International Journal of Scientific Research and Engineering Development-– Volume 6 Issue 5,Sep-Oct 2023

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

# Assembly of Pilot Scale Fermentor

Akila R[1], Dharshini R[1], Srimita S[1], Thilak R S[1],Dr Frankline Noah[2]

Department of Food Technology

Sri Shakthi Institute of Engineering and Technology

## Abstract:

Increased attention in recent years has been paid utilization of radiation, particularly ultraviolet (UV) light, for sterilization and disinfection in the context of industrial-scale fermentations in order to create a green fermentor, which consumes less energy. The pilot scale fermentation system is equipped with a range of UV light emitting diode, which are strategically positioned for consistent illumination in the bioreactor. In order to generate energy from sunlight and reduce the dependence of traditional electricity grids, photovoltaic panels are installed in a fermentor system. UV light is used in the fermentation tank for a number of reasons: Firstly, it acts as an effective disinfection and sterilisation technique that mitigates the risk of contamination during fermentation. Secondly, UV light exposure can be controlled and optimized to induce specific metabolic responses in microorganisms, enhancing the production of desired bioproducts. Moreover, the combination of UV light and photovoltaic modules is contributing to a reduction in carbon emissions and operating costs by providing an especially suited system for sustainability bioprocessing applications. This project provides insight into the potential of a pilot scale fermentation system as an innovative and environmentally friendly solution to large scale bioprocesses, which demonstrates that integrating UV light and solar panels can achieve sustainable and energy efficient bioprocessing processes.

**Keywords**: UV light, sterilization, photovoltaic panels, bioprocess, green fermentor

---------------------------------------------------*************---------------------------------------------------

## Introduction

Fermentation is one of the most commonly used bioprocesses in manufacture of different types of useful bioproducts such as pharmaceuticals, enzymes, food industries and biofuels, among others. A pilot scale fermenter is one of a crucial tool in the field of biotechnology, food industries and industrial microbiology. It allows scientists to study and optimize fermentation processes on a smaller, controlled scale before implementing them on a larger industrial level. In recent years, there has been growing interest in incorporating sustainable practices into these systems. One such innovation is the use of UV sterilization and solar panels for power supply.Scale-up of the fermentation process that can lead into manufacturing and marketing these products. The complexity of keeping the environment sterile and operating at a pilot scale leads to high power utilization and operational costs.

However, traditional fermentation often involves either heating or chemically intensive sterilization that could potentially have high associated energy costs and even environmental impact. On another note, UV sterilisation is based upon non-thermal, chemical free operation which involves utilising of ultraviolet light in killing of the bacteria present in the fermenter as well as its content. UV sterilization has many benefits such as saving energy, shortened cycles of operation and low ecological harm. This breakthrough includes incorporating UV sterilization into the pilot scale to give bioprocessing safer and efficient methods.

Electricity is the most crucial energy supply required for fermentor operation. The greenhouse gas emissions that arise from traditional power suppliers are usually high. However, to address this problem, a solar panel driven pilot-scale fermentor has been proposed in this study. A sustainable fermentation process should utilize solar energy as it is a renewable and clean power source. The pilot-scale fermentor leverages solar energy as a way of lowering operational expenses, minimizing atmospheric pollution, and minimizing dependence on fossil fuels.

However this combined approach involving UV sterilisation and solar panel driven power supply can increase in sustainability in addition it can reduce the operational cost. This integration signifies an increasing focus of environmental sustainability coupled with the shift to clean greener bio-processes in today's world.The pilot-scale fermentor design was considered in great details in this paper with a view of establishing its relevance in bio processing and also addressing other matters such as sustainability and costs.This combined approach, using UV sterilization and solar panel-based power supply, not only has the potential to enhance the sustainability of pilot-scale fermentation but also to substantially reduce operating expenses. The integration of these advanced technologies is a testament to the growing emphasis on environmental responsibility and the need to transition towards greener, more efficient bioprocessing methods.

This paper will explore in detail the design, implementation, and performance of the pilot-scale fermentor, emphasizing its potential for widespread adoption in the bioprocessing industry and its significant contributions to sustainability and cost-effectiveness.It also proposes a new pilot-scale fermentation that utilizes ultraviolet sterilization in place of autoclave, coupled with solar energy instead of electric power.

