

UNIT II

Bio-slurry is one of the major products from a biogas plant and it has multiple benefits in the field of agriculture. It can be used; as a valuable manure by the farmer to improve crop yields, for spraying against especially insect plant pests, to supplement animal feed rations and as a source of income when it is sold to other farmers without biogas plants.

Slurry handling in a biogas plant

Slurry handling is important in biogas production because it can:

- Reduce management costs

The biogas generation process reduces the organic load of the slurry, which can increase the amount that can be applied per hectare. This can save on fuel and labor costs.

- Improve soil quality

Biogas slurry can improve soil structure, increase fertility, and help loosen hard soil. It can also help plants deal with drought and salinity stress.

- Reduce environmental pollution

Biogas slurry can help mitigate environmental pollution by recovering nutrients.

- Create a solid, composted by-product

The slurry undergoes anaerobic composting in the biogas plant, which eliminates pathogens, seeds, and other undesirable components. This process creates a solid by-product with stabilized nutrients that can be used as a fertilizer.

- Create a liquid product

The liquid product can be certified as an organic fertilizer if it meets certain standards.

- Reduce the volume of slurry

The thermal energy generated by the biogas plant can be used to evaporate water from the digestate, which can concentrate the nutrients and make it cheaper to transport.

Factors to be considered in slurry handling

- Slurry composition

The composition of biogas slurry can vary due to a number of factors, including the type and age of the animals, their feeding practices, and how the slurry is diluted and stored.

- C/N ratio

The carbon to nitrogen ratio (C/N) is important for biogas production, and should be less than 10/1 or more than 23/1.

- Temperature

Temperature has a large impact on biological systems, and changes the metabolic activities of methane bacteria.

- Anaerobic digestion

Anaerobic digestion can help minimize the concentration of organic compounds in the condensate.

- Co-digestion

Co-digestion with food industry waste can increase biogas production and reduce the amount of water needed to evaporate.

- Acid addition

Adding an acid beforehand can lower the pH and minimize the concentration of ammoniacal nitrogen in the condensate.

- Acid scrubber

An acid scrubber can treat the air and water vapor from drying.

Control of bio-slurry quality during dung mixing and plant charging

• Use clean raw materials (dung, water or urine) which are not contaminated with substances like straw and chemicals (acaricides and soap). • Mix adequate dung according to plant size. Too much dung leads to production of smelly (semi-digested) bio-slurry and inadequate feeding leads to failure of slurry expulsion from the expansion chamber and hence production of maggots. • Use proper mixing ratios (porridge-like mixture). A thick mixture leads to production of smelly bio-slurry and a thin mixture leads to low gas production

Control of bio-slurry quality after expulsion from the expansion Chamber

Wastage due to exposure to sunshine, mixing with rain water and run-off, and contamination with foreign materials. • Conflicts with neighbours due to excess overflow into their plots. • A repellent appearance of the area around the biogas plant.

Conditions required for composting bio-slurry

Adequate wet and dry organic materials like feed remnants, grass clippings, straw, crop residues, and kitchen waste etc.

- Maintaining optimum amount of water (moisture) by removing excess water.
- Turning the compost pile in order to introduce in air/oxygen (“Aeration”).
- Introducing micro-organisms to decompose the materials (by adding black (loam) soil or mature compost).

Biomass slurry enrichment

Enrichment Process

1. **Collection of Biomass:** Gather organic materials from agricultural residues, food waste, or animal manure.

2. **Pre-Treatment:** Depending on the biomass type, pre-treatment methods such as chopping, shredding, or soaking can enhance the breakdown of materials.
3. **Fermentation:** Introducing specific microorganisms can accelerate the breakdown of complex organic matter, increasing the concentration of valuable nutrients and gases.
4. **Separation:** This can involve techniques like centrifugation or filtration to separate liquid and solid fractions, allowing for more efficient use of the enriched slurry.
5. **Nutrient Addition:** Adding nitrogen, phosphorus, or potassium can enhance the nutrient profile, making the slurry more beneficial for agricultural applications.
6. **Quality Control:** Regular monitoring of pH, microbial content, and nutrient levels ensures that the slurry remains effective and safe for its intended use.

