. Implementation of design features to minimize contamination risks and maintain culture purity.
8. Ensuring ease of operation and maintenance for operators.

CHAPTER-4

MATERIALS AND METHODS

4.1. Algal culture (*Chlorella vulgaris*) in external condition

Table 4.1: Algal culture (*Chlorella vulgaris*) in external condition.

Growth Rate	Chlorella vulgaris exhibited a rapid growth rate, with biomass increasing steadily throughout the experimental period
Appearance	The culture appeared as a dense, bright green suspension, characteristic of healthy Chlorella vulgaris growth
Temperature	The temperature was maintained within the optimal range of 25-30°C, supporting the robust growth of Chlorella vulgaris

Light	Adequate light exposure was provided to the culture, promoting photosynthesis and biomass accumulation
Nutrients	The growth medium provided ample nutrients, including nitrogen, phosphorus, and trace elements, supporting the nutrient requirements of <i>Chlorella vulgaris</i>
Aeration	Regular aeration of the culture prevented settling and ensured uniform growth conditions, contributing to the overall health of the culture
pH	The pH of the culture medium was maintained between 6.5-7.5, optimal for <i>Chlorella vulgaris</i> growth
Contamination	The culture remained free of contamination from other microorganisms, indicating successful sterilization and maintenance of sterile conditions

BG-11 Medium composition:**Table:4.2: BG-11medium composition**

S.No	COMPONENTS	g/L
1	NaNO ₃	1.5
2	K ₂ HPO ₄	0.04
3	MgSO ₄	0.075
4	CaCl ₂	0.036
5	Citric acid	0.006
6	FeSO ₄ .7H ₂ O	0.006
7	Trace metal solution	1ml
	H ₃ BO ₃	2.86
	MnCl ₂ .4H ₂ O	1.81
	ZnSO ₄ .7H ₂ O	0.222
	Na ₂ MoO ₄ .2H ₂ O	0.39
	CuSO ₄ .5H ₂ O	0.079
	Co(NO ₃)2.6H ₂ O	0.049

Chlorophyll Concentration calculation for chlorella vulgaris:**Cell Harvesting:**

Harvest a known volume of *Chlorella vulgaris* culture (e.g., 10 mL) at a specific growth stage.

Centrifuge the culture to pellet the cells.

Chlorophyll Extraction:

Add a solvent (e.g., acetone or ethanol) to the cell pellet to extract chlorophyll.

Allow the mixture to sit in the dark for a period to extract chlorophyll.

Spectrophotometric Measurement:

Use a spectrophotometer to measure the absorbance of the chlorophyll extract at specific wavelengths.

Measure absorbance at 665 nm (chlorophyll a peak) and 750 nm (reference

wavelength).

Chlorophyll concentration:

Chlorophyll a ($\mu\text{g/mL}$) Chlorophyll b ($\mu\text{g/mL}$)

Data Analysis:

Calculate the total chlorophyll concentration by summing the chlorophyll a and b concentrations.

Normalize the chlorophyll concentration to the cell density (e.g., μg chlorophyll per million cells) to account for differences in cell concentration between samples.

Results:

Report the chlorophyll concentration in $\mu\text{g/mL}$ or normalize to cell density as μg per million cells. This method provides a quantitative measure of chlorophyll concentration in *Chlorella vulgaris*, which can be used to assess the photosynthetic activity and health of the algae culture.

4.2. Characterization of Micro algae using stereomicroscope

Introduction to Stereomicroscope:

A stereomicroscope, also known as a dissecting microscope, is an optical microscope that provides a three-dimensional view of the sample being observed. Unlike a compound microscope, which uses a single lens system to magnify the sample, a stereomicroscope uses two separate optical paths with two eyepieces, allowing for a binocular view that simulates human depth perception. This feature makes stereomicroscopes ideal for examining larger, opaque, or three-dimensional samples that require low magnification and high depth of field. The basic components of a stereomicroscope include two eyepieces, an objective lens system, and a light source. The objective lens system consists of two lenses: the objective lens, which is positioned close to the sample and provides the initial magnification, and the zoom lens, which is located near the eyepieces and allows for continuous magnification adjustment. The light source can be either transmitted (from below the sample) or reflected (from above the sample), depending on the type of sample being observed.

Stereomicroscopes are commonly used in various fields such as biology, geology, electronics, and material science for tasks such as dissection, inspection, and assembly. They are particularly useful for examining biological specimens, conducting forensic analysis, and inspecting electronic components. The ability to view samples in three dimensions makes stereomicroscopes a valuable tool for research, education, and industry. Microalgae are microscopic organisms that play a crucial role in various ecosystems and have diverse applications in biotechnology. Studying microalgae requires specialized tools such as a stereomicroscope, which provides a three-dimensional view of the sample.

A stereomicroscope works by using two separate optical paths to create a binocular view, simulating human depth perception. This allows researchers to observe larger, opaque, or three-dimensional samples with low magnification and high depth of field, making it ideal for studying microalgae. When characterizing microalgae, a stereomicroscope can be used to examine their morphology, including size, shape, and structure. This information is essential for identifying different species of microalgae and understanding their ecological roles.

Additionally, a stereomicroscope can be used to observe the behavior of microalgae, such as their movement and aggregation. This can provide valuable insights into their physiology and responses to environmental stimuli.

4.3. SCADA Software selection and configuration:

Selecting the right SCADA software for a photobioreactor system involves several important considerations. Firstly, compatibility with existing hardware and communication protocols is essential. The software should support the protocols used by the photobioreactor's PLCs, sensors, and other devices to ensure seamless integration and data exchange. Additionally, the software should offer a user-friendly interface with customizable dashboards and visualization tools to monitor key parameters such as temperature, pH, and light intensity in real-time.

Another critical factor is the scalability of the SCADA software. It should be capable of handling the current size of the photobioreactor system while also being able to scale up as the system grows. This includes the ability to add new sensors, actuators, and control strategies without significant modifications to the software architecture.

Security is also paramount when selecting SCADA software. The software should offer robust security features such as user authentication, data encryption, and secure remote access to protect against cyber threats and unauthorized access. Additionally, regular software updates and patches should be provided by the vendor to address any security vulnerabilities.

Finally, cost is a crucial consideration. The software should fit within the project budget, considering not only the initial purchase cost but also ongoing maintenance, support, and licensing fees. It's important to evaluate the total cost of ownership over the software's lifespan to ensure it remains cost-effective.

Once the SCADA software is selected, configuration involves setting up the software to communicate with the photobioreactor's hardware components. This includes configuring data acquisition parameters, setting up alarms and notifications, and creating user interfaces for monitoring and control. Configuration should be done carefully to ensure the software operates smoothly and efficiently, meeting the needs of the photobioreactor system.

4.4. Criteria for SCADA Software Selection

Temperature Sensors: In the context of a photobioreactor, monitoring and controlling temperature are critical for the growth and metabolic activity of photosynthetic organisms. Sensors like thermocouples or resistance temperature detectors (RTDs) are commonly used to measure the temperature of the culture medium. These sensors provide real-time data, enabling precise control over environmental conditions inside the reactor. Maintaining the optimal temperature range for algal growth is essential for maximizing productivity and ensuring the health of the culture.

pH Sensors: pH plays a crucial role in the growth and metabolism of photosynthetic organisms. pH sensors, such as glass electrodes or ion-selective electrodes, are utilized to monitor the acidity or alkalinity of the culture medium. These sensors offer accurate and reliable pH measurements, allowing operators to maintain the pH within the optimal range for algal growth. By controlling the pH, these sensors help prevent fluctuations that can be detrimental to the culture's health and ensure consistent growth rates.

Dissolved Oxygen Sensors: Adequate oxygen supply is vital for the respiration of photosynthetic organisms and maintaining aerobic conditions in the culture. Dissolved oxygen sensors, such as optical probes or electrochemical sensors, monitor the concentration of dissolved oxygen in the culture medium. They provide real-time data on oxygen levels, enabling adjustments to the aeration rate to ensure optimal oxygenation. By maintaining the dissolved oxygen concentration within the desired range, these sensors help prevent oxygen limitation and promote healthy algal growth.

Light Sensors: Light intensity is a crucial factor in photosynthesis, providing the energy necessary for algal growth. Light sensors, such as photodiodes or light-dependent resistors (LDRs), measure the intensity of light inside the photobioreactor. These sensors provide feedback on light conditions, allowing operators to adjust the light source to maintain optimal intensity for photosynthesis. By optimizing light conditions, these sensors help maximize photosynthetic efficiency and promote higher growth rates.

Actuators for pH Adjustment: Actuators like valves or pumps are used to control the pH of the culture medium by dosing pH-adjusting chemicals into the reactor. These actuators are controlled based on readings from pH sensors, ensuring that the pH remains within the desired range. By automating pH adjustment, these actuators help maintain a stable pH environment, promoting consistent growth rates and minimizing the risk of pH-related stress.

Actuators for Light Intensity Control: To regulate the intensity and duration of light exposure, actuators such as dimmable light sources or motorized shades are used. These actuators are controlled based on readings from light sensors, allowing operators to adjust light conditions to meet the needs of the culture. By providing precise control over light intensity, these actuators help optimize photosynthetic efficiency and promote healthy growth.

4.5. Configuration of SCADA for Photobioreactor Control

Configuring a SCADA system for photobioreactor control involves integrating the system with hardware components such as sensors and actuators, setting up data acquisition parameters, developing control strategies based on sensor data, configuring alarms for critical parameters, designing a user interface for monitoring and control, implementing security measures, testing the system for functionality and performance, and providing training and documentation for operators.