## Materials and Methodology

### Materials

Our Bioreactor is made of stainless steel with a capacity of 5-7 litres. The stainless steel is food grade. To ensure proper sterilization of the bioreactor, we are incorporating UV sterilization technology into our design. UV sterilization is a highly effective method for killing bacteria, viruses, and other microorganisms. By installing UV lamps within the bioreactor, we can ensure that the cultured meat production process remains free from contamination.Additionally, we are exploring the use of solar power panels to provide energy for the bioreactor. This sustainable energy source not only reduces our carbon footprint but also makes our production process more cost-effective in the long run. By harnessing the power of the sun, we can achieve a more environmentally friendly and efficient operationThe use of stainless steel in the construction of the bioreactor ensures its durability and suitability for food-grade purposes(Allan et al., 2019).

### Methodology

The UV sterilization technology will be implemented by installing UV lamps within the bioreactor(Zhang et al., 2023). This lamp will emit UV-C light which is effective in killing the microorganism. The UV-C light emitted by the UV lamps installed within the bioreactor is effective in killing microorganisms through direct absorption of the UV-C photons by the nucleic acid bases and/or capsid proteins, leading to their inactivation.The solar power will be integrated into the bioreactor system to provide a sustainable source of energy for the fermentation process. Here we have installed solar panels on the side surface of our bioreactor to capture sunlight and convert it into a usable form of electricity.The solar power will be utilized to power various components of the bioreactor system, including the agitation system, temperature control, and nutrient supply(Leger et al., 2021). To monitor and control the fermentation process, we will also incorporate pH and temperature sensors into the bioreactor design. These sensors will provide real-time measurements of the pH level and temperature inside the bioreactor, ensuring optimal conditions for the growth of the cultured meat cells. For the pH sensor, we will use a reference pH electrode that is specifically designed for bioprocess applications. This electrode will accurately measure the acidity or alkalinity of the culture medium and allow us to make any necessary adjustments to maintain the desired pH level throughout the fermentation process.In addition, a temperature sensor will be placed inside the bioreactor to monitor the temperature of the fermentation media. This sensor will send real-time data to a temperature controller which will regulate the heating or cooling system to maintain the desired temperature range for optimal growth of the microorganism.To ensure efficient mixing and agitation of the medium, a spur gear system will be incorporated into the design of the bioreactor. Spur gears are one of the most commonly used gear types in bioreactor systems due to their simplicity and effectiveness. They consist of cylindrical gears with straight teeth that mesh together to transfer power and torque. The integration of a spur gear system allows for precise control over the agitation speed and direction, ensuring uniform distribution of nutrients and oxygen throughout the culture medium. This promotes optimal cell growth and metabolism, leading to higher productivity and quality of the cultured meat. In a study by Choi et al., the use of a spur gear system in a pilot-scale bioreactor significantly improved the mixing efficiency and ultimately increased the yield of the desired product.

To sterilize the bioreactor, we are implementing the UV sterilization method using a UV-C lamp as the light source. This method involves exposing the interior surfaces of the bioreactor to UV-C light which has a germicidal wavelength and can effectively kill microorganisms. The use of UV sterilization in water treatment and aquaculture has gained popularity, and its application in bioreactors is also becoming common. The UVC wavelengths, particularly around 253.7 nm, have been found to have the strongest disinfectant effects on bacteria. This is because the maximum absorbance of DNA and protein for most microorganisms falls within the range of 260 nm to below 280 nm, making them highly vulnerable to UVC radiation. In recent years, advancements in UV technology have made it more reliable and accessible for use in biological safety cabinets and ductwork within research facilities.In addition to temperature control and sterilization, the design of the bioreactor for fermentation also involves the integration of a DC motor. The DC motor plays a crucial role in driving the impellers of the bioreactor, ensuring effective mixing and agitation of the fermentation media. A DC motor, or direct current motor, converts electrical energy into mechanical energy through the interaction of a magnetic field and an electric current. This type of motor is commonly used in industrial applications, including bioreactors, due to its efficiency, reliability, and controllability. By incorporating a DC motor into the bioreactor design, we can achieve precise control over the speed and intensity of mixing, allowing for optimal nutrient distribution and enhanced oxygen transfer in the culture medium.The design and construction of a pilot-scale fermentor involve the incorporation of various components, including a heat exchanger, spur gear, and DC motor. The commonly used heat exchanger is the shell and tube heat exchanger (Kandasamy. S et al.,2019).

