

CRRI Liquid Biofertilizer Production Plant

Design, Operation, and Production

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P R E F A C E

Agriculture today faces the dual challenge of meeting the growing demand for food while ensuring environmental sustainability. Excessive use of chemical fertilizers over the years has resulted in soil degradation, reduced microbial activity, water pollution, and declining crop productivity. In this context, biofertilizers have emerged as an environmentally friendly and sustainable alternative for improving soil fertility and maintaining ecological balance.

A Liquid Biofertilizer Plant has been established to produce high-quality microbial formulations that enhance plant growth by increasing nutrient availability and improving soil health. These liquid biofertilizers contain beneficial microorganisms such as nitrogen-fixing bacteria, phosphate-solubilizing bacteria, and potassium-mobilizing cultures. Compared to conventional chemical fertilizers, liquid biofertilizers offer advantages such as longer shelf life, higher microbial population, ease of application, and better performance under field conditions. The growing awareness of organic farming and government initiatives promoting sustainable agriculture have further increased the demand for such products, particularly liquid formulations that are compatible with modern irrigation systems like drip irrigation and fertigation.

The establishment of a Liquid Biofertilizer Plant requires careful strain selection, sterile production processes, strict quality control, and compliance with regulatory standards. With proper infrastructure and trained technical personnel, such a plant can significantly contribute to sustainable agricultural development and rural economic growth.

This bulletin, *CRRI Liquid Biofertilizer Production Plant: Design, Operation, and Production*, presents the technical, economic, and operational aspects involved in setting up and managing a Liquid Biofertilizer Plant. It emphasizes efficiency, quality assurance, and environmental responsibility. By integrating biotechnology with sustainable agricultural practices, the initiative aims to support farmers in achieving higher productivity while preserving soil health for future generations.

We express our sincere gratitude to all the researchers associated with biofertilizer research since its inception at the ICAR-Central Rice Research Institute, Cuttack.

Author

1. Introduction

With the burgeoning population, demand for food crops is expected to increase by 60% in the next decade. Hence, with the anticipation of higher production, farmers are haphazardly using chemical fertilizers. Indiscriminate use of chemical fertilizers is leading to soil acidification, decreased water-holding capacity, reduced soil fertility, and nutritional imbalances. Such deteriorated soil health conditions can be restored with the help of beneficial endophytic or rhizospheric soil microorganisms. These plant growth-promoting microorganisms help to supplement nutrients in the soil through various mechanisms, including nitrogen fixation, nutrient solubilization, and mobilisation. They also play a major role in plant defence mechanisms (Kaur et al., 2019). A suitable combination of these beneficial microorganisms can be formulated as biofertilizers for sustainable plant production. They can be carrier mediated or liquid biofertilizers. They can be applied either through soil, seed, or root treatments.

Biofertilizers not only supplement growth nutrients but are also helpful in improving soil edaphic parameters. They help to improve soil fertility by conserving microbial biodiversity (Aponte et al., 2022). Biofertilizers can form an essential ingredient in organic and natural farming practices by improving both soil and environmental health (Hazra, 2016).

Liquid biofertilizers are a type of biofertilizer that comes in liquid form and contains beneficial microorganisms, such as bacteria, fungi, and other microbes, along with nutrients in a readily available form. These microorganisms form a symbiotic relationship with plants, promoting their growth and health. Liquid biofertilizers are used to enhance soil fertility and improve plant productivity in a sustainable and environmentally friendly manner. Their use aligns with the principles of organic and environmentally conscious farming practices (Poorniammal et al., 2020).

Liquid biofertilizers should contain the following essential components, including carrier liquid (30-45%), surfactant (5-7%), dispersant (3-5%), and suspender (2-3%), along with plant growth-promoting bacteria, algae, fungi, etc. (30-40%). Special



cell protectants that help in the prevention of development of cysts or dormant spores should also be included in the composition (Allouzi et al., 2022).

2. Liquid Biofertilizers

Liquid biofertilizers are the microbial formulation containing beneficial microorganisms which are capable of fixing, mobilizing or solubilizing the important plant nutrients by their biological activity.

They offer several advantages over traditional chemical fertilizers:

1. **Nitrogen fixation:** Some microorganisms in liquid biofertilizers have the ability to fix atmospheric nitrogen and make it available to plants. This reduces the need for synthetic nitrogenous fertilizers and helps to reduce production costs.
2. **Phosphorus solubilization:** Some biofertilizers contain phosphate-solubilizing microorganisms that release bound phosphorus in the soil, making it more accessible to plants.
3. **Improved nutrient uptake:** Beneficial microorganisms can enhance the uptake of essential nutrients by plants, improving their overall nutrient efficiency.
4. **Soil health:** The introduction of these microorganisms into the soil can help improve soil structure, water retention, and overall soil health.
5. **Reduced environmental impact:** Liquid biofertilizers are typically more environment-friendly compared to chemical fertilizers because they reduce nutrient runoff and potential water pollution (Poorniammal et al., 2020)).

2.1. Types of liquid biofertilizer:

Liquid biofertilizers are classified into 3 broad groups

2.1.1 Nitrogen fixers: Microbes that fix nitrogen symbiotically and non-symbiotically.

Ex- *Rhizobium*, *Azotobacter*, *Azospirillum*



2.1.2 Phosphorus solubilizers or mobilizers: Microbes that solubilize or mobilize important plant nutrients such as P, Zn, Cu, Mo etc. Examples of some important solubilizers or mobilizers are *Pseudomonas striata*, *Bacillus polymyxa*, *Aspergillus niger*, *Penicillium digitatum*, *Glomus*, *Gigaspora* and Arbuscular Mycorrhizal fungi.

2.1.3 Potash mobilizer: Microbes which mobilize elementary or a mixture of potassium in the soil. Use of potash mobilizing bacteria (KMB) would not only reduce the requirement of costly potassium fertilizers but would also mobilize insoluble potassium in soils and fertilizer to which they are applied. Ex. *Frateuria aurantia*.