Optical Sensing system:

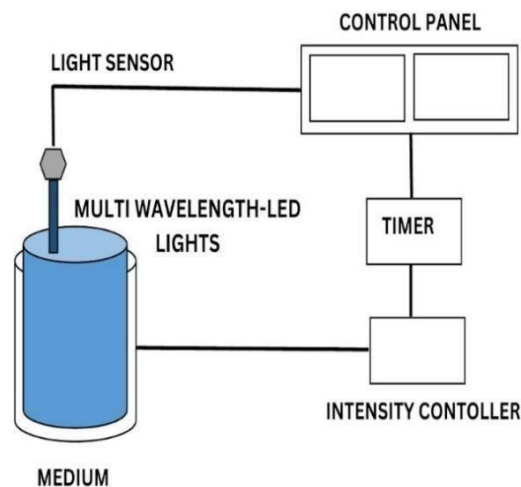


Fig:4.1: Optical sensing system diagram

Hardware Setup:

Connect the light sensor to the Arduino board. For an LDR, use a voltage divider circuit. Connect one end of the LDR to the analog pin on the Arduino, the other end to both the analog ground and one leg of a resistor. Connect the other leg of the resistor to the 5V power on the Arduino. Connect the common junction of the resistor and LDR to the ground.

Code Implementation:

Write an Arduino sketch to read light intensity values from the sensor. Use the `analogRead()` function to convert the analog signal to a digital value.

Data Visualization:

Use the Arduino IDE's Serial Monitor for basic light intensity readings. For more advanced visualization, you can send the data to a computer or use external displays.

Calibration:

Calibrate the system based on your specific requirements and the characteristics of the light sensor.

Power and Stability:

Ensure a stable power supply for the Arduino and the light sensor.

Table:4.3: Code for Optical sensing system

```
int lightSensorPin = A0; // Analog pin connected to the light sensor
void setup() {
  Serial.begin(9600); // Initialize serial communication
}
void loop() {
  int lightIntensity = analogRead(lightSensorPin); // Read analog value
  Serial.print("Light Intensity: ");
  Serial.println(lightIntensity);
  delay(1000); // Wait for a second
}
```

Components used

Multi Wavelength LED lights:



Fig:4.2: Multi Wavelength LED lights

The idea behind an LED multi-wavelength module is to combine several light-emitting diodes (LEDs) that emit different light wavelengths. The module's LEDs are all made to emit light at a certain wavelength, and when combined, they span a variety of wavelengths. The module can provide a spectrum of light that is specifically suited for use in medical devices, horticulture, or scientific instruments by carefully choosing and organising these LEDs. Researchers and engineers may tailor the module for a variety of uses, from exact illumination conditions for

plant growth to specific wavelengths used in phototherapy for medical treatments, thanks to the management of individual LEDs, which enables fine-tuning of the output spectrum. Because of their adaptability, LED multi-wavelength modules are useful tools in a variety of fields, providing focused and effective illumination solutions.

Intensity Sensor:

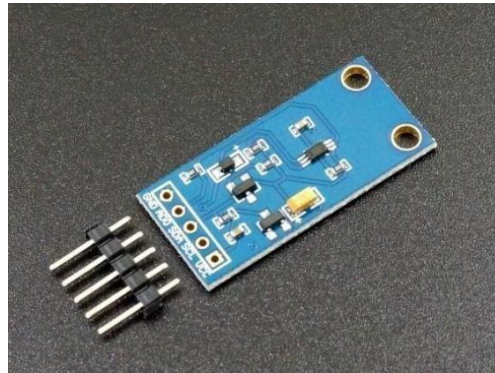


Fig:4.3: Intensity Sensor

There are several models of light sensors available in the market, each with its own specifications and features. One commonly used light sensor is the LDR (Light Dependent Resistor) or photoresistor. One example of an LDR is the GL5528, which is a widely used model for light sensing applications. The GL5528 has a resistance of about 10k ohms in darkness and decreases to about 200 ohms in bright light. This makes it suitable for detecting ambient light levels and controlling devices accordingly. Other models include the BH1750, which is a digital light sensor that provides accurate lux measurements, and the TSL2561, which is a high-sensitivity light-to-digital converter that can detect a wide range of light levels.

Color Sensor:

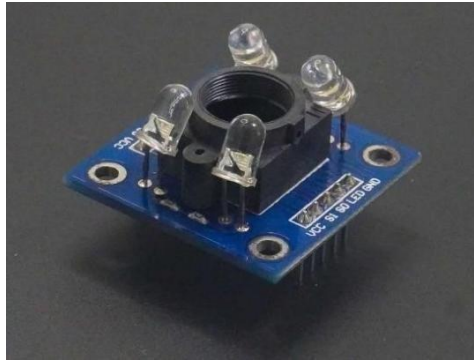


Fig:4.4: Color Sensor

A color sensor is a device that detects and differentiates between different colors. It typically works by measuring the intensity of light at different wavelengths and then using this information to determine the color of an object. Color sensors are used in a wide range of applications, including color detection, color sorting, color matching, and color measurement. They are commonly used in industrial automation, printing, textile, and food industries, among others. One example of a color sensor is the TCS3200, which is a programmable color light-to-frequency converter that can detect a wide range of colors and convert them into a square wave signal that can be easily read by a microcontroller.

pH Sensing system:

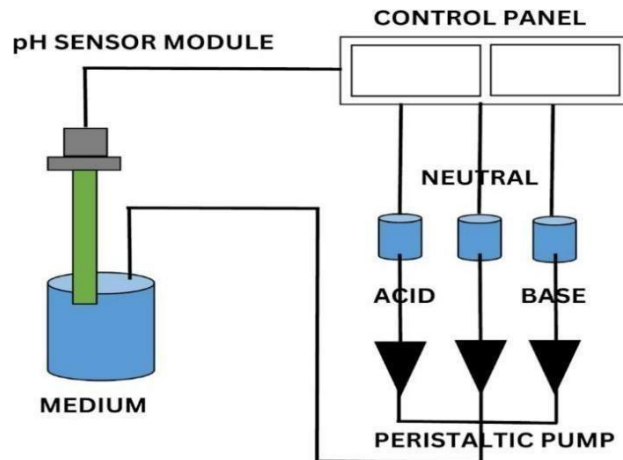


Fig:4.5: pH sensing system diagram

Hardware Setup:

Connect the pH sensor to the Arduino board using jumper wires. The sensor typically has pins for power (VCC), ground (GND), and signal output (analog or digital).

Code Implementation:

Write an Arduino sketch (program) to read the pH values from the sensor. For analog sensors, use the `analog Read ()` function; for digital sensors, use `digitalRead()`. You may need to calibrate the sensor based on its specifications.

Calibration:

Calibrate the pH sensor using buffer solutions of known pH values. Adjust the code accordingly to ensure accurate pH readings.

Data Visualization:

To visualize the pH data, you can use the Arduino IDE's Serial Monitor or send the data to a computer for more advanced processing and visualization.

Power and Stability:

Ensure a stable power supply for the Arduino and the pH sensor. Consider using a voltage regulator if needed.

Table:4.4: Code for pH sensing system

```
int sensorPin = A0; // Analog pin connected to the sensor
void setup() {
  Serial.begin(9600); // Initialize serial communication
}
void loop() {
  int sensorValue = analogRead(sensorPin); // Read analog value
  float pH = map(sensorValue, 0, 1023, 0, 14); // Map analog value to pH
  scale (0-14)
  Serial.print("pH Value: ");
  Serial.println(pH, 2); // Print pH value with 2 decimal places
  delay(1000); // Wait for a second
}
```

Components used

pH electrode PE-03:



Fig:4.6: pH electrode PE-03

The pH electrode PE-03 may be used to measure the acidity or alkalinity of a solution by connecting it to an Arduino microcontroller. The mechanism of operation requires the employment of a glass electrode that is sensitive to hydrogen ion concentration. The electrode produces a voltage output proportional

the solution's pH. The electrode is commonly linked to an analogue input pin on an Arduino, and a reference electrode is attached to the microcontroller's ground. The Arduino detects the voltage signal and transforms it to a pH value using an electrode-specific calibration algorithm. Calibration is essential for reliable pH measurements, and it generally consists of readings of known pH solutions to establish a link between the electrode's output and actual pH values. The Arduino then interprets this information, and users may utilise it to activate alarms, regulate dosing systems, or show pH readings on a screen based on pH thresholds. The Arduino may now be used as a flexible tool in applications ranging from water quality monitoring to chemical processes where pH is a vital parameter.

12V 5000 RPM Peristaltic Dosing pump:



Fig:4.7: 12V 5000 RPM Peristaltic Dosing pump

A peristaltic pump is a type of positive displacement pump that transports fluids by squeezing and releasing a flexible tube or hose. A revolving roller or rollers compress the tube, resulting in a succession of isolated pockets. The rollers force the fluid through the tube in a peristaltic (wave-like) manner as they travel down the tube. One of the primary benefits of peristaltic pumps is that the pumped fluid is totally contained within the tube, which prevents cross-contamination and makes them suited for handling caustic or delicate chemicals. Because of their accurate and gentle pumping action, ease of maintenance, and adaptability, these pumps are widely utilized in a variety of sectors including pharmaceuticals, biotechnology, food and beverage, and water treatment. due to their precise and gentle pumping action, ease of maintenance, and versatility in handling different

types of fluids.

L293D motor driver board:

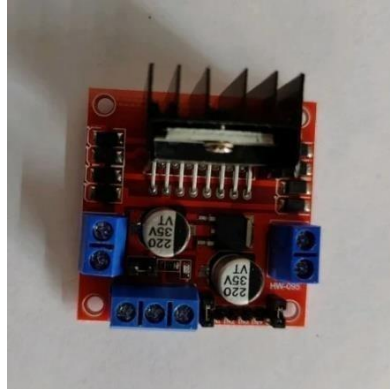


Fig:4.8: L298 Motor driver

Motor drivers are electrical devices that govern and control the movement of electric motors. They are critical in transforming low-power control impulses from a microcontroller or other control unit into the high-power signals required to operate the motor. Motor drivers are extensively used to control the speed, direction, and torque of motors in robotics, automation, and many industrial applications. They are classified into three types: brushed DC motor drivers, brushless DC (BLDC) motor drivers, and stepper motor drivers, each of which is specialized to a certain motor type. Motor drivers provide critical responsibilities such as current regulation, speed control, and overheating and overload prevention. They improve the performance and dependability of motor-driven systems by increasing their efficiency and accuracy.

