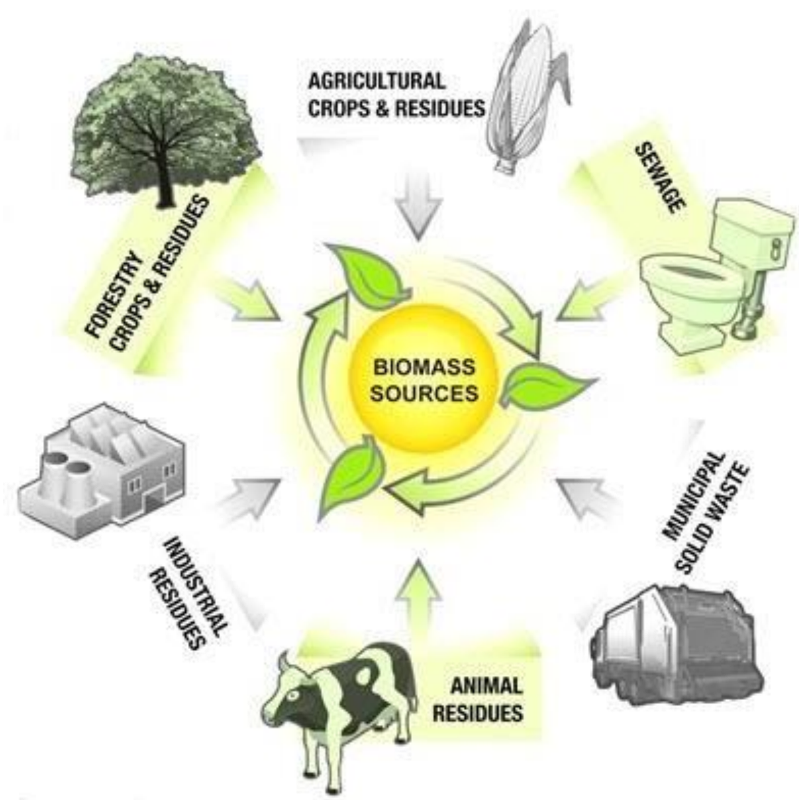
UNIT-5

BIOGAS AND BIOETHANOL PRODUCTION

TOPICS

- Screening of suitable lingo cellulosic substrate for biogas production,
- Determination of bio-energy potential of agro-waste,
- Estimating total solids - volatile solids - Calorific value - percent total carbohydrates, moisture, lignin and cellulosic contents.
- Preparation of feed stocks for anaerobic bio-digestion,
- Types of digesters,
- Factors affecting biogas production,
- Nutrient value and utilization of biogas slurry,
- Ethanol production from lingo cellulosic wastes,
- Processing of Biomass to Ethanol,
- Pre-treatment - fermentation - distillation.

Biomass:



Definition:

Biomass is defined as the organic matter derived from biological materials such as plants, animals, microorganisms and municipal wastes.

Why Biomass?

- With serious concern globally and in India on the use of fossil fuels, it is important for India to start using renewable energy sources.
- India is the seventh largest country in the world spanning **328 million hectares** and amply bestowed with renewable sources of energy.
- Among the renewable energy sources, biomass plays a vital role especially in rural areas, as it constitutes the major energy source to majority of households in India.
- India produces about 450-500 million tones of biomass per year.
- Biomass provides 32% of all the primary energy use in the country at present.

What is Biomass?

- It is a renewable form of energy as it can be replenished within a short period.
- It can be used as a solid fuel, or converted into liquid or gaseous forms for the production of electric power, heat, chemicals or fuels.
- As per the Energy Independence and Security Act of 2007, the term “renewable biomass” means each of the following:
- **Planted crops** and **crop residue** harvested from agricultural land cleared.



- **Planted trees** and **tree residue** from actively managed tree plantations on non-federal land cleared.



- Animal waste material and animal byproducts.

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<u>Reasons for utilizing biomass:</u>

- ✓ Readily available and renewable.
- ✓ Non-fossil forms of fixed carbon are not depletable, in contrast to fossil fuels such as coal, oil, petroleum fuels and natural gas.
- ✓ Biomass is available in large quantities and provides a raw material for conversion to major supplies of synthetic fuels.