BIO-SLURRY APPLICATION AND USE IN AGRICULTURE

Bio-slurry for crop production In crop production

It is used as quality organic fertilizer (root and foliar) and pesticide for the control of especially insect pests. It can be used to build healthy fertile soils for since it contains readily available plant nutrients (NPK) which contributes to;

- i. Increased crop yield and improved crop quality.
- ii. Total or partial replacement of chemical fertilizers.
- iii. Decrease in use of artificial pesticides.

However, effective bio-slurry manure use in crops is determined by 3 main factors; soil composition, seed quality and climatic conditions of the area. Bio-slurry can be applied and utilized on almost all crops which include; a) Vegetables. b) Coffee. c) Fruits such as mangos, oranges and paw paws. d) Bananas. e) Maize, sugarcane and rice. f) Fodder such as napier (elephant grass).

The bioslurry can be applied: (1) as a foliar fertiliser, being sprayed onto the crops; (2) in liquid form (diluted) onto the roots, or; (3) in dry and composted form regards to tillage, note that immediate incorporation of pig bioslurry through tillage would increase the N value and favour greater N/P fertiliser value⁴² (see below). However, it is imperative to take into account the risks associated with spreading the bioslurry directly on the crops or incorporating it

Bio-slurry for animal production

Animal enterprises in which bio-slurry is applied and utilized include; • Pig rearing/piggery • Local chicken/ Vermi-culture (growing worms) to feed to chicken • Pisciculture/Fish rearing

Bio-slurry for commercial Production (income generation)

Bio-slurry is sold as either liquid or composted manure to crop, livestock (piggery and chicken) and fish farmer who do not own biogas plants

Application and utilization in the growing of vegetables

Application and utilization in the growing of coffee

Bio-slurry can be applied to coffee plants just like other organic manures to fertilize the soil and increase coffee yields either directly as liquid (wet) bio-slurry or indirectly as composted bioslurry.

Application and utilization in the growing of bananas

Bio-slurry can be applied to bananas just like other organic manures to fertilize the soil and increase banana yields either directly as liquid (wet) bio-slurry or indirectly as composted bioslurry.

Application and utilization in fish farming (pisciculture)

In fish farming, bio-slurry is mainly used for fish pond fertilization (preparing the pond before introducing the fish and fertilization of the stocked ponds). It is favourable to the growth of water organisms especially the water plants which are the major food for the fish.

Organic Fertilizer from Biogas Plants

Organic substances in fertilizers While there are suitable inorganic substitutes for the nutrients nitrogen, potassium and phosphorous from organic fertilizer, there is no artificial substitute for other substances such as protein, cellulose, lignin, etc.. They all contribute to increasing a soil's permeability and hygroscopicity while preventing erosion and improving agricultural conditions in general. Organic substances also constitute the basis for the development of the microorganisms responsible for converting soil nutrients into a form that can be readily incorporated by plants.

Nutrients and soil organisms

Due to the decomposition and breakdown of parts of its organic content, digested sludge provides fast-acting nutrients that easily enter into the soil solution, thus becoming immediately available to the plants. They simultaneously serve as primary nutrients for the development of soil organisms, e.g. the replenishment of microorganisms lost through exposure to air in the course of spreading the sludge over the fields. They also nourish actinomycetes (ray fungi) that act as organic digesting specialists in the digested sludge. (Preconditions: adequate aeration and moderate moisture).

Reduction of soil erosion

The humic matter and humic acids present in the sludge contribute to a more rapid humification, which in turn helps reduce the rate of erosion (due to rain and dry scatter) while increasing the nutrient supply, hygroscopicity, etc. The humic content is especially important in low-humus tropical soils. The relatively high proportion of stable organic building blocks such as lignin and certain cellulose compounds contributes to an unusually high formation rate of stable humus (particularly in the presence of argillaceous matter). The amount of stable humus formed with digested sludge amounts to twice the amount that can be achieved with decayed dung. It has also been shown that earthworm activity is stimulated more by fertilizing with sludge than with barnyard dung.