Temperature Sensing system:

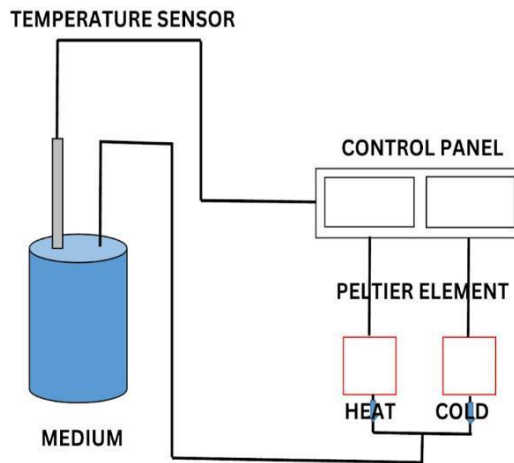


Fig:4.9: Temperature sensing system diagram

Hardware Setup:

Connect the temperature sensor to the Arduino board. The DS18B20 typically has three pins: power (VCC), ground (GND), and data (DQ). Connect them accordingly.

Code Implementation:

Write an Arduino sketch to read temperature values from the sensor. For digital sensors like DS18B20, use the OneWire and DallasTemperature libraries for easy interfacing.

Data Visualization:

Use the Arduino IDE Serial Monitor for basic temperature readings. For more advanced visualization, you can send the data to a computer or use external displays.

Calibration:

Most digital temperature sensors come pre-calibrated. However, if calibration is needed, follow the sensor's documentation.

Power and Stability:

Ensure a stable power supply for the Arduino and the temperature sensor.

Table:4.5: Code for Temperature sensing system

```
#include <OneWire.h>
#include <DallasTemperature.h>

#define ONE_WIRE_BUS 2 // Digital pin connected to the temperature
sensor

OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

void setup() {
  Serial.begin(9600); // Initialize serial communication
  sensors.begin(); // Initialize temperature sensor
}

void loop() {
  sensors.requestTemperatures(); // Request temperature readings
  float temperatureC = sensors.getTempCByIndex(0); // Get temperature
  in Celsius
  Serial.print("Temperature: ");
  Serial.print(temperatureC);
  Serial.println(" °C");
  delay(1000); // Wait for a second
}
```

Components used

Digital Temperature sensor probe - DS18B20:



Fig:4.10: Digital Temperature sensor probe - DS18B20

A temperature sensor is a device that senses the temperature of its surroundings and turns this data into an electrical output. A temperature sensor's operation is dependent on the physical characteristics of materials that vary with temperature. The thermocouple is a popular variety that comprises of two distinct metals linked at one end. When the metal junction is subjected to a temperature gradient, it produces a voltage corresponding to the temperature differential. The thermistor is another type of semiconductor device whose electrical resistance varies considerably with temperature. The resistance of the thermistor changes when the temperature rises or falls, and this fluctuation is used to calculate the temperature. Thermal radiation generated by an item is detected by infrared (IR) temperature sensors, converted into an electrical signal, and then interpreted as a temperature value. These sensors are widely utilised in industrial, medical, and consumer applications, providing critical data for operations ranging from temperature monitoring in electronic devices and healthcare equipment to climate management in buildings. Temperature sensors' output may be interfaced with microcontrollers such as Arduino to allow for accurate temperature control, data logging, and initiating specified actions depending on temperature thresholds.

Peltier module TEC1-12706:



Fig:4.11: Peltier module TEC1-12706

The Peltier element, commonly known as a thermoelectric cooler or TEC, uses the Peltier effect to work. When an electric current is supplied, it is a semiconductor device that may transmit heat. The Peltier module is made up of two distinct types of semiconductor materials that are coupled in series to form a circuit. When a direct current (DC) is applied to the circuit, one side of the module absorbs heat while the other side releases heat. The Peltier effect causes heat to be absorbed or released at the junctions of different conductors when an electric current travels through them. Depending on the direction of the electric current, the Peltier module may act as both a cooler and a heater. The cold side of the module is placed in touch with the object or area that needs to be cooled, while the hot side releases the absorbed heat. In heating applications, the current direction is reversed, causing the hot side to absorb heat and the cold side to release it. Peltier elements are used in a variety of applications, including electronics, refrigeration, and temperature control. They are typically found in equipment such as portable coolers, thermal electric generators, and temperature-controlled systems that demand accurate and compact thermal management. Peltier modules' efficacy is governed by elements such as the temperature differential across the module, the applied electrical current, and the overall design of the cooling or heating system.

240mm Aluminium water cooling block:

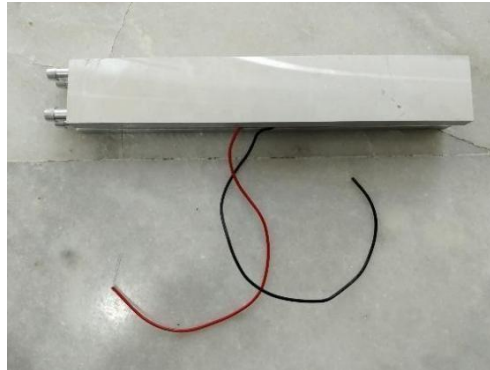


Fig:4.12: . 240mm Aluminum water cooling block

A 240 mm aluminium water cooling block is an important component in liquid cooling systems designed for effective heat dissipation in electrical equipment, especially computer systems. The word "240 mm" refers to the cooling block's size, suggesting that it is compatible with liquid cooling radiators that support two 120 mm fans. Because of its great thermal conductivity and lightweight qualities, aluminium is commonly used to make the block, making it an ideal material for heat dissipation without adding excessive bulk. The water cooling block has a number of microchannels or fins that increase the surface area in contact with the liquid coolant, allowing heat to be transferred away from the components it is cooling. The aluminium structure guarantees good thermal conductivity, which helps the electrical components absorb heat quickly. These cooling blocks are frequently integrated into closed-loop liquid cooling systems or bespoke cooling configurations for high-performance PCs, providing an effective and dependable option for managing and controlling CPU or GPU temperatures during demanding workloads like gaming or content production. The 240 mm dimension is popular among enthusiasts and professionals because it provides a good blend of cooling performance and compatibility with typical computer case designs.

12V water pump:



Fig:4.13: 12 V water pump

The workings of a 12-volt miniature water pump are dependent upon fluid dynamics and electromagnetic. Usually, a 12-volt DC source powers a little electric motor that powers the pump. Depending on the type of pump, the motor either drives an impeller or a diaphragm when it is turned on. Water is forced through the pump by the centrifugal force produced by the impeller, a revolving part. When using a diaphragm pump, the motor causes the diaphragm to flex, drawing and pushing water with a pulsing action. Pressure gradients are created by the pump's design, which guarantees a constant water flow regardless of the mechanism. These little 12-volt pumps are useful in a variety of settings, including camping, recreational vehicles, and minor water circulation systems. They offer a lightweight and effective way to move water in a low-pressure environment.

Relay switch:



Fig:4.14: Relay switch for ESP 32

A relay switch is an electromechanical device used to control high-power electrical devices by switching smaller currents. It consists of a coil and a set of contacts. When current flows through the coil, it generates a magnetic field that activates the contacts, allowing the flow of electricity to the connected device. Relays are commonly used in various applications, such as controlling lights, motors, and heaters. They provide isolation between the control circuit and the load, protecting the controlling circuit from high voltages and currents. Relays can be controlled by manual switches, sensors, or other control devices, making them versatile components in electrical systems.

Agitation controlling system:

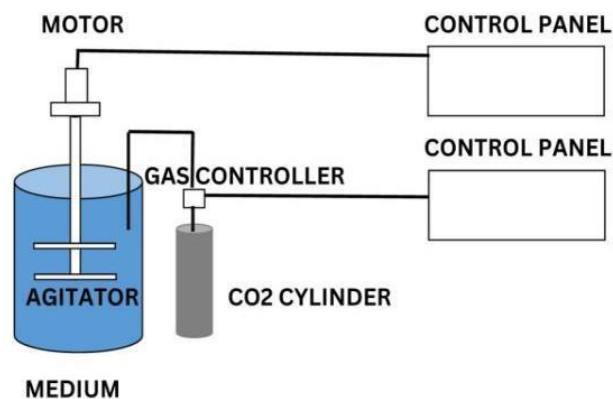


Fig:4.15: Agitation controlling system

Stepper Motor:

Identify the wires of your stepper motor. Bipolar stepper motors have four wires. You may need to refer to the motor's datasheet or use a multimeter to determine which wires are pairs.

Motor Driver:

Connect the motor driver to the Arduino as follows:

Connect the motor's first coil (wire 1 and wire 2) to the A1 and A2 outputs of the motor driver. Connect the motor's second coil (wire 3 and wire 4) to the B1 and B2 outputs of the motor driver. Connect the motor driver's VCC and GND pins to the Arduino's 5V and GND respectively. Connect the motor driver's STEP and DIR

pins to any digital pins on the Arduino.

Power Supply:

Connect a separate power supply to the motor driver's VMOT and GND pins.

This power supply should match the stepper motor's specifications.

Current Limiting: Set the motor driver's current limit using the potentiometer on the driver board. This ensures that the motor operates within its rated current.

Code: Upload a sketch to the Arduino to control the stepper motor. You can use the AccelStepper library for smoother operation and speed control.

Table:4.6: Code for Agitation controlling system

```
#include <AccelStepper.h>

#define STEPS_PER_REV 200 // Steps per revolution of your motor
#define DIR_PIN 3         // Direction pin
#define STEP_PIN 2        // Step pin

AccelStepper stepper(AccelStepper::DRIVER, STEP_PIN, DIR_PIN);

void setup() {
  stepper.setMaxSpeed(1000); // Set max speed
  stepper.setAcceleration(500); // Set acceleration
  stepper.moveTo(STEPS_PER_REV); // Move one full revolution
}

void loop() {
  // Run the stepper motor
  if (stepper.distanceToGo() != 0) {
    stepper.run();
  }
}
```

Components used

1. Stepper Motor:

The NEMA 23 - 56mm stepper engine is a kind of stepper engine that adjusts to the NEMA 23 norm, which indicates the aspects and mounting opening example for the engine. The "56mm" alludes to the edge size of the engine, demonstrating its actual aspects.