Liquid biofertilizers have several advantages over conventional carrier based biofertilizers including longer shelf-life, greater potential to fight with native microbial community, better survival potential in seed or soil, can be used with modern machinery, can withstand high temperatures up to 45°C and ease of application to seeds or soil. They may have high commercial revenue due to their longer stability, cost effectiveness and higher export potential.

2.2. Methods of application of Liquid Biofertilizer:

The method of application involves three major processes such as seed treatment, soil treatment, root dipping, and, in rare cases, foliar application.

2.2.1 Seed Treatment:

One kg of seed is treated with 5-10 ml of liquid biofertilizer mixed with 100 ml of rice gruel and shade dried for 30 minutes. The treated seeds should be sown within 24 hours. Seed treatment is applicable in pulses, cereals like wheat, millets, maize, and sorghum, and oil seeds like mustards, etc.

2.2.2 Root dipping:

It is suitable for seedlings of vegetables and fruits, where they are dipped in liquid culture of the microorganisms and then sown immediately. The root dipping method is suitable for all plants that need transplanting for proper growth, like paddy. About 250 ml liquid biofertilizer is mixed with 8-10 L of water or rice gruel,

and roots of the seedlings meant for one acre are dipped in for at least 30 minutes and transplanted within 4-6 hrs.

2.2.3 Soil Treatment:

In direct inoculation, beneficial microorganisms of biofertilizers are directly incorporated into the soil. About 250 ml of liquid biofertilizer is mixed with 1 litre of water and thoroughly mixed with 10 kg of powdered soil and broadcast in an area of one acre. Soil treatment is good for plants like tea, coffee, rubber, etc.

2.2.4 Foliar Application:

Microbial cultures in liquid form are sprayed over plants, which are absorbed through stomatal pores or epidermal cells present on the leaf surface. A spray of 1% of liquid methylobacterium biofertilizer concentration is administered either early morning or late evening.

3. ICAR-CRRI biofertilizer production plant

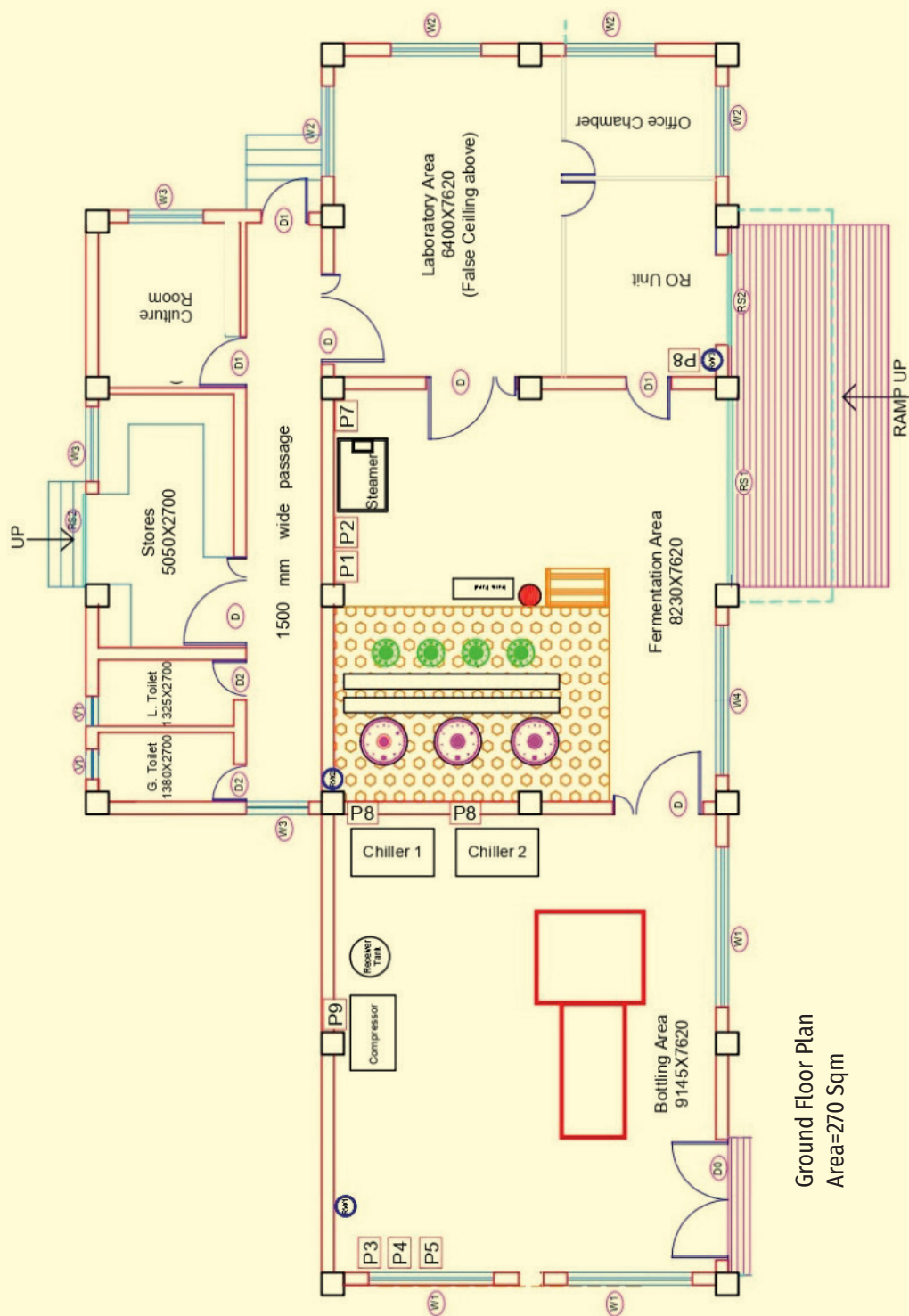
A model liquid biofertilizer plant has been set up at ICAR-CRRI, Cuttack (Funded by RKVY, Government of Odisha) for mass production and commercialization of liquid bioinoculants in order to check the deterioration of soil health due to the application of synthetic chemical fertilizers and to enhance rice yield.