- ✓ Combining waste disposal and energy recovery processes offers recycling opportunities as well as improved disposal technology, often at low cost.
- ✓ Clean and nearly pollution free combustion.
- ✓ Energy and capital requirement for production is low.

CHARACTERIZATION OF BIOMASS:

- Detailed and accurate characterization of biomass feedstock, intermediates, and products is a necessity for any **biomass to biofuels conversion.**
- Understanding how the individual biomass components and reaction products interact at each stage in the process is important for researchers.

Typical biomass components:

(a) Cellulose

(b) Hemicellulose

(c) Lignin

Cellulose, hemicellulose, and lignin are universally found in many kinds of biomass, and are the most plentiful natural carbon resources on Earth.

(d) Starch

(e) Proteins.

Characterizing biomass:

- ➢ **Total Solids:**

  A way to determine the moisture content within the sample.

- ➢ **Ash Determination:**

  The amount of inorganic or mineral material present in the sample.

- ➢ **Exhaustive Ethanol and Water Extractable:**

The removal of non-structural material from the biomass sample to prevent interferences during other analyses, as well as free sugar determination.

- ➢ **Structural Carbohydrates:**

The determination of glucose, xylose, galactose, arabinose and mannose concentrations in the sample; used to determine cellulose and hemicellulose concentrations in the biomass.

- **Acetyl Content:**

Acetic acid concentration in the sample, may also include formic and levulinic acid content depending on the feedstock.

- **Lignin:**

Determination of the structural plant material that does not contribute to the sugar content in the sample.

- **Starch Content:**

Represents the readily available source of sugar within some feedstock.