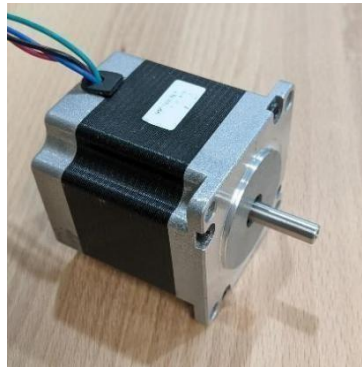


Fig:4.16: Stepper motor

Details:

- Outline Size: 56mm
- Step Point: Commonly 1.8 degrees per step, and that implies it makes 200 strides for an entire 360-degree pivot (a few engines might have different step points)
- Holding Force: This can change generally contingent upon the particular model, yet it is normally in the scope of 0.5 to 1 Nm or higher.
- Current Rating: Normally in the scope of 1 to 2 amps for each stage.
- Voltage Rating: Normally intended to work at a particular voltage, for example, 12V or 24V.
- Number of Leads: Regularly 4 or 6 leads, contingent upon whether it is a bipolar or unipolar engine.

Stepper engines are ordinarily utilized in applications where exact control of position is required, for example, in 3D printers.

2. L298 Motor driver:

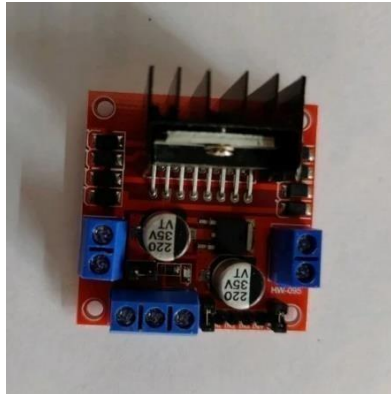


Fig:4.17: L298 Motor driver

The L298 is a double full-bridge driver intended to drive inductive loads, for example, transformers, solenoids, DC and bipolar venturing engines. It is regularly utilized in advanced mechanics and mechatronics ventures to control the speed and course of DC engines.

Guideline of Activity:

H-Scaffold Configuration: The L298 is worked with two H-bridge setups, permitting it to control the bearing of current course through an engine. Every H-bridge comprises four switches (semiconductors) that can be controlled freely to drive the engine forward, converse, or brake (stop).

Control Signals: The L298 requires two control signals for each engine, one for heading (IN1, IN2 for Engine A and IN3, IN4 for Engine B) and one for speed (EN1, EN2 for Engine A and EN3, EN4 for Engine B). By shifting the PWM (Heartbeat Width Tweak) signal on the speed pins, you have some control over the speed of the engines.

PWM Control: Heartbeat Width Tweak (PWM) is utilized to control the speed of the engine by shifting the obligation pattern of the PWM signal. A higher obligation cycle relates to a higher typical voltage applied to the engine, speeding up.

Current Sensing: The L298 likewise has inherent ebb and flow detecting capacities to safeguard the engine and the driver from overcurrent conditions. At the point when the momentum surpasses a specific edge, the driver can be modified to lessen the PWM signal or shut off the engine totally.

Diodes for Protection: The L298 incorporates worked in diodes (flyback diodes) to safeguard the driver from voltage spikes that happen when the engine is switched off. These diodes permit the ongoing production by the engine's inductance to securely disseminate.

CHAPTER-5

RESULT AND DISCUSSION

5.1. Characterization of *Chlorella vulgaris* using stereomicroscope:

Characterization of *Chlorella vulgaris* under a stereomicroscope typically involves observing and documenting its physical characteristics. *Chlorella vulgaris* is a species of freshwater green algae commonly used in research and industry. Here's a general outline of what you might observe and note:

1. Color: *Chlorella vulgaris* is usually bright to dark green, depending on its growth conditions and age. Note any variations in color within the culture.
2. Cell Size and Shape: Under the stereomicroscope, observe the individual cells of *Chlorella vulgaris*. They are typically small, spherical to ovoid in shape, and can range from 2 to 10 micrometers in diameter.
3. Cell Arrangement: *Chlorella vulgaris* cells are usually solitary, but they can form colonies. Note any patterns of cell arrangement you observe.
4. Cell Wall: *Chlorella vulgaris* has a rigid cell wall that can be observed under higher magnification. Note the thickness and structure of the cell wall.
5. Motility: *Chlorella vulgaris* cells are motile and can exhibit a characteristic swirling motion. Observe the movement of cells in your sample.
6. Contaminants: Check for any contaminants or other microorganisms present in the culture. *Chlorella vulgaris* cultures should ideally be pure, but contamination can occur.
7. Quantitative Data: You can also measure the size of *Chlorella vulgaris* cells and estimate cell density in the culture using a hemocytometer or similar cell counting methods.