  

Agitation: Agitation is important in the fermentation process as it ensures the microorganisms are evenly distributed in the fermentor and the nutrients are evenly mixed. The pilot-scale fermentor is equipped with the spur gear mechanism with the DC motor. DC motor provides adequate agitation (Zeng, R., et al.,2018).

Temperature sensor and control: The fermentor is equipped with a temperature sensor to maintain the temperature throughout the fermentation process. The temperature sensor is connected to the temperature control system to monitor and control the excess temperature in the heat exchanger. The monitoring system ensures that the temperature remains within the optimal range for microbial growth (Yang, Y., et al.,2020).

**Components used**

**DC motor**

A DC motor in a fermenter can serve various purposes, but it's often used to drive an impeller for the purpose of agitating the fermentation broth. This mechanical agitation helps maintain uniform conditions within the vessel, ensuring proper mixing of nutrients, oxygen, and microorganisms for efficient fermentation. By using a DC motor to drive the impeller, which helps in creating a controlled environment via agitation which influences the microbial growth and the production of fermentation products.

**Spur Gear**

Spur gears are the simplest and most common type of gear. Their general form is a cylinder or disk. The teeth project radially, and with these straight-cut gears, the leading edges of the teeth are aligned parallel to the axis of rotation. These gears can only mesh correctly if they are fitted to parallel axles. The torque ratio can be determined by considering the force that a tooth of one gear exerts on a tooth of the other gear. It helps by linking the dc motor to the impeller for agitation.

**Impeller**

An impeller in a fermenter is a mechanical device designed to agitate and mix the contents of the bioreactor vessel, which typically includes a culture medium and microorganisms or cells. The impeller is a critical component of the fermenter, and its primary purpose is to ensure uniform distribution of nutrients, oxygen, and other essential components in the culture medium, as well as to facilitate heat transfer and gas exchange. It plays a vital role in the success of a fermentation process.

**Rushton Turbine:** This is a common type of radial flow impeller with multiple flat blades that extend outward from the impeller shaft. It's known for its strong axial flow and effective mixing.

**UV Radiation**

UV-C radiation, also known as ultraviolet-C radiation, is a type of ultraviolet (UV) radiation with wavelengths in the range of 100 to 280 nanometres (nm). It is a high-energy form of UV radiation, and it is germicidal, meaning it has the ability to kill or inactivate microorganisms such as bacteria, viruses, and other pathogens.

**Three-way meter**

A three-way meter, also known as a multiparameter meter, is a device used in fermenters and other applications to simultaneously measure and monitor multiple environmental parameters. In the context of a fermenter, which is used for microbial or cell culture processes, these three parameters are commonly pH (acidity/alkalinity), moisture (liquid level or humidity), and light (for certain specialized applications).

- **pH (acidity/alkalinity):** pH is a measure of the acidity or alkalinity of a solution. In a fermenter, maintaining the proper pH level is crucial for the growth and health of the microorganisms or cells being cultured.

- **Moisture (liquid level):** Monitoring the moisture level, or liquid level, is essential in a fermenter to ensure that there is enough liquid medium to support microbial or cell growth.
- **Light:** Light measurement is not a common parameter in standard fermenters. However, in some specialized applications, such as the cultivation of photosynthetic microorganisms like algae, or in bioprocessing involving genetically modified organisms sensitive to light, light intensity might be a relevant parameter.

**Temperature Sensors**

Temperature control and monitoring are critical aspects of fermenter operation, as they directly influence the growth and metabolic activities of microorganisms or cells in the bioprocess. In a fermenter, a temperature sensor is used to measure and control the temperature of the culture medium. There are various types of temperature sensors used in fermenters, and their selection depends on the specific requirements and characteristics of the fermentation process.