Forms of bioslurry Application

Liquid form

The liquid form can be applied through foliar spraying, a bucket, or irrigation canal. In this way the bioslurry can be applied directly to the crops. It can also be applied to the soil as a basal and/or top dressing. If it is applied to standing crops, it must be diluted at different rates, depending upon the biodigester type.

Dried form

The dried bioslurry loses part of its nitrogen (particularly ammonium) and therefore bioslurry needs to be applied as soon as possible to avoid loss .

The composted form of bioslurry is the best way to overcome the transportation issue related to liquid bioslurry and the nutrient loss of the dried form⁵⁴. Indeed, 'One part of the slurry will be sufficient to compost about 3 to 4 parts of dry plant material. This results in the increase in the amount of compost on the farm

Composition of bio gas

Substance	Symbol	Percentage
Methane	CH ₄	50 - 70
Carbon Dioxide	CO ₂	30 - 40
Hydrogen	H ₂	5 - 10
Nitrogen	N ₂	1 - 2
Water vapour	H ₂ O	0,3
Hydrogen Sulphide	H ₂ S	Traces

Biogas guideline data

1 Kg firewood => 0.2 m³ biogas
1 Kg dried cow dung => 0.1 m³ biogas
1 Kg Charcoal => 0.5 m³ biogas
1 Litre Kerosine => 2.0 m³ biogas

Bio gas appliances

Biogas is a lean gas that can, in principle, be used like other fuel gas for household and industrial purposes, especially for: • Gas cookers/stoves • Biogas lamps • Radiant heaters • Incubators • Refrigerators • Engines

Gas cookers/stoves

Biogas cookers and stoves must meet various basic requirements: • simple and easy operation • versatility, e.g. for pots of various size, for cooking and broiling • easy to clean • acceptable

cost and easy repair • good burning properties, i.e. stable flame, high efficiency • attractive appearance

Two-flame burners

A cooker is more than just a burner. It must satisfy certain aesthetic and utility requirements, which can vary widely from region to region. Thus, there is no such thing as an all-round biogas burner. Most households prefer two-flame burners. The burners should be set initially and then fixed. Efficiency will then remain at a high practical level. Single-flame burners and lightweight cook-stoves tend to be regarded as stop-gap solutions until more suitable alternatives can be afforded.

Biogas lamps

Efficiency of biogas lamps In villages without electricity, lighting is a basic need as well as a status symbol. However, biogas lamps are not very energy-efficient. This means that they also get very hot. The bright light of a biogas lamp is the result of incandescence, i.e. the intense heat-induced luminosity of special metals, so-called "rare earth" like thorium, cerium, lanthanum, etc. at temperatures of 1000-2000°C. If they hang directly below the roof, they cause a fire hazard. The mantles do not last long. It is important that the gas and air in a biogas lamp are thoroughly mixed before they reach the gas mantle, and that the air space around the mantle is adequately warm.

Optimal tuning The performance of a biogas lamp is dependent on optimal tuning of the incandescent body (gas mantle) and the shape of the flame at the nozzle.

Adjusting a biogas lamp

Biogas lamps are controlled by adjusting the supply of gas and primary air. The aim is to make the gas mantle burn with uniform brightness and a steady, sputtering murmur.

Radiant heaters

Infrared heaters are used in agriculture for achieving the temperatures required for raising young stock, e.g. piglets and chicken in a limited amount of space. The nursery temperature for piglets begins at 30-35°C for the first week and then gradually drops off to an ambient temperature of 18-23°C in the 4th/5th week. As a rule, temperature control consists of raising or lowering the heater. Good ventilation is important in the stable / nursery in order to avoid excessive concentrations of CO or CO₂. Consequently, the animals must be kept under regular supervision, and the temperature must be checked at regular intervals.

Incubators

Incubators are supposed to imitate and maintain optimal hatching temperatures for eggs. They are used to increase brooding efficiency.

Refrigerators

Absorption-type refrigerating machines operating on ammonia and water and equipped for automatic thermo-siphon circulation can be fuelled with biogas.

Biogas-fueled engines

Gas demand If the output of a biogas system is to be used for fueling engines, the plant must produce at least 10 m³ biogas per day.