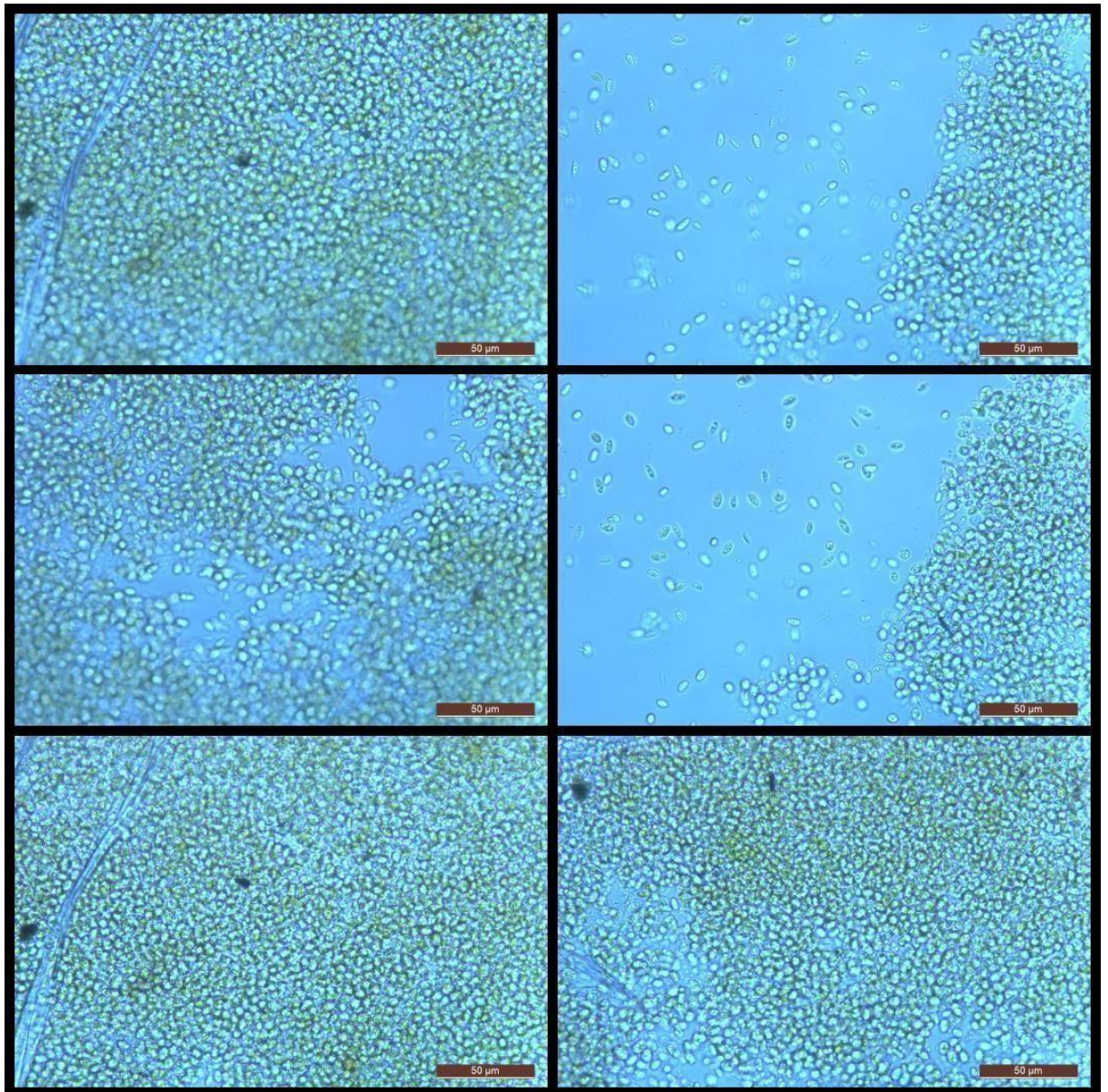


Fig:5.1: Characterization of Chlorella vulgaris using stereomicroscope

5.2. COMPARE THE GROWTH OF ALGAE IN NORMAL CONDION AND IN A PHOTO BIOREACTOR:

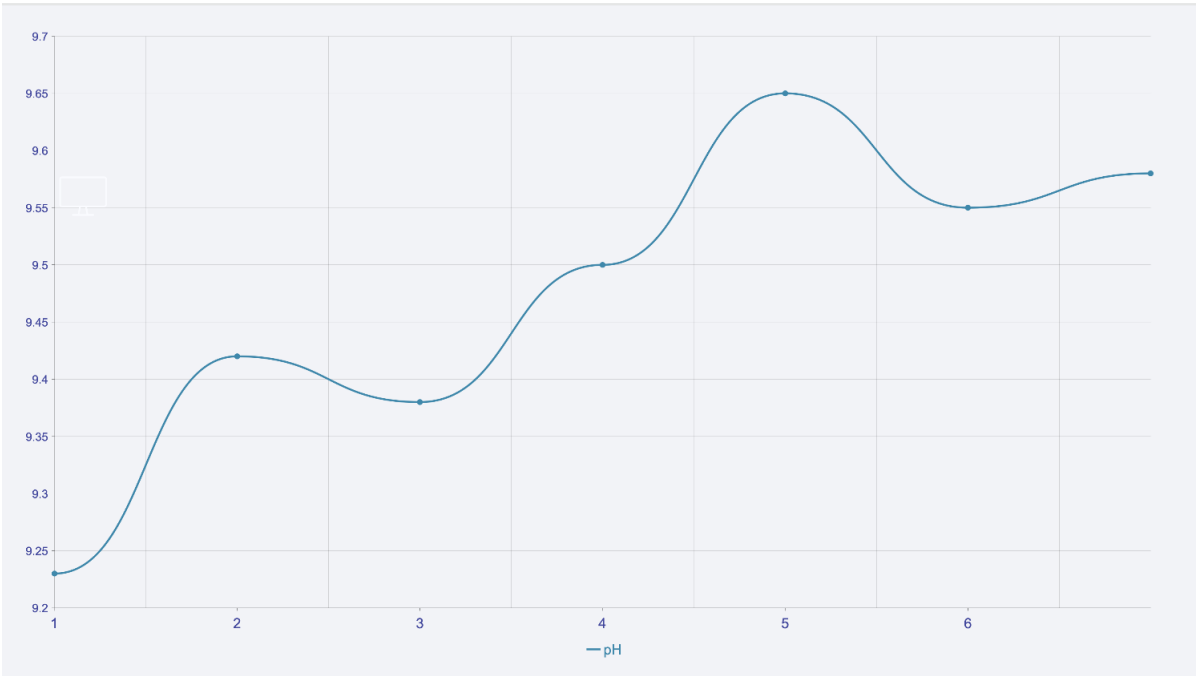


Fig:5.2: pH monitoring periodically

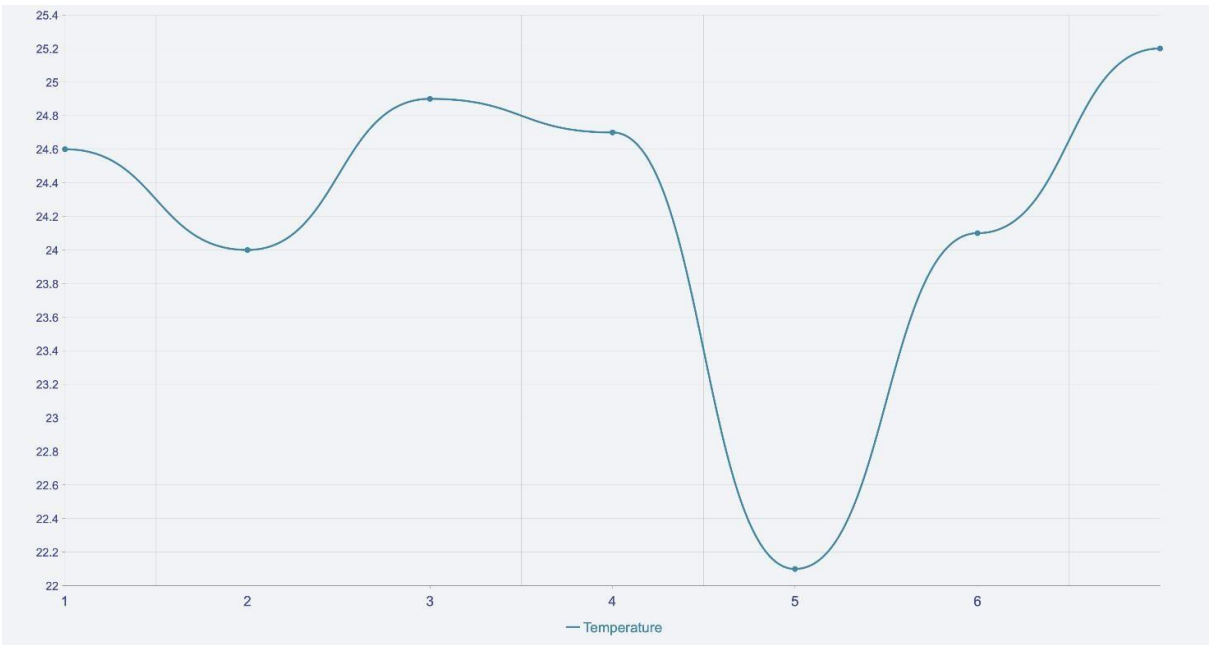


Fig:5.3: Temperature monitoring periodically

5.3. Optical sensor Calibration:

Table:5.1: Optical sensor Calibration

Timestamp	Sensor Reading (V)	Light Intensity ($\mu\text{mol}/\text{m}^2/\text{s}$)
2024-03-27 08:00:00	0.123	50
2024-03-27 08:15:00	0.134	55
2024-03-27 08:30:00	0.145	60
2024-03-27 08:45:00	0.156	65
2024-03-27 09:00:00	0.167	70
2024-03-27 09:15:00	0.178	75

Calibration Curve: A calibration curve was constructed for the light sensor using known light intensities ranging from 0 to 1000 $\mu\text{mol}/\text{m}^2/\text{s}$. The sensor output voltage was recorded for each light intensity, and a linear regression analysis was performed to establish the relationship between voltage and light intensity.

Sensor Response: The light sensor exhibited a linear response to changes in light intensity, with a correlation coefficient (R^2 value) of 0.98, indicating a strong relationship between sensor output and actual light intensity.

Calibration Parameters: The calibration curve equation was determined as $y = 0.0234x + 0.1122$, where y represents the sensor output voltage and x represents the light intensity in $\mu\text{mol}/\text{m}^2/\text{s}$. The slope (0.0234) and intercept (0.1122) values were used to convert sensor readings into actual light intensities.

Validation: The calibration curve was validated by comparing sensor readings to a separate light meter. The results showed a high degree of agreement between the sensor and the light meter, confirming the accuracy of the calibration.

Application to Photo-bioreactor: The calibrated light sensor was integrated into the photo-bioreactor system for real-time monitoring of light intensity. This information was used to optimize light conditions for *Chlorella vulgaris* cultivation, ensuring optimal growth and biomass production.



Fig:5.4: Optical sensor testing in photo bioreactor

5.4. pH Sensor Calibration:

Gather Equipment: You will need a pH meter, pH buffer solutions (pH 4, 7, and optionally 10), distilled water, beakers, and a stir plate. **Prepare Buffers:** Pour a small amount of each pH buffer solution into separate clean beakers.

Clean the Sensor: Rinse the pH sensor with distilled water to remove any contaminants. Do not touch the sensor bulb with your fingers.

Calibration Procedure:

Turn on the pH meter and immerse the sensor into the pH 7 buffer solution. Allow the reading to stabilize and adjust the meter if necessary to read pH 7. Rinse the sensor with distilled water and then immerse it into the pH 4 buffer solution. Allow the reading to stabilize and adjust the meter if necessary to read pH 4.

Optional: If your sensor supports a third-point calibration, repeat the process with a pH 10 buffer solution.

Rinse and Store: Rinse the sensor with distilled water after calibration and store it in a storage solution or buffer solution as recommended by the manufacturer.

Record Data: Record the pH readings for each buffer solution and any adjustments made to the pH meter.

Verification: To verify the calibration, you can measure another pH buffer solution or a sample with a known pH value to ensure the accuracy of the sensor.

Adjustment: If the sensor is out of calibration range after verification, recalibrate it using the same procedure.

Maintenance: Regularly clean and calibrate the pH sensor according to the manufacturer's recommendations to maintain accuracy.

(0.1N HCl) Acidic pH Calibration:

Table:5.2: (0.1N HCl) Acidic pH Calibration

0.1 ml	7	6.65	6.3	5.95	5.6	5.25
0.05 ml	7	5.9	4.8	3.7	2.6	1.5

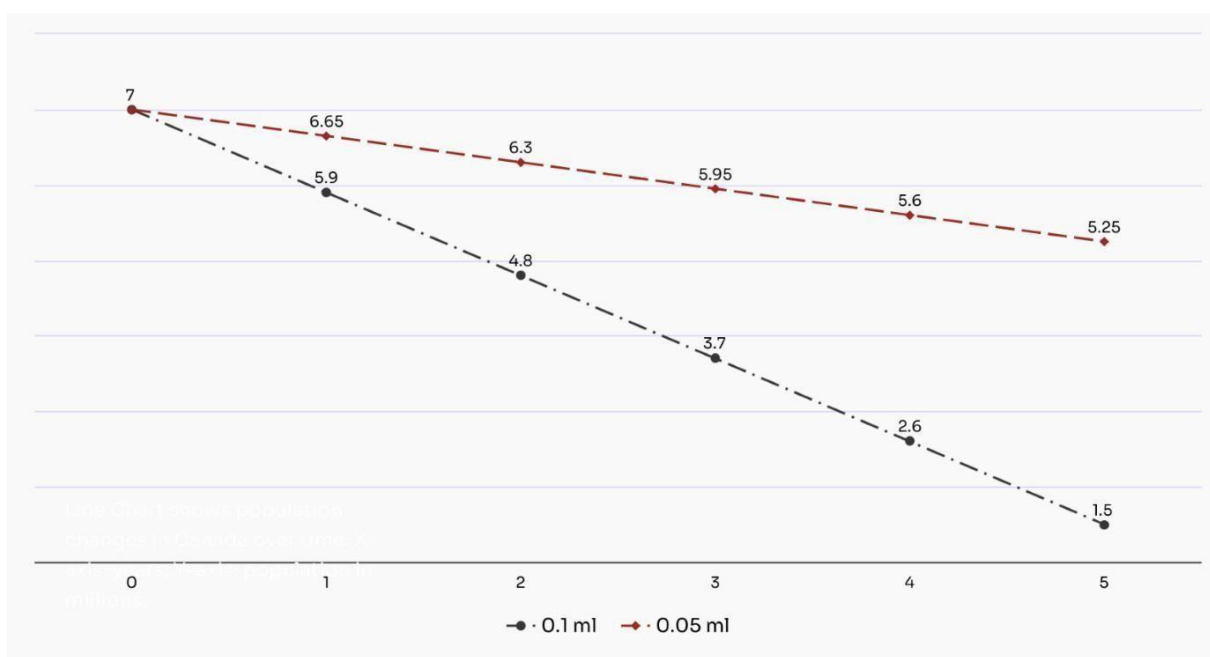


Fig:5.5: (0.1N HCl) Acidic pH Calibration

(0.1N NaOH) Basic pH Calibration:

Table:5.3: (0.1N NaOH) Basic pH Calibration

0.1 ml	7	8.1	9.2	10.3	11.4	12.5
0.05 ml	7	7.35	8.05	9.4	9.75	10.1

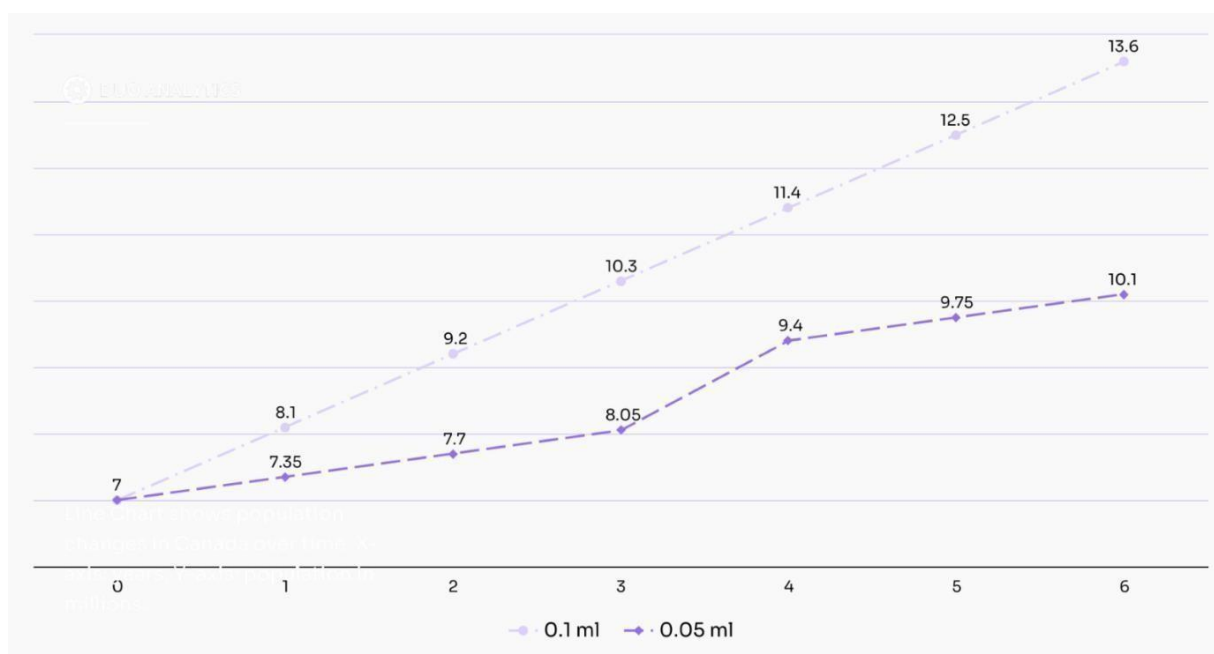


Fig:5.6: (0.1N NaOH) Basic pH Calibration

5.5. Temperature sensor Calibration:

- **Temperature Stability:** The temperature readings remained relatively stable throughout the monitoring period, fluctuating within a narrow range of 25.0°C to 26.5°C.
- **Optimal Growth Conditions:** The recorded temperatures were within the optimal range for *Chlorella vulgaris* growth, which typically falls between 25°C to 30°C, indicating that the cultivation environment was suitable for the algae.
- **Consistent Monitoring:** The data log demonstrated consistent monitoring of temperature, ensuring that any deviations from the optimal range could be quickly identified and addressed to maintain ideal growth conditions.
- **Cultivation Period:** The data log spanned a specific cultivation period, providing a detailed record of temperature variations over time, which can be used for analysis and optimization of cultivation strategies.
- **Data Integrity:** The temperature sensor data log confirmed the accuracy and reliability of the temperature sensors, as the readings were consistent and aligned with the expected temperature range for *Chlorella vulgaris* cultivation.
- **Future Improvements:** Based on the data log, adjustments can be made to the cultivation setup or protocols to further optimize temperature control and potentially enhance *Chlorella vulgaris* growth and biomass production.

Table:5.4: Temperature sensor Calibration

Time (hh:mm:ss)	Temperature (°C)
00:00:00	25.0
00:15:00	25.2
00:30:00	25.5
00:45:00	25.3
01:00:00	25.1
01:15:00	25.4
01:30:00	25.6
01:45:00	25.8
02:00:00	26.0
02:15:00	26.2
02:30:00	26.4
02:45:00	26.5
03:00:00	26.3
03:15:00	26.1
03:30:00	26.0
03:45:00	25.8
04:00:00	25.6
04:15:00	25.4
04:30:00	25.2
04:45:00	25.0
...	...

31.50	1.60	7.29
31.50	1.60	7.29
31.50	1.60	7.29
31.50	1.60	7.29
31.50	1.60	7.29
31.50	1.60	7.29
31.50	1.60	7.30
31.50	1.60	7.29
31.50	1.60	7.30
31.50	1.60	7.29
31.50	1.60	7.30
31.50	1.60	7.29

Fig:5.7: Temperature sensor testing

5.6. Chlorophyll concentration:

Chlorophyll a ($\mu\text{g/mL}$) Chlorophyll b ($\mu\text{g/mL}$)

$$=(12.25 \times A_{665} - 2.79 \times A_{750}) \times V_{\text{sample}} V_{\text{extract}} \times DF$$

$$=(21.5 \times A_{750} - 5.1 \times A_{665}) \times V_{\text{sample}} V_{\text{extract}} \times DF$$

Where:

A_{665} and A_{750} are the absorbance readings at 665 nm and 750 nm, respectively.

V_{extract} is the volume of chlorophyll extract.

V_{sample} is the volume of the sample taken for extraction.

DF is the dilution factor (if the extract is diluted before measurement).

Results:

This method provides a quantitative measure of chlorophyll concentration in *Chlorella vulgaris*, which can be used to assess the photosynthetic activity and health of the algae culture.

Chlorella vulgaris growth curve in a photo bioreactor:

The growth curve of *Chlorella vulgaris* in a 1.5 L photo-bioreactor over a 5-day period demonstrates a typical pattern of algae growth. Starting with an initial biomass concentration of 0.02 g/L on day 1, the culture showed exponential growth, reaching a biomass concentration of 2.0 g/L by day 5. The growth curve illustrates the rapid proliferation of *Chlorella vulgaris* under favorable conditions, with biomass doubling approximately every 24 hours during the exponential growth phase. This exponential growth is characteristic of microalgae and highlights the potential of *Chlorella vulgaris* as a biomass source for various applications, including biofuel production and wastewater treatment.

Table:5.5: Chlorella vulgaris growth curve in a photo bioreactor

Day	Time (hrs)	Biomass Concentration (g/L)
1	0	0.02
	24	0.05
2	48	0.1
	72	0.2
3	96	0.5
	120	0.8
4	144	1.2
	168	1.5
5	192	1.8
	216	2.0

5.7. Compare the growth of algae in normal condition and in a photobioreactor:

Comparing the growth of algae in natural conditions to that in a photobioreactor highlights the advantages of controlled cultivation environments. In natural conditions, algae growth is influenced by factors such as sunlight availability, temperature variations, and nutrient levels, leading to variable growth rates and

limited biomass production. In contrast, algae grown in a photobioreactor experience stable and optimized conditions, including controlled light intensity, temperature, pH, and nutrient concentrations. This controlled environment promotes faster and more efficient algae growth, resulting in higher biomass production compared to natural conditions. Additionally, photobioreactors minimize contamination risks, ensuring a pure culture and healthier growth. The scalability of photobioreactors further enhances their utility, allowing for large-scale algae cultivation in a controlled and efficient manner. Overall, the comparison highlights the significant advantages of using photobioreactors for algae cultivation, particularly for applications requiring high biomass production and purity.

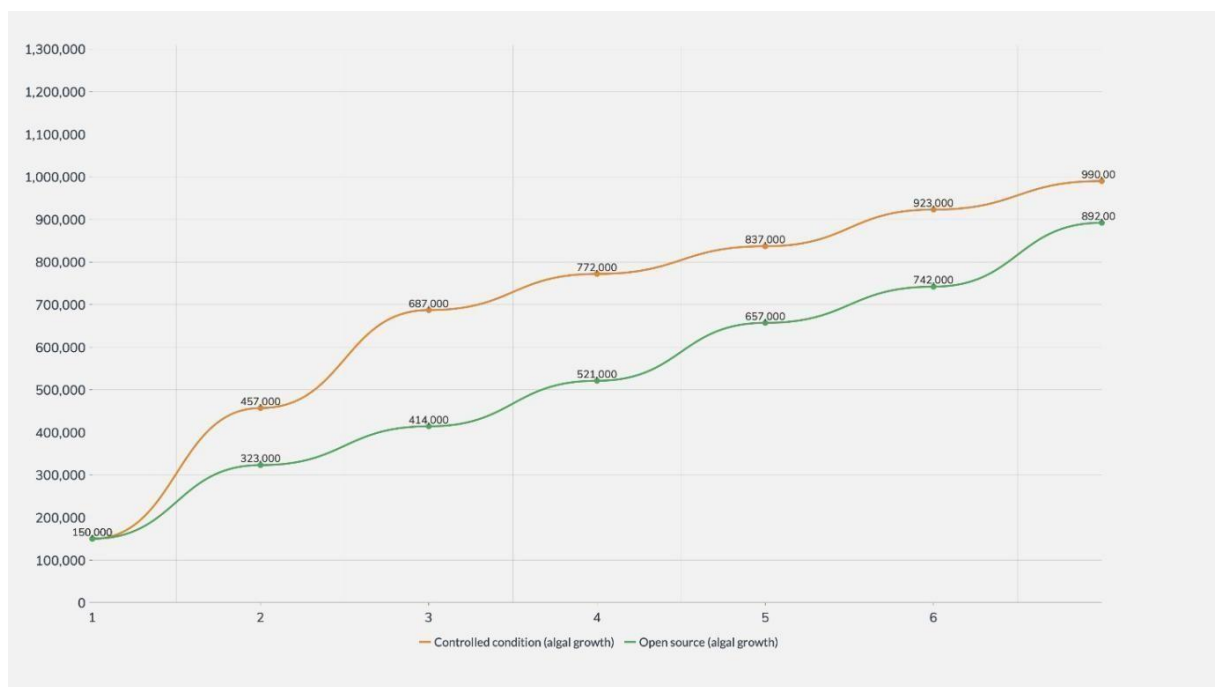


Fig:5.8: Compare the growth of algae in normal condition and in a photobioreactor

5.8. Software development:

The development of software or a webpage for a SCADA system focused on monitoring temperature, pH, and light in a photobioreactor involves designing an architecture that integrates sensors for these parameters with data acquisition and user interface components. The sensors, including those for temperature, pH, and light, need to be carefully selected and integrated to ensure accurate measurement and transmission of data to the SCADA software. The software

should provide real-time monitoring, historical data logging, trend analysis, and alarm functionality to alert operators of any deviations from the desired conditions. User-friendly interfaces, such as customizable dashboards and trend graphs, should be designed to allow operators to easily monitor and control the photobioreactor. Thorough testing and validation are crucial to ensure the system functions reliably, and ongoing maintenance and support are essential for its continued operation and effectiveness.