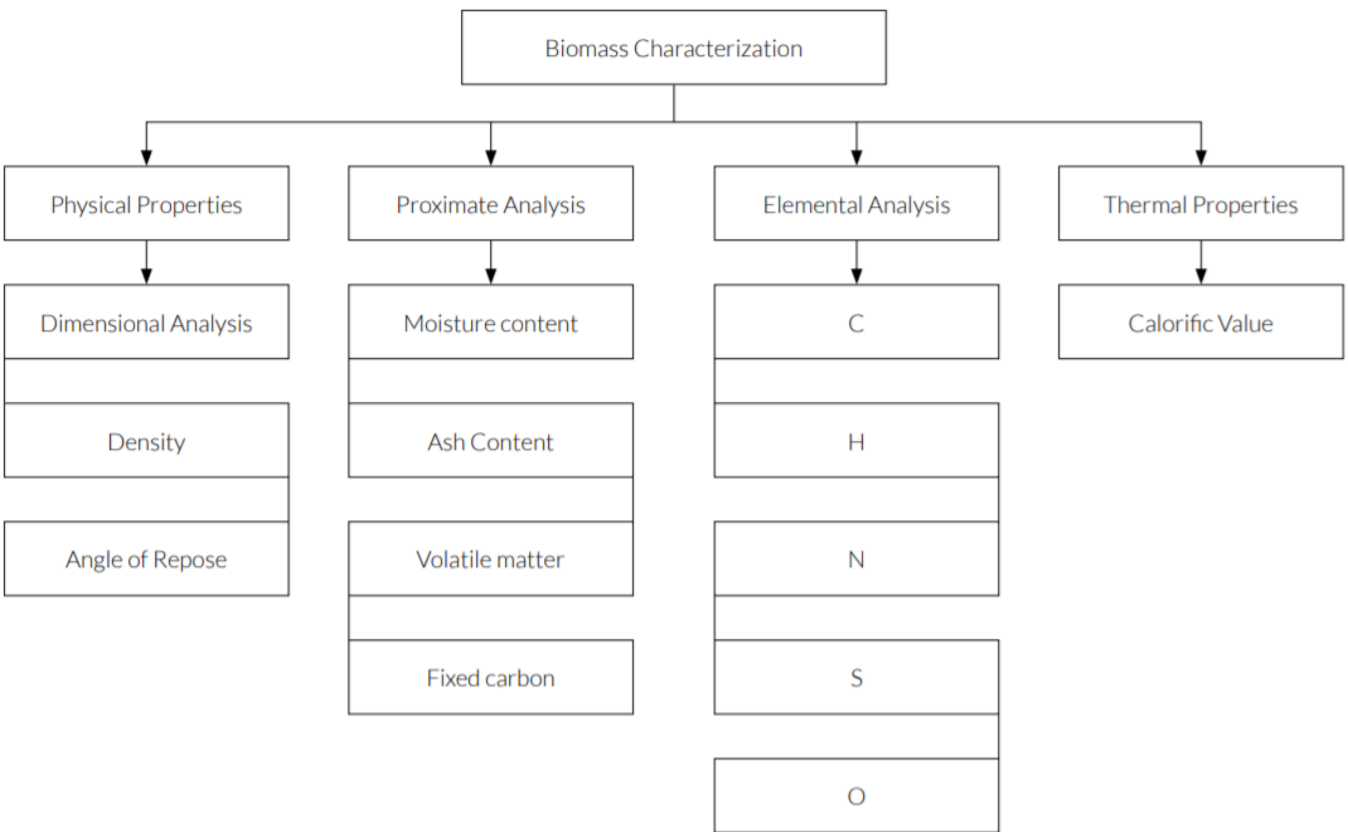
- **Ethanol Content:**

Analysis of fermentation broths using gas chromatography.

- **Bomb Calorimetry:**

The determination of the sample's calorific value.

Biomass Characterization:



- ✓ The viability and feasibility of bio-energy generation from agricultural biomass depends upon the characteristics of biomass available.
- ✓ Biomass could be employed for energy conversion by means of different processes, such as chemical, biochemical, thermal-chemical etc.
- ✓ The process choice specifically depends on the biomass characteristics;
- ✓ Biomass characterization is essential to study various biomass related properties, fuel value, ash handling, combustion, information for design, development and operation of biomass conversion system.

Physical Properties:

- Bulk density
- Particle size distribution
- Particle density
- Angle of repose
- Heat capacity
- Thermal conductivity

Particle density:

- Measure of bio mass weight per unit volume(kg/m^3)
- Most common device - pycnometer.

Bulk density:

- Same as particle density, but volume include void space.

Particle size distribution:

- Bio mass need to be size reduced if they are used for any conversion.
- Bio mass of less than 10 mm in size are normally used in conversion process.
- Measured using sieve analysis.

Angle of repose:

- Angle of repose defined as internal angle between the surface of pile and the horizontal surface.
- Factor affecting angle of repose are, density, surface area, shape of the particle, co-eff of friction of material.
- Important for designing equipment for bio mass storage (silos), hopper, width of belt in belt conveyer.

Angle of friction:

- It is that **angle with which a pile of biomass will slide when raised from the horizontal**.
- One can observe, **bio mass will slide easily (lower angle) in smooth surface rather than rough surface**.
- Design of conveying system and hopper.

Heat capacity:

- Ratio of **amount of heat energy transferred to the material** to **resulting increasing in temperature of the material**.
- Unit- Joules/kelvin.
- Limited research in this area.

Thermal conductivity:

- **Ability of the material to conduct or transfer heat**.
- If more **Thermal Conductivity, then more heat transfer ability**.
- Low Thermal conductivity used as **insulation.**
- Unit of Thermal conductivity **- W/(m-K)**

The three sets of commonly used biomass characterization related to thermal conversion are

- Proximate analysis,
- Ultimate analysis,
- Heating value analysis.

<u>Proximate analysis:</u>

- Include measurement of **moisture content (mc), volatile combustible matter (VCM), fixed carbon (FC) and ash**.
- Moisture content high as 99% for aquatic biomass such as algae and low as 10% for some field crops.

TABLE 3.2
Some Proximate Analysis of Common Biomass (as Received)

Biomass	MC (%)	Ash (%)	VCM (%)	FC (%)	HV (MJ/kg)
Rice straw (CA)	8.2	13.8	67.5	10.5	15.8
Rice straw (TX)	8.7	16.3	61.6	13.4	15.4
Corn stover	9.9	5.7	70.7	13.7	15.6
Woodchips (softwood)	10.0	0.3	78.5	11.2	19.4
Switchgrass	9.3	3.6	76.3	10.7	19.8
Cotton gin trash	10.6	6.9	66.7	15.7	17.9
Peat	14.4	2.8	58.8	24.1	19.0
Wheat straw	8.7	10.8	69.4	11.1	17.5
Rice husks (or hulls)	10.0	17.8	60.3	11.9	14.4
Poultry manure	10.7	29.0	48.7	11.6	11.8
Almond shells (outer)	9.5	5.7	65.9	18.9	18.7
Almond hulls (inner)	9.3	1.9	73.5	15.3	19.6
Alligator grass	11.3	14.2	64.4	10.1	17.1
Coconut shells	11.2	0.8	72.7	15.3	20.6
Sorghum biomass	12.8	7.4	65.4	14.4	17.0
Jatropha shells	9.7	4.1	64.5	21.6	19.2
Arundo donax	9.4	5.2	73.2	12.3	18.7