Proposed lay out and plant design:

- The design of plant building area has been proposed at about 270 m², covering fermentation area, bottle filling and labelling area, laboratory area, air-conditioned culture maintenance room, air-conditioned biofertilizer store room, office area and washroom (Male & Female) (Fig. 1).
- This unit has wide range of products that includes NRRI-EndoN, NRRI-EndoNPK, NRRI-PSB, NRRI-KSB etc.

The biofertilizer production plant at ICAR-CRRI has been designed properly according to the layout (Fig. 2). This setup has the following areas equipped with respective machines and instruments.





Ground Floor Plan
Area=270 Sqm

Fig. 1 Layout of biofertilizer plant at ICAR-CRRI

1. Fermentation area
 - Seed fermenters (4 No.).
 - Batch fermenters (3 No.)
 - Steam generator/Boiler
2. Bottle filling and Labeling area
 - Automatic Bottle filling and capping machine
 - Automatic labelling machine
 - Air compressor
 - Chiller
 - Horizontal autoclave
 - Vertical autoclave
3. Laboratory area
 - Weighing balance
 - Glass ware
 - Cooling micro-centrifuge
 - Rotary shaker
4. Air-conditioned Culture maintenance room
 - Horizontal laminar air flow
 - BOD incubator
 - Fridge
5. Air-conditioned Biofertilizer store room
6. Office area & RO unit room
7. Washroom (Male & Female)



Fig. 2 Biofertilizer Production Unit at ICAR-CRRI, Cuttack

4. Description of all instruments and machinery located at ICAR-CRRI Biofertilizer Production Unit

4.1. Bioreactor

A bioreactor is a device or vessel that provides a controlled environment for the cultivation of microorganisms, cells, or biological molecules. Bioreactors are commonly used in various fields, including Biotechnology, Microbiology, and Chemical engineering, for processes such as fermentation, tissue culture, and enzyme production. They are designed to provide optimal conditions for the growth and maintenance of living organisms or biological processes (Fig. 3).



Fig. 3 All bioreactors at biofertilizer production Unit

Key features and components of a bioreactor include:

1. **Vessel:** The main chamber or container where the biological processes take place. It is typically made of materials that are biocompatible and can be sterilized.
2. **Agitation System:** Stirrers or impellers are used to maintain uniform mixing of the culture medium, ensuring even distribution of nutrients and oxygen. Proper mixing and aeration promote uniform distribution of nutrients and prevent the formation of concentration gradients.

3. **Temperature Control:** Bioreactors have a heating and cooling system to maintain a constant temperature, which is crucial for the growth of specific organisms or biological processes.
4. **pH Control:** The pH level of the culture medium is monitored and adjusted using pH probes and chemicals (acid/base) to maintain the desired pH range.
5. **Aeration and Gas Supply:** Oxygen is supplied to support aerobic growth, and other gases can be controlled as needed.
6. **Nutrient Feeding System:** Nutrients are added to the culture medium in a controlled manner to support the growth of organisms.
7. **Monitoring and Control Systems:** Sensors and controllers are used to monitor and regulate various parameters, including temperature, pH, dissolved oxygen, and agitation speed.
8. **Sterilization System:** To ensure aseptic conditions, bioreactors are sterilized before use, and the culture medium is often sterilized before being introduced into the bioreactor or else it can also be sterilized after addition to fermenter vessel.
9. **Harvesting and Product Recovery:** Depending on a specific process, bioreactors may be equipped with mechanisms for harvesting or recovering the desired product or biomass after the cultivation period.

The basic principle of a bioreactor is to create a controlled and optimized environment that supports the growth and metabolic activities of the biological material being cultivated. This ensures the efficient and reproducible production of desired products, such as biofertilizers.

Bioreactor specification installed at CRRRI biofertilizer unit: The plant is equipped with four seed fermenters (75 L each) and three large-volume fermenters (750 L each) (Fig. 3). The overall capacity of these fermenters is a production of 1,50,000 L per annum. Specifications of these systems are given in Table 1.

Table 1: Specifications of the bioreactor

Specification	Seed fermenter	Batch fermenter
Vessel total capacity	75 L	750 L
Working volume	50 L	500 L
Sterilization pressure	1.2 bar max	1.2 bar max
Sterilization temperature	123°C max	123°C max
Process temperature	35.0-40.0°C	35.0-40.0°C
Process pressure	To maintain positive pressure	To maintain positive pressure
Agitation	Top drive, 3 phase servomotor, with mechanical seal	Top drive, 3 phase servomotor, with mechanical seal
Agitation speed	40-300 rpm	40-300 rpm
Power	415V A.C, 50Hz, 3.6 A	415V A.C, 50Hz, 3.6 A

4.2. Boiler:

Boilers are commonly used in fertilizer production units to provide the necessary steam for various processes, particularly in the production of ammonium nitrate, urea, and other nitrogen-based fertilizers (Fig. 4). The boiler's primary role is to generate high-pressure steam, which can be utilized in several ways within a fertilizer production facility. The fundamental principle of a boiler involves the conversion of energy from a fuel source into thermal energy, which is then used to produce steam or hot water for various purposes.

Principle:

1. **Heat Generation:** Boilers are designed to generate heat by the combustion of a fuel source, such as natural gas, oil, coal, biomass, or electricity. The heat is produced in a combustion chamber, furnace, or heating element within the boiler.