**Two wire Temperature Sensors**

The 2-wire RTD Temperature Sensor is designed for various applications and offers high precision and waterproof performance. The sensor uses a platinum resistance temperature detector connected to a flexible silicone cable. The sensor is encapsulated in a stainless-steel tube with a double-roll crimp.

**Baffle**

In a fermenter or bioreactor, a baffle is an essential component designed to improve the mixing and control of the contents within the vessel. It consists of vertical plates or strips attached to the inner surface of the bioreactor's cylindrical wall. The primary purpose of baffles in a fermenter is to enhance the efficiency of the agitation and mixing provided by the impeller(s), which is vital for achieving uniform distribution of nutrients, oxygen, and other components in the culture medium and for preventing irregular flow patterns within the vessel.

**Sparger**

A sparger is an important component in fermentation processes, particularly in bioreactors and fermenters used for microbial or cell culture. Its primary function is to introduce and distribute gases, such as oxygen or air, into the liquid culture medium. Spargers play a crucial role in providing the necessary oxygen for aerobic fermentations and in some cases for mixing and dispersing other gases as well.

**Product collecting valve**

A product collection valve in a fermenter is a critical component designed to enable the controlled and aseptic withdrawal of the final fermentation product from the vessel.Once the fermentation process is complete, the desired product, which can be a biofuel, enzyme, pharmaceutical, or any other bioproduct, needs to be collected for further processing or purification. The product collection valve allows for the controlled removal of the product from the fermenter without exposing it to contamination.

**Heat Exchanger**

The heat exchanger plays a critical role in fermentation processes by maintaining and controlling the temperature within the fermenter. Temperature control is vital for successful fermentation for several reasons:

- To control Microbial Growth and Activity
- Effectiveness of the Enzyme Activity
- Resulting in better Product Quality and Yield.

**Solar Panel**

A solar panel is a device that converts sunlight into electrical energy. In the context of a fermenter, it can be used to harness solar energy and convert it into electrical power for running the DC motor.

**Battery**

A battery is a rechargeable energy storage device that stores the electrical energy generated by the solar panel. The stored energy can be used to power the DC motor when sunlight is not available, such as during cloudy days or at night. Batteries provide a reliable power source and ensure continuous operation of the fermenter.

**Assembly of pilot scale**

Step 1: Assemble the Lid Section

1.1 Three-way Meter:

- Install the Moisture Content Sensor, pH Level Sensor, Light Intensity Sensor, and Temperature Sensor onto the lid, positioning them in a way that they can monitor the contents inside the container.

1.2 Dc Motor:

- Attach a DC Motor to the lid, ensuring it is securely mounted.
- Connect the DC Motor to the impeller using the spur gear mechanism.

1.3 UV Light:

- Install the UV Lamps on the inner surface of the lid, making sure they are evenly distributed.

Step 2: Assemble the Container

2.1 Baffle:

- Insert the baffle into the container, ensuring it's positioned to avoid vortex formation during agitation. The baffle height should be 29 cm from the bottom.

2.2 Sparger:

- Attach the sparger to the bottom of the container to facilitate efficient air circulation. Ensure it is securely fastened.

2.3 Product Collection Valve:

- Install the product collection valve at the bottom of the vessel to enable controlled and sterile withdrawal of the final fermentation product.

Step 3: Assemble the Heat Exchanger

- Position the heat exchanger around the container.
- The heat exchanger consists of an inner pipe circle with a diameter of 2 cm and an outer pipe with a diameter of 2 cm.

Step 4: Assemble the Stand

- Place the stand at the desired location and ensure it is stable.
- Position the vessel on the stand. The distance between the vessel and the stand should be approximately 17.5 cm.
- Securely attach the lid to the vessel. The lid's radius is 20 cm.

Step 5: Impeller Assembly

  

- The impeller, with a diameter of 29 cm and impeller wings measuring 4.5 x 1.3, is already welded to the DC Motor via the spur gear mechanism.

Step 6: Inlet Pipe Installation

- Connect the inlet pipe (2 cm diameter) to the vessel.
- This pipe can be used for adding or removing liquids or gases as needed during the fermentation process.

Step 7: Ensure Proper Connections

- Ensure all sensors and instruments in the lid section are properly connected to monitoring and control systems.
- Confirm that the UV lamps are connected to a sterilization control system and are properly positioned.