In the dual fuel approach the diesel engine remains extensively unmodified, except for the addition of a gas/air mixing chamber on the air-intake manifold (the air filter can be used as a mixing chamber). The injected diesel fuel still ignites itself, while the amount injected is automatically reduced by the speed governor, depending on how much biogas is injected into the mixing chamber. The biogas supply is controlled by hand. The maximum biogas intake must be kept below the point at which the engine begins to stutter.

Biochemical characteristics of bioresources

The biochemical characteristics of bioresources refer to the chemical compounds and processes associated with living organisms and organic materials. These characteristics are crucial for understanding how bioresources can be utilized for various applications, such as bioenergy, bioremediation, and biomanufacturing. Here are some key aspects:

1. Composition of Biomolecules

- **Carbohydrates:** Includes sugars and polysaccharides (e.g., cellulose, starch) that serve as energy sources and structural components.
- **Proteins:** Made up of amino acids, proteins are involved in catalysis (enzymes), structural roles, and signaling.
- **Lipids:** Fats and oils that serve as energy storage, membranes, and signaling molecules.
- **Nucleic Acids:** DNA and RNA, which are essential for genetic information and protein synthesis.

2. Metabolic Pathways

- **A metabolic pathway is** a series of chemical reactions that occur within a cell and are catalyzed by enzymes:
- Enzymes break down or build up molecules. The reactants, products, and intermediates of these reactions are called metabolites.
- Metabolic pathway comprises of series of chemical reactions which occurs inside the cells. The reactants, products, and intermediates which are formed as a result of these enzymatic reactions are called as Metabolites. These enzymes typically need dietary minerals, vitamins, and different cofactors to perform.
- Types of metabolic pathways

There are two main types of metabolic pathways:

- **Anabolic pathways:** Synthesize and store biomolecules, like proteins, lipids, and carbohydrates.
- **Catabolic pathways:** Break down biomolecules to generate energy

3. Enzymatic Activity

- Enzymes from bioresources can catalyze various biochemical reactions, making them valuable for industrial applications, such as biocatalysis in pharmaceuticals or food processing.
- **Types of Enzymes:** Enzymes that facilitate biochemical reactions, such as amylases, proteases, and lipases.
- **Kinetics:** Understanding enzyme efficiency and reaction rates (e.g., Michaelis-Menten kinetics).

4. Microbial Interactions

- The biochemical characteristics of microorganisms (bacteria, fungi) can influence nutrient cycling, decomposition, and plant growth, which are essential for ecosystem health and agricultural productivity.

5. Chemical Composition Analysis

- Techniques such as chromatography, mass spectrometry, and spectroscopy are used to analyze the biochemical composition of bioresources to understand their potential uses and benefits.

6. Biodegradability

- The ability of bioresources to decompose naturally is important for waste management and environmental sustainability. Understanding the biochemical properties can help in developing biodegradable materials.

7. Biochemical Diversity

- The variety of biochemical compounds in different organisms contributes to biodiversity, which is vital for ecosystem resilience and offers a pool of resources for biotechnology.

8. Energy Production

- Biochemical processes like fermentation and anaerobic digestion convert biomass into biofuels (e.g., bioethanol, biogas), highlighting the energy potential of bioresources.

9. Primary and secondary metabolites

Primary plant metabolites- These are considered as basic plant constituents. They are simple in structure and they do not have biological and pharmacological activity associated with them. Primary metabolites are utilized by plants for building up their body and responsible for physiological functioning of the plant body. eg. Starch, Cellulose, Chlorophyll, Calcium oxalate crystals etc.

Secondary metabolites

organic compounds produced by plants. Do not play any role in growth of plant. Required for plant survival. Help in response to stress.

10. Genetic diversity is a crucial biochemical characteristic of bioresources, influencing their adaptability, resilience, and potential for use in various applications. Here's how genetic diversity relates to biochemistry and bioresources.

11. Biotechnological Applications

- **Crop Improvement:** Genetic diversity in plants can be harnessed for breeding programs aimed at enhancing traits like yield, disease resistance, or nutritional content.
- **Microbial Diversity in Industry:** In industrial biotechnology, diverse microbial strains can be selected for specific biochemical processes, such as enzyme production or biofuel generation.

Bioenergetics

Bioenergetics is the field of biochemistry concerned with the transformation and use of energy by living cells. So, basically Bioenergetics is "the study of energy changes in biological reactions".