Volatile Combustible Matter (VCM):

- Bone dry sample placed in platinum crucible with close fitting cover and placed in tube furnace at 950 (+) or (-) 20^0C.
- Exposed for 7min then celled and re-weighted.
- Loss in weight is VCM.
- $(V_1-V_2/V_1) \times 100$.
- VCM responsible for more combustible gas during conversion.

FC and ash:

- After measuring VCM.
- Open the cap and set the furnace temp as 600^0C for 1hr.
- Ensure no carbon left.
- Then re weight, it is the ash.
- Difference between the ash content and VCM is the FC.
- % ASH = 100 - % VCM - % FC
- FC is more important; It is **the primary element for making liquid bio fuels**.

<u>Ultimate analysis:</u>

- ✓ Measure of component of bio mass such as C, H, O, Nitrogen (N), Sulfur (S) and Ash.
- ✓ Elemental analyzer.
- ✓ Carbon (C) varies from low at (poultry) of 27% to high of 49.5% (peat).

The major challenges involve in biomass characterization for bio-energy production are as follows:

- ✓ Nature of biomass feed stocks.
- ✓ Multiphase conversion processes.
- ✓ Type of bio-fuel.
- ✓ Technological advancement.
- ✓ Experiment validation.
- ✓ Process optimization.
- ✓ By-products utilization.

BIOGAS PRODUCTION:

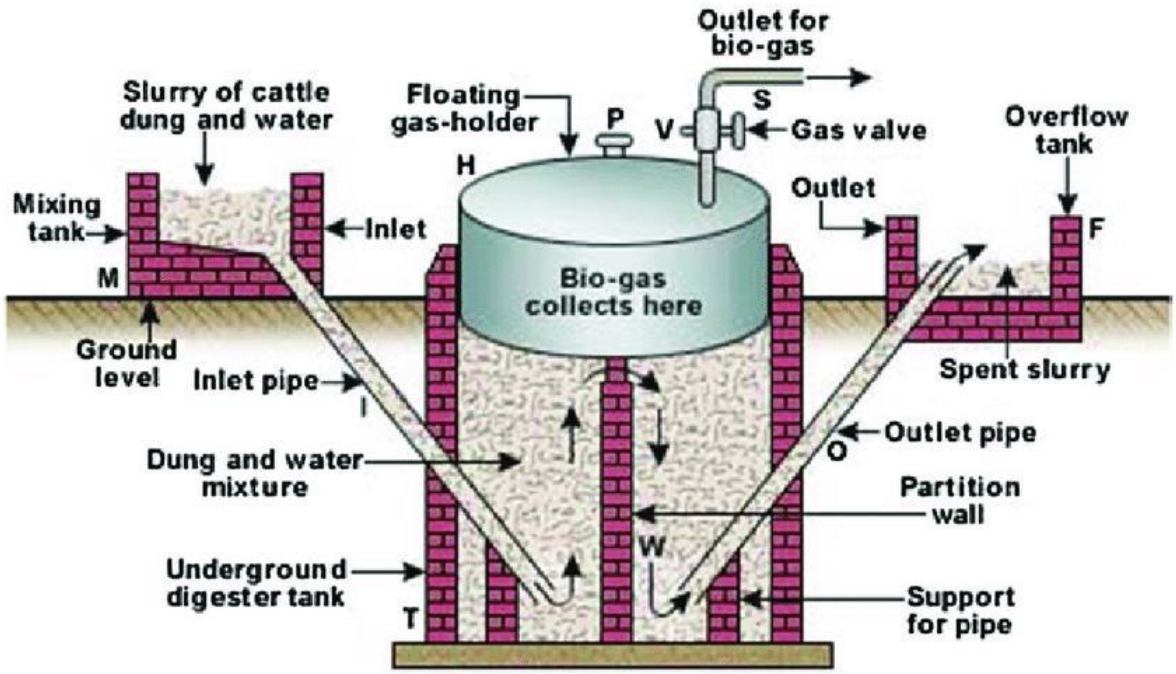
What is Biogas?