2. **Water Heating:** Water, or sometimes a specialized heat transfer fluid, is used to absorb the generated heat. The water is typically stored in a vessel known as the boiler drum or in a series of tubes.
3. **Steam Generation or Water Heating:** Depending on the boiler type and application, the heat-absorbing water is either converted into steam or heated to provide hot water. The phase change from water to steam occurs when the water is heated to its boiling point and vaporizes.
4. **Pressure Generation:** Steam boilers are designed to operate at high pressures to facilitate various applications. The pressure is achieved by heating water to its boiling point at a specific temperature under controlled conditions.
5. **Controlled Steam or Hot Water Delivery:** Boilers are equipped with mechanisms to control the flow and distribution of steam or hot water to meet specific requirements of the application. This includes usage of pipes, valves, and control systems to regulate the flow and temperature.
6. **Efficiency and Energy Transfer:** The efficiency of a boiler is a critical consideration, and modern boilers are designed to maximize energy transfer from the fuel source to the heat-absorbing medium (water or heat transfer fluid). Higher efficiency means more energy is converted into steam or hot water for a given amount of fuel.
7. **Safety Features:** Boilers incorporate safety features to prevent overheating, overpressure, and other potential hazards. Safety valves, pressure relief systems, and automatic controls are common safety measures.
8. **Exhaust and Emission Control:** Depending on the type of fuel used, boilers may have exhaust systems and emission control devices to minimize air pollutants and comply with environmental regulations.
9. **Maintenance and Control Systems:** Regular maintenance is essential to ensure the safe and efficient operation of boilers. Control systems are used to monitor and adjust key parameters like temperature, pressure, and fuel input to maintain optimal conditions.

The specific design and operation of a boiler can vary widely depending on its intended application, such as power generation, heating, or industrial processes. Whether used in residential heating systems, industrial power plants, or other applications, the fundamental principle of a boiler is to convert energy from a fuel source into thermal energy and, if applicable, into steam or hot water for various uses.



Fig. 4 Boiler

Need of boiler:

1. **Steam for drying:** Many fertilizer production processes involve the use of dryers to remove moisture from the product. High-pressure steam from the boiler is used as a heat source for these drying processes. For example, in urea production, prilling towers are used to produce solid urea granules, and steam is used to control the temperature and moisture content of the prills.
2. **Heat Exchange:** Boilers provide hot water or steam for various heat exchange processes throughout the fertilizer production unit. This includes heating process streams, evaporating liquids, and maintaining specific temperatures in different stages of the production process.
3. **Power Generation:** Some fertilizer production units may utilize a portion of the steam produced by the boiler to generate electricity, which can be used within the facility or even exported to the grid.
4. **Cleaning and Sterilization:** In some cases, boilers are used for cleaning and sterilization processes, such as sanitizing equipment, pipelines, and vessels to maintain hygienic conditions during fertilizer production.
5. **Controlled Reaction Environments:** Certain fertilizer production processes, especially those involving chemical reactions, require precise control of temperature and pressure. The boiler plays a critical role in maintaining the necessary conditions for these reactions.
6. **Safety Measures:** Fertilizer production units must adhere to strict safety standards. Boilers may be equipped with safety features to control pressure, temperature, and other critical parameters to prevent accidents.

When implementing a boiler in a fertilizer production unit, it's important to consider factors like the type of fuel used (natural gas, coal, biomass, etc.), boiler efficiency, emission control, and safety measures. Compliance with environmental regulations is crucial, and modern boilers are often designed with technologies to reduce emission of pollutants such as nitrogen oxides (NO_x) and sulphur dioxide (SO₂).

Overall, boilers are a critical component in many fertilizer production processes, and their efficient and reliable operation is essential for the production of high-quality fertilizers.

Standard operating protocol:

1. Ensure all three phases are available; the feed water inlet valve is kept open which is connected with water tank; the steam outlet valve is kept closed and keep exhaust valve 95% closed.
2. Turn on the MCB at the back side of the boiler.
3. When all three phase lights are on, push down the lever to turn on the power to boiler.
4. Maintain appropriate water level in the tank connected to boiler. Depending on the water level, the feed pump may run briefly till the operating level is reached (If the vessel had been drained, the pump will run for a long time before reaching level).
5. Temperature controller is factory set for optimum operating value and need not to be changed. The temperature of the water is indicated initially and slowly rises till the default temperature is reached. After the temperature reaches 145°C the boiling process will automatically shut off and steam will be liberated through the drain silicone pipe.
6. If you are running single (50 L) fermenter then rotate right 'Batch 1' regulator and if running more than one fermenter turn on all the three regulators. After the pressure reaches 2 bar, turn on the steam line valve to provide steam to jacket for sterilization.
7. For shutting down, switch off the Mains. Close the steam outlet valve. Open the exhaust valve fully. In case the unit is to be left unused for a long time, open the drain valve while the steam is still in the vessel and allow the steam to blow out through the piping. Ensure that the drain outlet is safely guided out of the reach of any human activity. When the water has drained out, close the

drain valve.

8. Clean the steam generator regularly with citric acid (1 kg for 10 L of water) by increasing the temperature up to 100°C and draining the boiler fully. After the run is over, make sure to switch off the boiler by pulling up the lever at the control panel.

Maintenance:

1. Always keep the equipment clean by dusting and wiping with a clean cloth. Use a cloth sprayed with a household cleaner, such as Colin, if necessary. Never use a wet cloth.
2. Check the feed pump for adequate lubricating oil every 3 months and refill as necessary.

4.3. Chiller:

A chiller is a refrigeration system designed to remove heat from a space, substance, or process, thereby maintaining a lower temperature. Chillers are commonly used in various applications, including air conditioning, process cooling, and industrial refrigeration (Fig. 5). Chillers are not typically used in the production of liquid biofertilizers because the production process for biofertilizers generally does not require cooling or refrigeration. Liquid biofertilizer production primarily involves the cultivation and fermentation of beneficial microorganisms, and the process typically occurs at or near ambient temperatures. The microorganisms used in biofertilizers are often sensitive to extreme temperatures, so the production environment is carefully controlled within a suitable temperature range.

Basic principle:

1. **Heat Absorption:** Chillers operate by absorbing heat from a specific area or process that needs to be cooled. This heat is transferred to a heat-absorbing fluid, known as the refrigerant.
2. **Vapor Compression Cycle:** Most chillers use a vapor compression cycle as the fundamental operating principle. This cycle consists of four main components:

a compressor, an evaporator, a condenser, and an expansion valve.