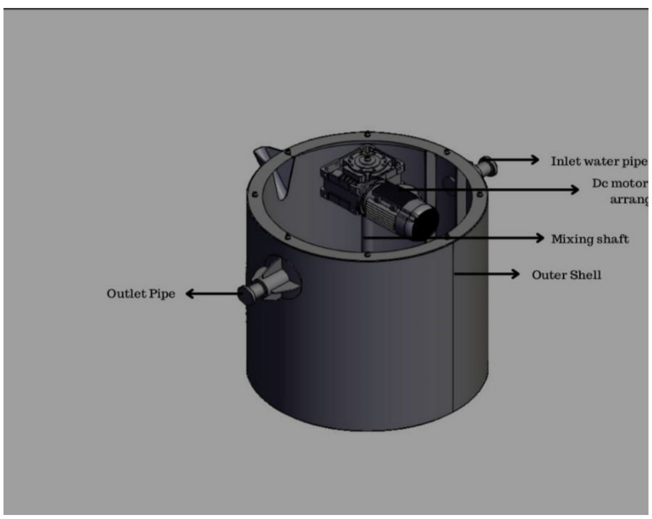


**Fig 1- 3D Diagram of Fermentor in AUTOCAD**

## Wiring and connections

Establish a direct electrical link by connecting the positive (+) terminal of the solar panel to the corresponding positive terminal of the battery.Create a parallel electrical path by connecting the negative (-) terminal of the solar panel to the corresponding negative terminal of the battery.Enable power transfer to the circuit board by connecting the positive (+) terminal of the battery to the designated input terminal of the circuit board.Establish a common electrical reference point by connecting the negative (-) terminal of the battery to the ground (GND) terminal on the circuit board.Employ a transistor as an active electronic component to regulate temperature within the system. The specific configuration of the transistor should be determined based on the circuit design and requirements. It is often used for amplifying and controlling electrical signals to manage temperature-related processes.Implement a control mechanism by introducing a switch in-line between the output of the circuit board and the DC motor. This switch provides the capability to selectively activate or deactivate the DC motor as needed, offering operational control and enhancing safety and efficiency.

## Result and discussion

In the pursuit of enhancing bioprocessing technologies and promoting sustainability, we designed a pilot-scale fermentor incorporated with UV sterilization and solar energy panels. The improvement and assessment of this revolutionary gadget yielded valuable insights and diagnosed each benefits and boundaries, paving the manner for destiny improvements in renewable power-powered fermentation methods. All the above mentioned parts are shown in figure 1.

## Importance of pilot-scale fermentors

The significance of pilot-scale fermentors in various industries cannot be overstated. They facilitate method development, scale-up validation, and product exceptional assurance. In our observe, we tested the adaptability of this generation, providing a stepping stone toward massive-scale, sustainable fermentation strategies. By optimizing conditions and minimizing inefficiencies inside the laboratory, we pave the course for a seamless transition to business manufacturing.

**Advantages of uv sterilization over thermal sterilization**

Our incorporation of UV sterilization inside the fermentor added forth numerous compelling advantages. Firstly, the non-contact nature of UV sterilization is mainly treasured, safeguarding delicate or warmness-touchy substances frequently used in biotechnology and pharmaceutical packages. Furthermore, the absence of chemical compounds and speedy sterilization ensure eco-friendliness and efficiency. The residual warmth related to thermal sterilization methods is removed, and bodily changes to the sterilized gadgets are averted, making sure product integrity. Continuous sterilization, power efficiency, and minimal renovation further give a boost to the advantages of UV sterilization.

**Advantage of solar power over normal power**

Solar strength's myriad advantages have been discovered in our gadget. The maximum outstanding gain lies in its renewable and environmentally friendly nature, decreasing greenhouse gas emissions and selling strength sustainability. Reduced power bills and electricity independence were noted, as sun power structures empower centers to generate their own electricity. While the preliminary setup fees may be higher, long-time period value financial savings grow to be obvious, specially in remote or off-grid locations. The scalability of solar energy structures provides flexibility, and their low upkeep requirements make certain lengthy-term cost-efficiency.