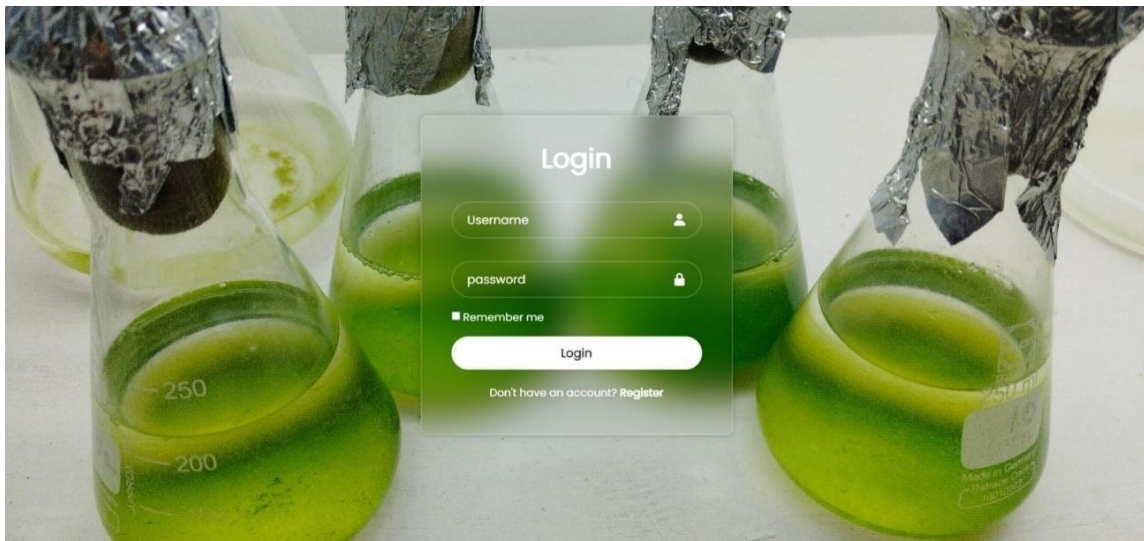


Fig:5.9: SCADA photo bioreactor webpage login page

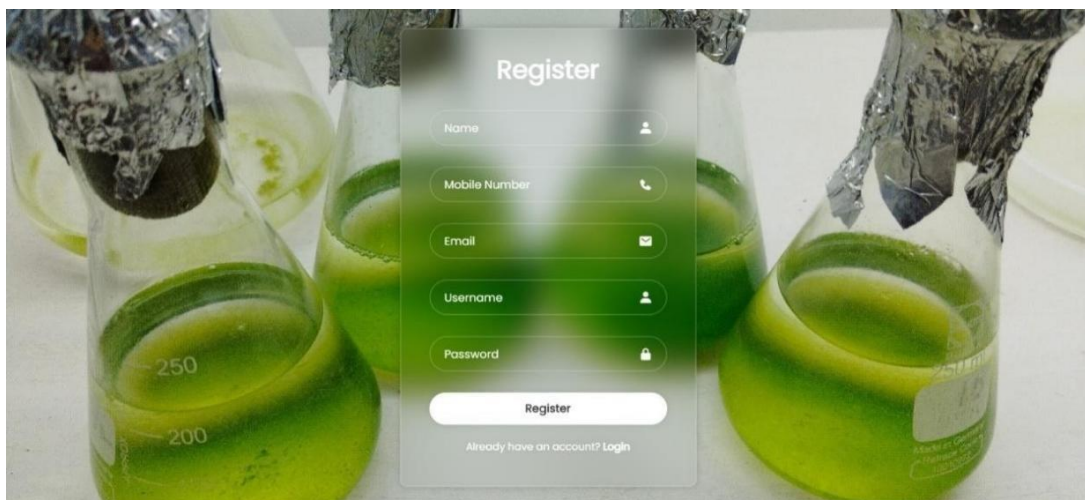


Fig:5.10: SCADA photo bioreactor webpage register page

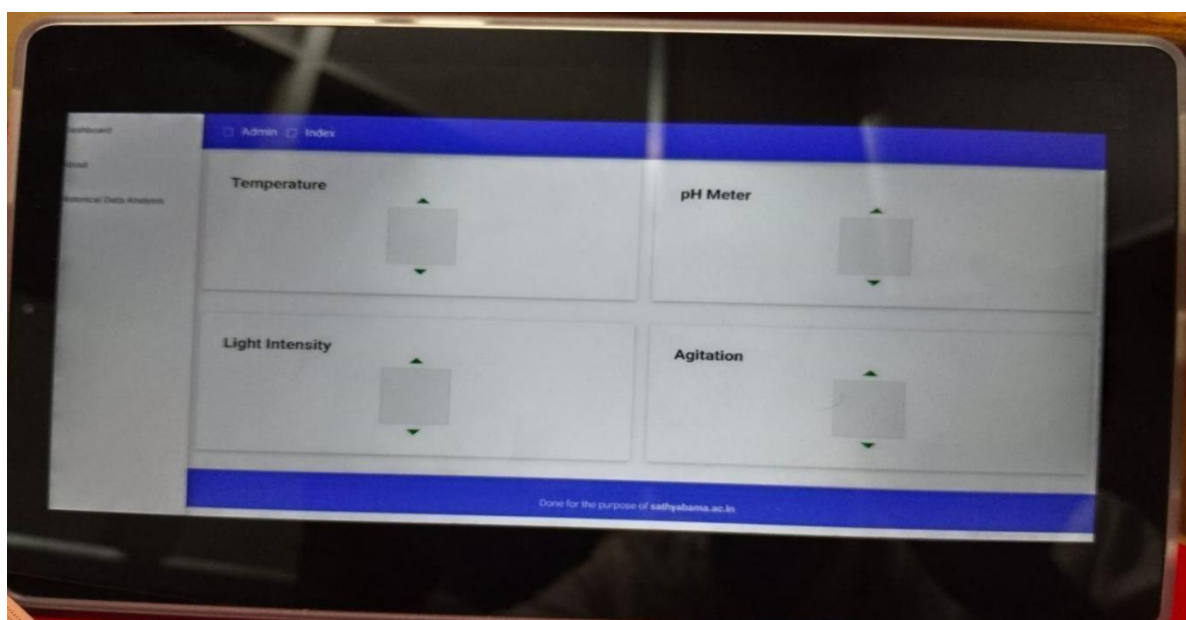


Fig:5.11: SCADA photo bioreactor webpage dash board in data acquisition device

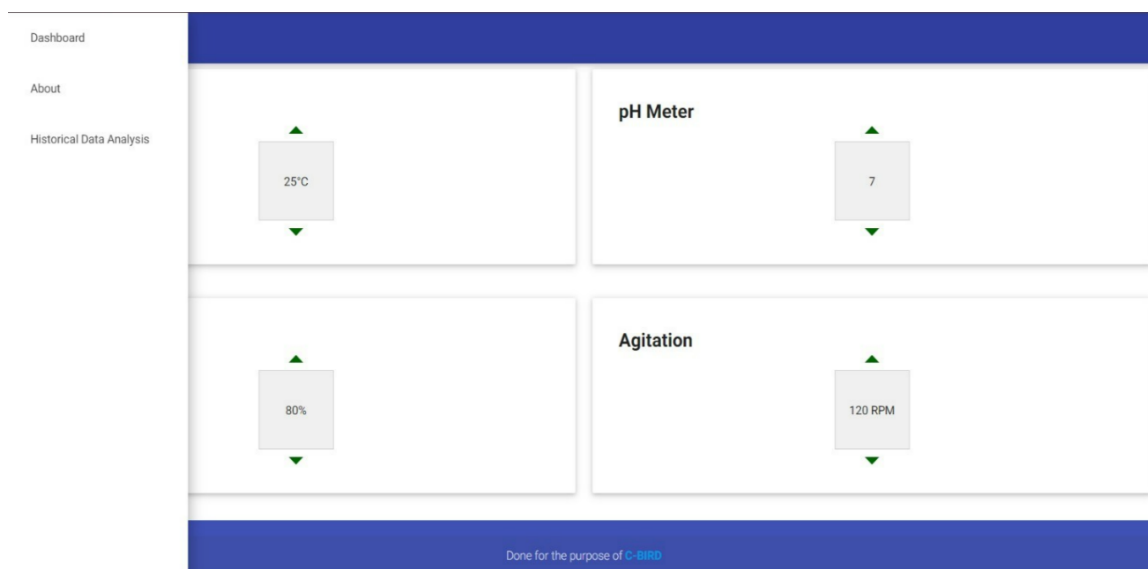


Fig:5.12: SCADA photo bioreactor webpage dashboard

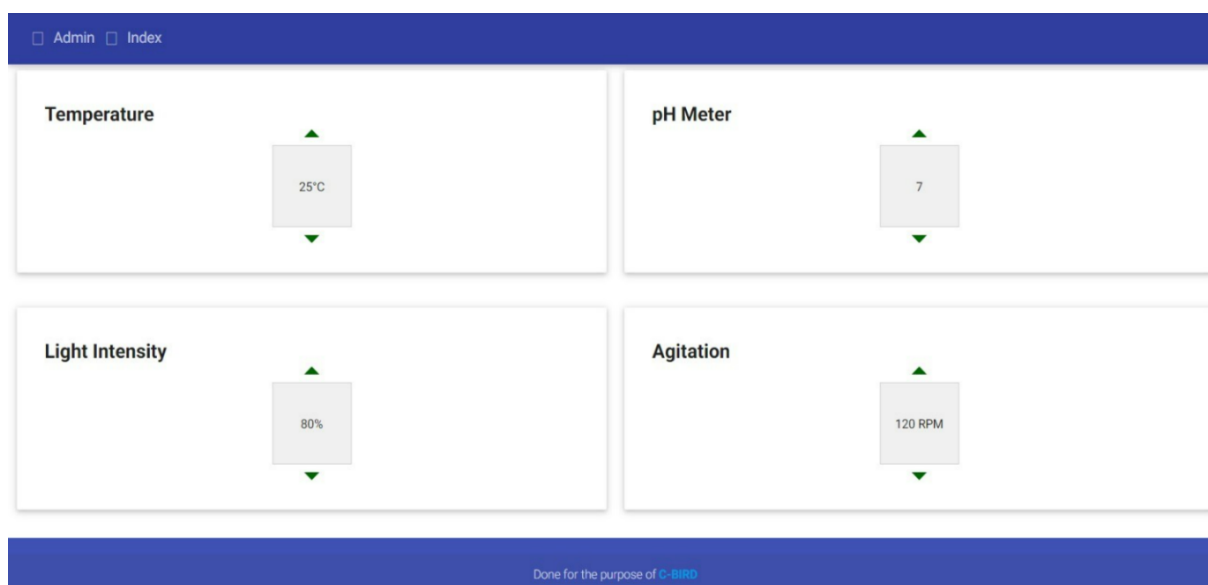


Fig:5.13: SCADA photo bioreactor webpage dashboard interface

In addition to optimizing growth conditions for *Chlorella vulgaris*, the SCADA-controlled photobioreactor offers immense potential for further research and innovation in the field of microalgae cultivation. With its ability to precisely monitor and adjust parameters such as light intensity, pH levels, and temperature, the system provides a versatile platform for studying the effects of various stressors on microalgae growth. The controlled environment of the photobioreactor allows researchers to subject microalgae to specific stress conditions, such as light stress, pH stress, and temperature stress, mimicking real-world scenarios where microalgae may encounter adverse conditions. By studying how microalgae respond to these stressors, scientists can gain valuable insights into the mechanisms underlying stress tolerance and adaptation in these organisms. Moreover, the ability to manipulate growth conditions opens up new possibilities for the production of novel molecules with potential applications in various industries, including pharmaceuticals, nutraceuticals, and biofuels. By altering environmental factors in the photobioreactor, researchers can induce microalgae to produce specific compounds of interest, unlocking new avenues for biotechnological innovation. Furthermore, the collaborative nature of such research endeavors, involving engineers, scientists, stakeholders, and communities, fosters interdisciplinary collaboration and knowledge exchange. This collaborative approach not only accelerates technological advancements but also promotes inclusivity and diversity in research and innovation. Overall, the SCADA-controlled photobioreactor represents a powerful tool for advancing our understanding of microalgae biology, driving innovation in biotechnology, and contributing to the development of sustainable solutions for societal and environmental challenges. By harnessing the potential of microalgae cultivation, we can pave the way towards a more sustainable and resilient future for generations to come.

SUMMARY AND CONCLUSION

In an era where pollution has taken center stage, ways to effectively mitigate pollution have gained prominence. Algal bioremediation and products from the algal community have become a biotechnologists paradise. Growth of algae using various types of photo bioreactor is being practiced by environmentalists with an aim of mitigating pollution and obtaining value added products from them. With computer and AI invading every discipline this work combines the growth of algae with IOT. An effective SCADA software with versatility in controlling the key growth parameters of microalgae viz. Light, pH and Temperature was designed and tested with an ability to remotely control the growth parameters, This SCADA photo bioreactor has proved to be a definitive answer to the controlled growth of microalgae for various applications.

The SCADA Photobioreactor for algal culture stands as a testament to the potential of engineering to address pressing societal and environmental challenges. By automating the process of algal culture, we are not only advancing technological frontiers but also contributing to a more sustainable future. Exhibiting steadfast devotion and energy as a technologist engaged with Photobioreactor research, our team embodies a relentless pursuit of knowledge and innovation. With a hunger for information and a commitment to lifelong learning, we continuously seek to expand our understanding of algal cultivation and automation technology. Our sharp, insightful mentality allows us to tackle complex challenges with creativity and precision, while our multidisciplinary approach enables us to integrate diverse perspectives and expertise into our work. By combining these qualities, we are able to push the boundaries of what is possible in Photobioreactor research, driving forward progress towards a more sustainable and prosperous future.

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ANNEXURE

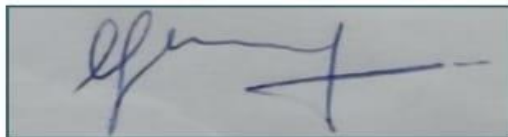
Gate Score card

		GRADUATE APTITUDE TEST IN ENGINEERING 2024 अभियांत्रिकी स्नातक अभिक्षमता परीक्षा २०२४ ORGANISING INSTITUTE: INDIAN INSTITUTE OF SCIENCE, BENGALURU ADMIT CARD	
Name of the Candidate YUVA RAJA T			
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Paper Code/Name		BT : Biotechnology	
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INSTRUCTIONS TO CANDIDATES			
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Photograph



Signature