3. **Compression:** The compressor is responsible for increasing the pressure and temperature of the refrigerant vapor. This causes the refrigerant to become a high-pressure, high-temperature gas.
4. **Heat Rejection:** The high-pressure, high-temperature refrigerant gas is then condensed in the condenser, which is typically located outside the space or process to be cooled. During this phase, the refrigerant releases heat to the surroundings and changes from a gas to a high-pressure liquid.
5. **Expansion:** After leaving the condenser, the high-pressure liquid passes through an expansion valve or an expansion device. This valve reduces the pressure and temperature of the refrigerant, causing it to expand and evaporate.
6. **Heat Absorption and Cooling:** The cold, low-pressure refrigerant flows through the evaporator, which is located within the space or process to be cooled. Here, it absorbs heat from the surroundings, causing the refrigerant to evaporate and return to a low-pressure vapor state.
7. **Refrigerant Circulation:** The vaporized refrigerant is then returned to the compressor, and the cycle repeats. The compressor boosts the pressure and temperature of the refrigerant, and the process continues to remove heat from the cooling space or process.
8. **Temperature Control:** The cooling capacity and temperature of the chilled water or air can be controlled by adjusting various parameters, such as the refrigerant, flow rate and the setpoint temperature.
9. **Cooling Medium:** The chilled water or air is circulated through the space or process to absorb heat and lower the temperature.
10. **Efficiency and Energy Savings:** Chiller systems are designed to operate efficiently and may incorporate features like variable speed compressors, economizers, and heat recovery to save energy and reduce operating costs.



Fig. 5 Chiller

Here are some key points to consider about the use of chillers in a biofertilizer production unit:

1. **Room Temperature:** The production of liquid biofertilizers typically occurs at or around room temperature (approximately 20-30°C or 68-86°F). This temperature range is ideal for the growth and maintenance of the beneficial microorganisms.
2. **Microbial Sensitivity:** Beneficial microorganisms used in biofertilizers, such as nitrogen-fixing bacteria and phosphate-solubilizing bacteria, may be adversely affected by low temperatures. Chillers could potentially harm these microorganisms, reducing the effectiveness of the biofertilizer.

- 3. Energy Efficiency:** Adding a chiller to the production process when it is not necessary would increase energy consumption and operational costs. Liquid biofertilizer production is often designed to be energy-efficient and environment friendly.

In the production of liquid biofertilizers, the focus is primarily on creating an optimal environment for the growth of microorganisms and maintaining their viability. Controlling factors like temperature, pH, nutrient availability, and oxygen levels are essential, but cooling or refrigeration is not typically part of this process.

4.4 Air compressor:

The basic principle of an air compressor is to convert mechanical energy into compressed air. Air compressors are used to increase the pressure and decrease the volume of air, creating a stream of high-pressure compressed air that can be used for various applications. The fundamental operation of an air compressor involves several key principles:

- 1. Compression:** The core function of an air compressor is to compress air. It does so by drawing in atmospheric air and reducing its volume while simultaneously increasing its pressure. This is achieved by using mechanical components within the compressor.
 - 2. Air Inlet:** Atmospheric air is drawn into the compressor through an inlet. In many cases, the air is filtered to remove impurities and contaminants that could damage the compressor or affect the quality of the compressed air.
 - 3. Compression Chamber:** Inside the compressor, there is a compression chamber where the air is compressed. This chamber typically contains a piston or a rotating screw or vane. As the piston moves or the rotor turns, it reduces the space available for the air, which causes the air to be compressed and pressurized.
 - 4. Pressure Buildup:** As the compression chamber reduces the volume of the air, the pressure of the air increases. The specific pressure level achieved depends on the design and capacity of the compressor.
- 

5. **Heat Generation:** During compression, the air temperature rises due to the work done on the air. This heat needs to be managed to prevent overheating. Some compressors are equipped with cooling systems to dissipate the heat generated during compression.
6. **Pressure Regulation:** Air compressors often include pressure regulation mechanisms to maintain the desired output pressure. Pressure switches, valves, and controls help to ensure that the compressed air reaches the required pressure level and maintains it.
7. **Air Outlet:** The compressed air is delivered through an outlet or discharge port. The compressed air can then be directed to various applications, such as pneumatic tools, industrial processes, HVAC systems, or other uses.
8. **Maintenance and Lubrication:** Many air compressors require lubrication to reduce friction and wear in the moving parts, such as pistons or rotors. Proper maintenance and lubrication are essential for the efficient and reliable operation of the compressor.

Air compressors are commonly used in biofertilizer production units for various purposes. They play a critical role in providing compressed air, which can be used in multiple aspects of the production process (Fig. 6). Here are some key applications of air compressors in a biofertilizer production unit:

1. **Aeration and Agitation:** Air compressors are used to provide aeration and agitation in bioreactors or fermentation tanks. Oxygen is essential for the growth of beneficial microorganisms in liquid biofertilizer production. Compressed air is introduced into the fermentation tanks to ensure that the microorganisms receive sufficient oxygen for their metabolic activities.
2. **Mixing and Blending:** In the preparation of liquid biofertilizer formulations, various ingredients, such as microbial cultures, carriers, and nutrients, need to be thoroughly mixed and blended. Air-driven mixers or agitators can be powered by compressed air to achieve uniform mixing.
3. **Drying and Cooling:** Air compressors can be used to generate hot or cold air

for drying or cooling processes in biofertilizer production. For instance, in the formulation of solid biofertilizer products, hot air can be used to dry the product after granulation. Conversely, cold air can be employed to cool down certain processes.

4. **Pneumatic Conveying:** Compressed air is utilized in pneumatic conveying systems to transport materials within the production unit. This can include the movement of raw materials, finished products, or even waste materials.
5. **Cleaning and Sterilization:** Air compressors may be used for cleaning and sterilizing equipment and production areas. Compressed air can power cleaning tools, air blowers, and sterilization systems.
6. **Controlled Atmosphere:** In some specific biofertilizer production processes, maintaining a controlled atmosphere is critical. Air compressors can be used to supply gases or maintain specific pressure conditions in reactors or storage vessels.
7. **Energy Recovery:** In some biofertilizer production units, excess heat generated by air compressors can be captured and used for other purposes, such as space heating or for process heating.