**Scope of equipment**

Our have a look at delved into the comprehensive scope of designing a pilot-scale fermentor. We emphasised the importance of defining layout parameters, deciding on appropriate substances, establishing strong sterilization and cleansing processes, imposing a precise manage device, and utilising specialised bioreactor software for records acquisition and evaluation. The purposeful evaluation section changed into important in determining the fermentor's capacity to assist microbial increase, product formation, and scalability.

**Applications**

The packages of our integrated gadget are various and promising. Biopharmaceuticals, meals and beverage production, biotechnology, environmental biotechnology, agriculture, studies and education, scaling up manufacturing, bioenergy, pharmaceutical intermediates, cosmetics, and private care merchandise all stand to benefit from the technology. Its flexibility and adaptability make it a valuable asset in diverse industries.

**Overall advantages**

The common benefits of our system include improved energy efficiency, environmental sustainability, value financial savings, power independence, sterilization efficiency, procedure reliability, scalability, far flung operation abilties, and reduced protection necessities. These advantages align with sustainability dreams and make contributions to accountable and cost-powerful bioprocessing.

**Limitations**

Our study additionally uncovered several limitations that ought to be addressed in destiny studies and improvement. The dependence on solar energy introduces challenges associated with intermittent power supply and seasonal variability. Initial investment costs can be prohibitive for smaller operations. Maintenance and backup systems are necessary to ensure continuous operation, in particular throughout damaging weather situations. Some fermentation tactics might not be suitable for solar-powered fermentors, and infection dangers should be cautiously controlled. Scaling up the technology for huge-scale production presents a complicated set of demanding situations.

Furthermore, our prototype-based development identified critical areas for improvement. Two separate switches for UV lamp operation are essential to ensure precise control of sterilization processes. Additionally, the incorporation of an air compression system for the sparger is imperative to facilitate efficient aeration and agitation within the fermentor. These modifications are vital for optimizing the functionality and reliability of the system as it progresses from prototype to a fully operational unit.

## Conclusion

Fermentation is a extensively used bioprocess within the production of diverse bioproducts, and a pilot scale fermenter is a essential tool for studying and optimizing fermentation techniques.Incorporating sustainable practices such as UV sterilization and solar panel power supply can enhance the sustainability of pilot-scale fermentation and substantially reduce operating expenses. The use of stainless steel, UV sterilization, solar power, pH and temperature sensors, spur gear system, and DC motor are important components of the bioreactor design for efficient mixing, agitation, and monitoring of the fermentation process.

## References

1. Allan, S J., Bank, P D., & Ellis, M. (2019, June 12). Bioprocess Design Considerations for Cultured Meat Production With a Focus on the Expansion Bioreactor.
2. Leger, D., Matassa, S., Noor, E., Shepon, A., Milo, R., & Bar□Even, A. (2021, June 21). Photovoltaic-driven microbial protein production can use land and sunlight more efficiently than conventional crops.
3. Zhang, W., Huang, R., Zhang, T., Wang, B., Li, N., Sun, Y., Ma, H., Zhang, Q., Zhang, J., & Liu, Y. (2023, May 12). Study on the inactivation and reactivation mechanism of pathogenic bacteria in aquaculture by UVC-LED.
4. Choi, S. M., Ho Son, S., Rho Yun, S., Woung Kwon, O., Hoon Seon, J., &Yoeup Paek, K. (2000). Pilot-scale culture of adventitious roots of ginseng in a bioreactor system. *Plant cell, tissue and organ culture*, *62*, 187-193.
5. Kandasamy, S., Khan, F., & Vignesh, R. Modeling and Analysis of Heat Exchanger using Shell and Tube configuration. International Journal of Latest Research in Science and Technology, 2019.
6. Zeng, R., Wang, H., Liu, X., & Zhao, J.. Operating parameters optimization and fermentation strategy for high cell-density cultivation of recombinant Escherichia coli in a 5 L stirred-tank fermentor. Bioprocess and Biosystems Engineering, 2018.
7. Yang, Y., Wang, L., Zhang, X., & Kan, J. Control strategy for implementing programmable temperature profile in a large-scale fermentor using a LabVIEW-based supervisory control and data acquisition system. Bioprocess and Biosystems Engineering, 2020.

  