- **Biogas** is the mixture of gases produced by the **breakdown of organic matter** by microorganisms in the **absence of oxygen** (anaerobically).
- Biogas, a mixture containing **55-65%** methane, **30-40% Co_2** and the rest being the impurities (H_2, H_2S, and some N_2), can be produced from the decomposition of animal, plant and human waste.
- It is a clean but slow burning gas and usually has a colorific value-between **5000 to 5500 kcal/m^3.**
- **Methane is a combustible gas**. The energy content of biogas depends on the amount of methane it contains.

Name of the gas	Composition in biogas (%)
Methane (CH_4)	50-70
Carbon dioxide (CO_2)	30-40
Hydrogen (H_2)	5-10
Nitrogen (N_2)	1-2
Water vapour (H_2O)	0.3
Hydrogen sulphide (H_2S)	Traces

A few other materials through which biogas can be generated are,

- **Algae, crop residues (agro-wastes), garbage kitchen wastes, paper wastes, sea wood, human waste, waste from sugarcane refinery, water hyacinth etc**., apart from the above mentioned animal wastes.
- Any **cellulosic organic material** of animal or plant origin, which is easily biodegradable, is a potential raw material suitable for biogas production.

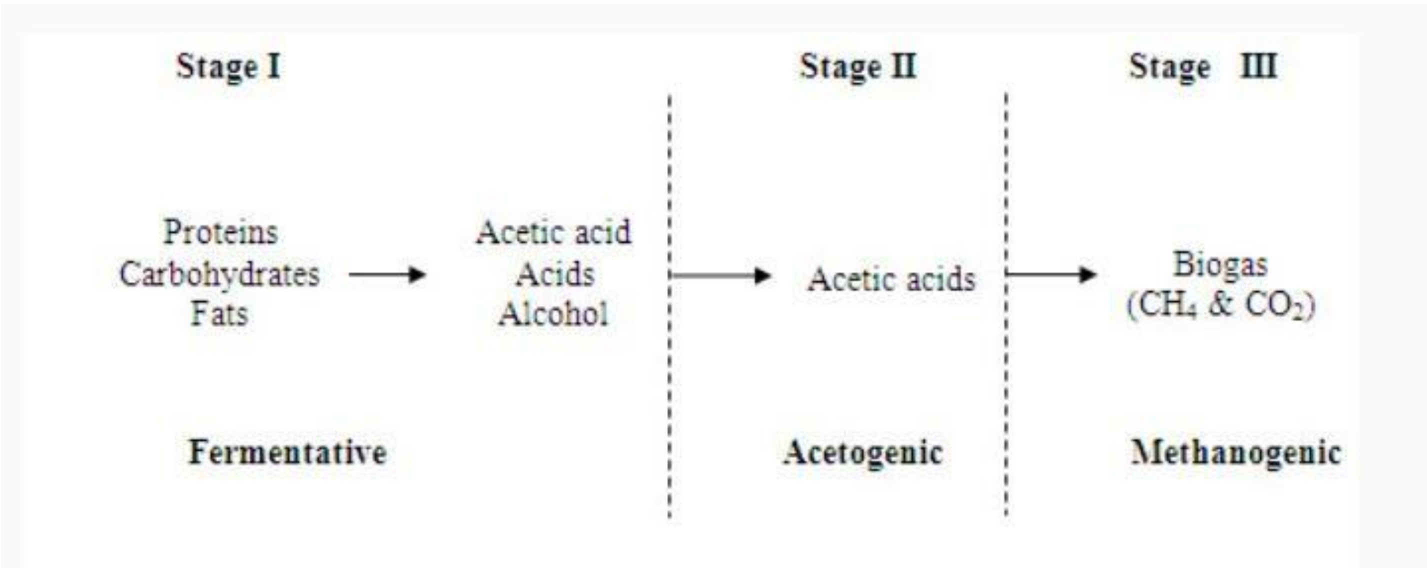


MICROBIOLOGY OF BIOGAS PRODUCTION:

- The production of biogas from organic material under anaerobic condition **involves sequence of microbial reactions.**
- During the process complex organic molecule present in the biomass are *broken down to* ***sugar, alcohols, pesticides and amino acids*** *by acid producing bacteria*.
- The resultant products are then *used to produce methane by another category of bacteria*.
- The biogas production process involves three stages namely:
  - Hydrolysis,
  - Acid formation, and
  - Methane formation.
- The process of degradation of organic material in every step is *done by range of bacteria, which are specialized in reduction of intermediate products formed.*
- *The efficiency of the digestion depends how far the digestion happens in these three stages*. Better the digestion, shorter the retention time and efficient gas production.