When selecting and using air compressors in a biofertilizer production unit, it's important to consider factors such as the required air pressure, volume, energy efficiency, and the quality of compressed air to prevent contamination of the products. Proper maintenance and regular checks of air compressors are crucial to ensure their reliability and performance in a production environment.

Overall, air compressors are versatile tools in biofertilizer production, helping to meet the specific needs of various processes and ensuring the efficient and effective production of high-quality biofertilizer products.

Standard Operating Protocol:

1. Turn on the MCB and the channel valve on the right to fill the cylinder with compressed air.
- 



Fig. 6 Air compressor

2. The compressor will automatically turn off after the pressure reaches 125 psi.
3. The cylinder should be filled up to 8 bar pressure to supply air to the fermenter.

Clean up:

1. The compressor should be cleaned every day after running to get rid of the moisture deposit. To clean the compressor, open the valve below the compressor, which drains out all the moisture. Then close the valve.
2. The cylinder should be cleaned after every 3–4 days of run, by turning on the valve slightly anticlockwise to remove the moisture.

4.5. Automatic bottle filling and capping machine:

A bottle filling machine is essential in the biofertilizer industry to ensure accurate, efficient, and consistent filling of bottles while maintaining product quality and adhering to regulatory requirements. It offers a range of benefits, from increased production capacity and reduced labour costs to improved product safety and quality control.

An automated bottle filling machine operates based on a set of principles and mechanisms to accurately fill bottles with a liquid or product (Fig. 7). The specific design and operation of the machine may vary depending on the type of liquid or product being filled and the container's shape and size.

Below listed are some key principle/features of automated bottle filling machine at ICAR-CRRI, Cuttack.

Container Handling: Bottles are loaded onto a conveyor or a platform that transports them to the filling station.

Filling method:

- **Pressure Filling:** A pressure differential is created to force the liquid into the bottles.
- **Volumetric Filling:** This method uses displacement of a specific volume of the product to fill each bottle.



Fig. 7 Automatic bottle filling and capping machine with attached hopper to fill formulations

Nozzles: The machine is equipped with a set of filling nozzles, which can be adjusted in height and position to match the bottle's position.

Sensors: Various sensors, such as proximity sensors or optical sensors, are used to detect the presence and position of bottles, ensuring that the right containers are filled.

Dosing and Accuracy: The machine is programmed to dispense the exact amount of product into each bottle. This is achieved by controlling the filling method, filling time, and other parameters.

Anti-Drip and Drip Collection: To prevent drips or spillage, the machine may incorporate features like anti-drip nozzles and a collection system for any excess product.

Output Conveyor: Filled bottles are moved to an output conveyor for further processing, such as capping, sealing, labelling, or packaging.

Maintenance and Quality Control: Regular maintenance and quality control checks are essential to ensure the machine's consistency and accurate operation.

4.6. Automatic bottle labelling machine:

A bottle labelling machine is used to automatically apply labels to bottles, jars, or containers in a precise and efficient manner. The machine consists of a conveyor system which is used to transport bottles from the input station to the labelling station and then to the output station followed by label roll holder to hold and dispense the label rolls and then to labelling head that applies the labels to the bottles followed by bottle positioning system that ensures precise label placement by aligning each bottle before the label is applied and then to Human-Machine Interface (HMI) and sensors to ensure appropriate labelling (Fig. 8).

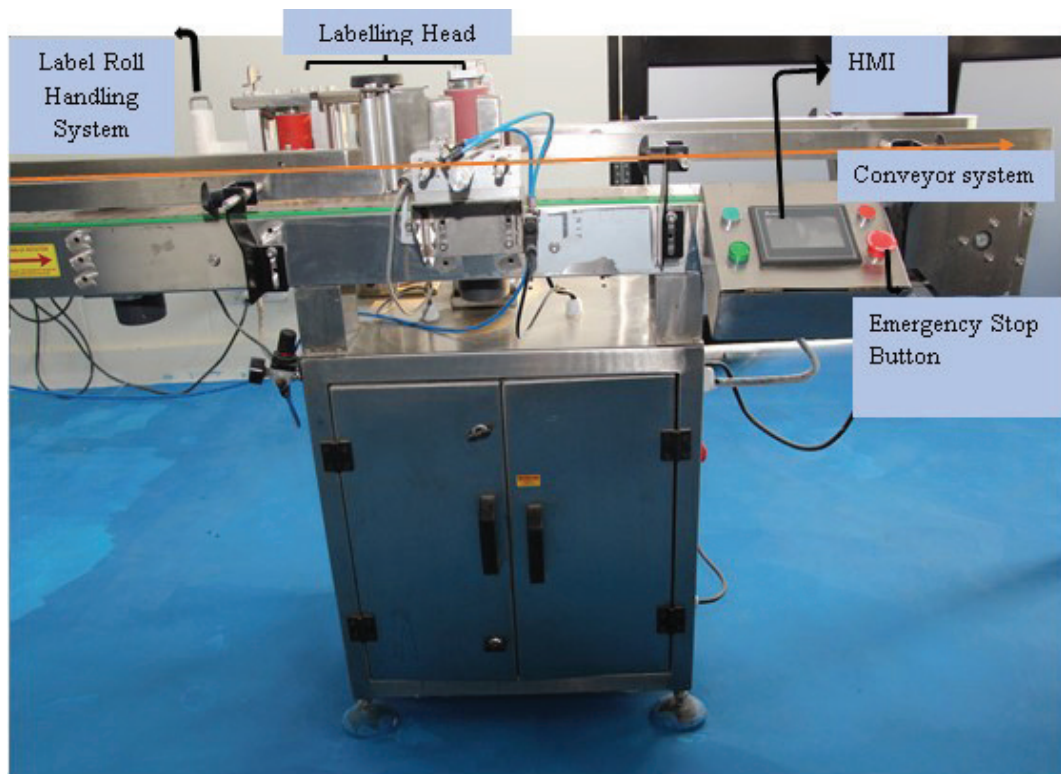


Fig. 8 Automatic bottle labelling machine

4.7. Horizontal Autoclave:

The horizontal autoclave typically has a cylindrical chamber that lies horizontally, as opposed to the more common vertical orientation (Fig. 9a). A horizontal autoclave is widely used in various industries, including healthcare, laboratories, and manufacturing, to ensure that instruments and materials are free from microorganisms. These are equipped with control systems to monitor and regulate temperature, pressure, and sterilization time (Fig. 9b).