Bioenergetics is the quantitative study of the energy transductions that occur in living cells and of the nature and function of the chemical processes underlying these transductions. The goal of bioenergetics is to describe how living organisms acquire, transform and utilize energy in order to perform biological work. The study of metabolic pathways is thus essential to bioenergetics.

Biological Energy Transformations Obey the Laws of Thermodynamics

The **first law** is the principle of the conservation of energy: for any physical or chemical change, the total amount of energy in the universe remains constant; energy may change form or it may be transported from one region to another, but it cannot be created or destroyed. The **second law** of thermodynamics, which can be stated in several forms, says that the universe always tends toward increasing disorder: in all natural processes, the entropy of the universe increases. Living organisms consist of collections of molecules much more highly organized than the surrounding materials from which they are constructed, and organisms maintain and produce order, seemingly oblivious to the second law of thermodynamics. But living organisms do not violate the second law; they operate strictly within it.

The reacting system is the collection of matter that is undergoing a particular chemical or physical process; it may be an organism, a cell, or two reacting compounds. The reacting system and its surroundings together constitute the universe. Living cells and organisms, however, are open systems, exchanging both material and energy with their surroundings; living systems are never at equilibrium with their surroundings, and the constant transactions between system and surroundings explain how organisms can create order within themselves while operating within the second law of thermodynamics.

Three thermodynamic quantities that describe the energy changes occurring in a chemical reaction.

Gibbs free energy, G, expresses the amount of energy capable of doing work during a reaction at constant temperature and pressure. When a reaction proceeds with the release of free energy (that is, when the system changes so as to possess less free energy), the free-energy change, ΔG , has a negative value and the reaction is said to be exergonic. In endergonic reactions, the system gains free energy and ΔG is positive.

Enthalpy, H, is the heat content of the reacting system. It reflects the number and kinds of chemical bonds in the reactants and products. When a chemical reaction releases heat, it is said to be exothermic; the heat content of the products is less than that of the reactants and ΔH has, by convention, a negative value. Reacting systems that take up heat from their surroundings are endothermic and have positive values of Enthalpy, ΔH , is the heat content of the reacting system. It reflects the number and kinds of chemical bonds in the reactants and products.

Entropy, S, is a quantitative expression for the randomness or disorder in a system. When the products of a reaction are less complex and more disordered than the reactants, the reaction is said to proceed with a gain in entropy.

Under the conditions existing in biological systems (including constant temperature and pressure), changes in free energy, enthalpy, and entropy are related to each other quantitatively by the equation

$$\Delta G = \Delta H - T \Delta S$$

By convention, ΔS has a positive sign when entropy increases and ΔH , as noted above, has a negative sign when heat is released by the system to its surroundings. Either of these conditions, which are typical of favorable processes, tend to make ΔG negative. In fact, ΔG of a spontaneously reacting system is always negative

The second law of thermodynamics states that the entropy of the universe increases during all chemical and physical processes, but it does not require that the entropy increase take place in the reacting system itself. The order produced within cells as they grow and divide is more than compensated for by the disorder they create in their surroundings in the course of growth and division. In short, living organisms preserve their internal order by taking from the surroundings free energy in the form of nutrients or sunlight, and returning to their surroundings an equal amount of energy as heat and entropy

Cells Require Sources of Free Energy Cells are isothermal systems—they function at essentially constant temperature (they also function at constant pressure). Heat flow is not a source of energy for cells, because heat can do work only as it passes to a zone or object at a lower temperature. The energy that cells can and must use is free energy, described by the Gibbs free-energy function G , which allows prediction of the direction of chemical reactions, their exact equilibrium position, and the amount of work they can in theory perform at constant temperature and pressure. Heterotrophic cells acquire free energy from nutrient molecules, and photosynthetic cells acquire it from absorbed solar radiation.

The Standard Free-Energy Change Is Directly Related to the Equilibrium Constant

The composition of a reacting system (a mixture of chemical reactants and products) tends to continue changing until equilibrium is reached. At the equilibrium concentration of reactants and products, the rates of the forward and reverse reactions are exactly equal and no further net