Marks out of 100[#]

2.33

Qualifying Marks^{##}

38.9

General

35

OBC-NCL/EWS

25.9

SC/ST/PwD

[#] Normalized marks in case of multisession papers (CE and
CS)

CLOSE

Abstract Publication



Designing a fully automated bioreactor

Yuvaraja T , Ramesh Kumar V

120

Abstract Book: The 11th International Conference on the Integration of Science and Technology for Sustainable Development 2024 organized by Sathyabama Institute of Science and Technology, Tamil Nadu, India during 1-3, February 2024 (**ISBN: 978-93-834**

¹Department of Biotechnology, Sathyabama Institute of Science and Technology, Ch 119, Tamil Nadu, India

Bioreactors assume a crucial part in different biotechnological processes, fi controlled conditions for the development of microorganisms, cells, or tissues for the important bio-items. This theoretical investigates the new progressions in the advanced completely computerized bioreactors, meaning to smooth out and upgrade bioprocess mix of state of the art advancements, including man-made consciousness, sensor mechanical technology, has empowered the making of another age of bioreactors that independently, giving remarkable accuracy, effectiveness, and reproducibility of bioproduction. Key parts of these completely mechanized bioreactors incorporate control frameworks able to do progressively managing key boundaries like temperature, disintegrated oxygen, and supplement fixations. Moreover, the joining of AI calculations versatile control, expecting and answering changes in the bioprocess conditions control. The utilization of modern sensors and checking gadgets empowers persistent monitoring, obtaining, guaranteeing complete understanding into the bioreactor climate. The existing automated frameworks for undertakings like vaccination, testing, and gathering decreases the requirement for human mediation, upgrading the adaptability and quality of bioproduction processes. In addition, the improvement of easy to use interface with remote checking and control, opening additional opportunities for decentralized biomanufacturing. While the reception of completely computerized bioprocess presents huge benefits concerning effectiveness, reproducibility, and adaptability, difficult high starting expenses, framework intricacy, and the requirement for specific mastery tended to. This theoretical examines the present status of completely robotized bioprocess featuring their likely effect on different businesses, including drugs, biopharmaceuticals, biofuels. The continuous innovative work in this field plan to conquer existing difficulties, make ready for the broad reception of completely mechanized bioprocessing for reforming the scene of biotechnology and biomanufacturing.



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Name of the student : Yuvaraja T

Register Number : 40230049

Title of the Thesis : Designing a supervisory control and data acquisition
(SCADA) system for photo Bioreactor

Internal Guide Name : Dr.V.Ramesh Kumar

PO / PSO / PEO / SDG	Justification
PO-1	Designing a SCADA system for a photobioreactor involves integrating sensors and creating interfaces for real-time monitoring and control, with a focus on safety and reliability.
PO-2	Analyzing the problem for a photobioreactor SCADA system means choosing sensors and controls to optimize algal growth.
PO-3	Developing a SCADA for a photobioreactor involves creating a user interface and integrating sensors with control algorithms for efficient algae cultivation.
PO-5	Modern SCADA tools for photobioreactors use advanced software and IoT devices for remote monitoring and control, optimizing algae growth.
PO-6	In designing a SCADA system for a photobioreactor, engineers consider sustainability and food security, while ensuring data security and public trust.
PO-7	Designing a SCADA system for a photobioreactor involves ensuring energy efficiency and minimizing environmental impact for sustainable operation.
PO-8	Ethical design of a SCADA photobioreactor involves safeguarding data integrity and implementing fail-safes to prevent environmental damage.
PO-11	Project management involves setting clear timelines, while finance requires careful budgeting for hardware, software, installation, and maintenance costs in designing a SCADA photobioreactor.
PSO-3	Bioprocess techniques in photobioreactors, coupled with SCADA integration, drive technological advancements and foster bioentrepreneurship through efficient, scalable production of valuable bio-products.
PEO-2	As a committed technologist in SCADA design for photobioreactors, strive for ongoing learning, research, and multidisciplinary thinking for innovative solutions.



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SDG-7	Designing a SCADA system for a photobioreactor with Affordable and Clean Energy involves maximizing energy efficiency and potentially integrating renewable energy sources like solar power to reduce costs and environmental impact.
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