The principle of a horizontal autoclave is based on using high-pressure steam to achieve the sterilization of materials and equipment placed inside the autoclave chamber. The autoclave creates an environment of elevated temperature (121°C) and pressure (15 psi), which is lethal to microorganisms, including bacteria,

viruses, and spores. The combination of high temperature, pressure, and holding time (15-20 min) is critical for effective sterilization.



Fig. 9a Horizontal Autoclave, 9b. Monitor

4.8. RO Unit:

Reverse Osmosis (RO) units play a crucial role in liquid biofertilizer plants for the purification of water (Fig. 10). Reverse Osmosis is a water purification process where water is forced through a semi-permeable membrane with high pressure to remove impurities, contaminants, and ions from water. RO units ensure that the water used in the formulation of biofertilizers is free from impurities, salts, and unwanted ions so as to inhibit any negative impact on the quality of the biofertilizer.



Fig. 10 RO Machine

5. Quality Control

Quality control is crucial in the production of liquid biofertilizers to ensure that the final product meets the desired specifications and standards set up by FCO. Here are some key aspects of quality control to be maintained in liquid biofertilizer production:

1. **Raw Material Quality:** Ensure the quality of raw materials, such as organic matter, nutrients, and microbial inoculants. Use high-quality inputs to guarantee the effectiveness of the final product.
 2. **Microbial Count and Viability:** Regularly assess the microbial count and viability of the beneficial microorganisms present in the biofertilizer. This can be done through plating techniques, microscopic examination, or molecular methods.
 3. **Nutrient Content:** Monitor and control the nutrient content of the liquid biofertilizer, including nitrogen, phosphorus, potassium, and other essential elements. Analyse the nutrient levels using appropriate laboratory techniques.
 4. **pH Level:** Maintain a consistent pH level within the recommended range for optimal microbial activity. Frequent testing should be conducted, and adjustments are to be made if necessary.
 5. **Sterility and Contamination:** Implement strict sterilization procedures during production to prevent contamination by unwanted microorganisms. Regularly test for sterility and address any contamination issues promptly.
 6. **Consistency in Production:** Ensure consistency in the production process to achieve uniform product quality. Document standard operating procedures (SOPs) and train staff to follow them diligently.
 7. **Storage and Shelf Life:** Establish proper storage conditions to maintain the viability of microorganisms and prevent degradation of nutrients. Monitor the shelf life of the product and establish expiry dates.
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8. **Packaging:** Use appropriate packaging materials that maintain the quality of the biofertilizer and protect it from external factors. Check for leaks or damage in packaging to avoid product deterioration.
9. **Regulatory Compliance:** Adhere to regulatory standards and guidelines for biofertilizer production. Ensure that the final product meets the requirements set by relevant authorities.
10. **Quality Control Testing:** Conduct regular quality control testing at different stages of production, including in-process testing and final product testing. This may involve laboratory analysis and quality assurance checks.
11. **Record Keeping:** Maintain detailed records of each batch produced, including raw material specifications, production processes, and quality control results. This documentation aids in traceability and troubleshooting.
12. **Training and Documentation:** Train production staff on quality control procedures and ensure that they are aware of the importance of maintaining high-quality standards. Practice document training processes and keep records of personnel involved in production.

Implementing a robust quality control system is essential for producing reliable and effective liquid biofertilizers. Regular monitoring, documentation, and corrective actions contribute to the overall success and sustainability of the product.

To maintain desirable quality and efficacy of the liquid biofertilizers, Ministry of Agriculture and Farmers Welfare has set up the guidelines named as Fertilizer Control Order (FCO) guidelines to set specific standards for nutrient contents, physical characteristics, impurities and labelling requirements. By implementing these standards, FCO aims to prevent the sale of low-quality fertilizers that may have detrimental effects on crop productivity and soil health. Table 2 contains brief information of FCO guidelines for liquid biofertilizers.

Table 2: Specifications and guidelines of Liquid Biofertilizers

S. N	Type of Culture Used	Specification
1	<i>Rhizobium</i>	
	Total viable count	CFU minimum: 5×10^7 cells per gram of powder, granules, or carrier material/or per gram capsule content in gelatine base, or 1×10^8 cells per ml of liquid.
	Contamination level	No contamination at 10^5 dilutions.
	pH	6.5-7.5
	Efficiency character	Should show effective nodulation on all the species listed on the packet, and there should be a minimum of 25% increase in dry matter yield in the test plant after 25 Days After Sowing (DAS), when tested as per the method given under controlled conditions.
2	<i>Azotobacter</i>	
	Total viable count	CFU minimum: 5×10^7 cells per gram of powder, granules, or carrier material/or per gram capsule content in gelatine base, or 1×10^8 cells per ml of liquid.
	Contamination level	No contamination at 10^5 dilutions.
	pH	6.5-7.5
	Efficiency character	The strain should be capable of fixing at least 10 mg of nitrogen per gram of sucrose consumed.
3	<i>Azospirillum</i>	
	Total viable count	CFU minimum: 5×10^7 cells per gram of powder, granules, or carrier material/or per gram capsule content in gelatine base, or 1×10^8 cells per ml of liquid.
	Contamination level	No contamination at 10^5 dilutions.
	pH	6.5-7.5
	Efficiency character	Formation of white pellicle in semisolid Nitrogen free Bromothymol blue media.

4	Phosphate-Solubilising Bacteria	
	Total viable count	CFU minimum: 5×10^7 cells per gram of powder, granules, or carrier material/or per gram capsule content in gelatine base, or 1×10^8 cells per ml of liquid.
	Contamination level	No contamination at 10^5 dilutions.
	pH	6.5-7.5 for moist/dry powder, granulated carrier based and 5.0-7.5 for liquid based.
5	Efficiency character	The strain should be capable of solubilizing at least 30 mg/litre of Phosphorus in liquid broth when tested as per the method given using Tricalcium Phosphate, Aluminium Phosphate, or Iron Phosphate as Phosphate source.
	Mycorrhizal Biofertilizers	
	Total viable count	Minimum 10 viable spores per gram of finished product.
	pH	6.0-7.5
6	Inoculum potential	1200 IP per gram of finished product by MPN method with 10-fold dilution.
	Potassium Mobilising Biofertilizers (KMB)	
	Total viable count	CFU minimum: 5×10^7 cells per gram of powder, granules, or carrier material/or per gram capsule content in gelatine base, or 1×10^8 cells per ml of liquid.
	Contamination level	No contamination at 10^5 dilutions.
7	pH	6.5-7.5 for moist/dry powder, granulated carrier-based based and 5.0-7.5 for liquid-based.
	Efficiency character	The strain should be capable of solubilizing at least 20 mg/litre of Potash in liquid broth when tested as per the method given using Aluminium Potassium Silicate as K source.
	Zinc Solubilising Bacteria	
	Total viable count	CFU minimum: 5×10^7 cells per gram of powder, granules, or carrier material/or per gram capsule content in gelatine base, or 1×10^8 cells per ml of liquid.
	Contamination level	No contamination at 10^5 dilutions.
	pH	6.5-7.5 for moist/dry powder, granulated carrier-based based and 5.0-7.5 for liquid-based.
	Efficiency character	The strain should be capable of solubilizing at least 20 mg/litre of Zinc in liquid broth when tested as per the method given, using Zinc oxide/Zinc carbonate/Zinc phosphate as Zinc source.

8	Acetobacter	
	Total viable count	CFU minimum: 5×10^7 cells per gram of powder, granules or carrier material/or per gram capsule content in gelatine base or 1×10^8 cells per ml of liquid.
	Contamination level	No contamination at 10^5 dilutions.
	pH	pH 5.5- 6.0 for moist /dry powder, granulated or carrier and 3.0-6.0 for liquid.
	Efficiency character	Formulation of yellowish pellicle in semi solid N free medium.
9	Carrier-based Consortia	
	Individual organism viable Count	CFU minimum in a mixture of any 2 or a maximum of three of the following micro-organisms: • CFU minimum of Rhizobium or Azotobacter or Azospirillum: 1×10^7 cells per gram (g) • CFU minimum PSB: 1×10^7 cells per gram (g) • CFU minimum KSB: 1×10^7 cells per gram (g)
	Total viable count of all the biofertilizers in the product	CFU minimum: 3×10^7 cells per gram of carrier/powder.
	Efficiency character	The efficiency character of individual microorganisms is to be determined, as mentioned in the case of individual biofertilizers, through quantitative estimation methods.
10	Liquid Consortia	
	Individual organism viable Count	CFU minimum in a mixture of any 2 or a maximum of three of the following micro-organisms: CFU minimum: • <i>Rhizobium</i> or <i>Azotobacter</i> or <i>Azospirillum</i>: 5×10^7 cells per millilitre (ml). • CFU minimum PSB: 5×10^7 cells per millilitre (ml). • CFU minimum KSB: 5×10^7 cells per millilitre (ml).
	Total viable count of all the biofertilizers in the product	CFU minimum 1.5×10^8 cells per millilitre (ml).
	pH	5.0-7.0
	Contamination level	No contamination at any dilution.
	Efficiency character	The efficiency character of individual microorganisms is to be determined, as mentioned in the case of individual biofertilizers, through quantitative estimation methods.

11	Phosphate Solubilising Fungal biofertilizers	
	Spore Count	Minimum 1×10^6 spores/gram Minimum 1×10^7 viable fungal spores/ml of the liquid.
	Contamination level	Nil for liquid inoculum; 1×10^3 cells per gram for carrier-based preparation.
	pH	Liquid: 3.5 to 5.5 Carrier: 6.0 to 7.7
	Efficiency character	The strain should be capable of solubilizing at least 30 mg/litre of Phosphorus in liquid broth when tested as per the method given using Tricalcium Phosphate, or Aluminium Phosphate, or Iron Phosphate as Phosphate source.

Source@: Ministry of Agriculture and Farmers Welfare (Department of Agriculture, Cooperation and Farmers Welfare) ORDER- New Delhi, the 1st July, 2021

References:

- Allouzi M. M. A, Allouzi S. M. A, Keng, Z. X., Supramaniam, C. V., Singh, A., and Chong, S. (2022). Liquid biofertilizers as a sustainable solution for agriculture. Heliyon.
- Poorniammal, R., Prabhu, S., Kannan, J., and Janaki, D. (2020). Liquid biofertilizer boon to sustainable agriculture. Biot. Res. Tod, 2, 915-918.
- Kaur, P., and Purewal, S. S. (2019). Biofertilizers and their role in sustainable agriculture. Biofertilizers for sustainable agriculture and environment, 285-300.
- Hazra, G. (2016). Different types of eco-friendly fertilizers: An overview. Sustainability in Environment, 1(1), 54.
- Aponte, H., Galindo-Castañeda, T., Yáñez, C., Hartmann, M., and Rojas, C. (2022). Microbial community-level physiological profiles and genetic prokaryotic structure of burned soils under Mediterranean sclerophyll forests in central Chile. Frontiers in microbiology, 13, 824813.

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Notes

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