Hydrolysis:

- The complex organic molecules like fats, starches and proteins which are water insoluble contained in *cellulosic biomass are broken down into simple compounds with the help of enzymes secreted by bacteria*.
- This stage is also known as **polymer breakdown stage** (polymer to monomer).
- The major end product is glucose which is a simple product.



Acid formation:

- The resultant product (monomers) obtained in hydrolysis stage serve as **input** for acid formation stage bacteria.
- Products produced in previous stage are ***fermented under anaerobic conditions to form different acids***.
- The major products produced at the end of this stage are acetic acid, propionic acid, butyric acid and ethanol.

Methane formation:

- The acetic acid produced in the previous stages is converted into ***methane and carbon dioxide by a group of microorganism called "Methanogens".***
- In other words, it is process of production of methane by methanogens. They are obligatory anaerobic and very sensitive to environmental changes.

- Methanogens utilize the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water.
- It is these components that make up the majority of the biogas emitted from the system.

CH_3COOH Acetic acid			→	CH_4 Methane	+	CO_2 Carbon dioxide
$2CH_3CH_2OH$ Ethanol	+	CO_2 Carbon dioxide	→	CH_4 Methane	+	$2CH_3COOH$ Acetic acid
CO_2 Carbon dio-xide	+	$4\ H_2$ Hydrogen	→	CH_4 Methane	+	$2\ H_2O$ Water

FACTORS INVOLVED IN BIOGAS PRODUCTION:

1. C/N Ratio:

- The **ratio of carbon to nitrogen** present in the feed material is called C: N ratio. It is a crucial factor in maintaining perfect environment for digestion.
- **Carbon is used for energy** and **nitrogen for building the cell structure.**
- Optimum condition for anaerobic digestion to take place ranges from **20 to 30:1**. This means the bacteria use up carbon about 20 to 30 times faster than they use up nitrogen.
- When there is **too much carbon** in the raw wastes, *nitrogen will be used up first* and carbon left over. This will make the digestion slow down and eventually stops.
- On the other hand, if there is **too much nitrogen**, the *carbon soon becomes exhausted* and fermentation stops. The nitrogen left over will combine with hydrogen to form ammonia.
- This can kill or inhibit the growth of bacteria specially the methane producers.

2. **Temperature:**
    - Temperature affects the *rate of reaction happening inside the digester*.
    - Increase in the ambient temperature increases the rate of reaction thus increasing the biogas production as well.
    - Methane bacteria work best at a temperature of **35^0-38^0C**.
    - The fall in gas production starts at 20^0C and stops at a temperature of 10^0C.
    - Studies showed that 2.25 m^3 of gas was produced from 4.25 m^3 of cattle dung every day when the digester temperature was 25^0C.
    - When the temperature raises to 28.3^0C the gas production was increased by 50 per cent to 3.75 m^3 per day.
3. **Retention time:**
    - It is the **theoretical time that particular volume of feedstock remains in the digester**.
    - In other words, retention time describes the **length of time the material is subjected to the anaerobic reaction**.
    - It is calculated as the volume of digester divided by the feedstock added per day and it is **expressed in days**.
    - Under anaerobic condition, *the decomposition of the organic substances is slow and hence need to keep for long time to complete the digestion.*
    - In case of Indian digesters, where the feed stock is diluted with equal composition, so demarcation prevails between solid and liquid.
    - In this case, biomass in the form of bacteria is washed out; *hence the solid retention time (SRT) is equal to hydraulic retention time (HRT).*
4. **Loading rate:**
    - Loading rate is the *amount of raw material fed to the digester per day per unit volume.*
    - If the reactor is **overloaded**, acid accumulation will be more obviously affecting daily gas production.
    - On the other hand**, under loading** of digester have negative impact in designed gas production.

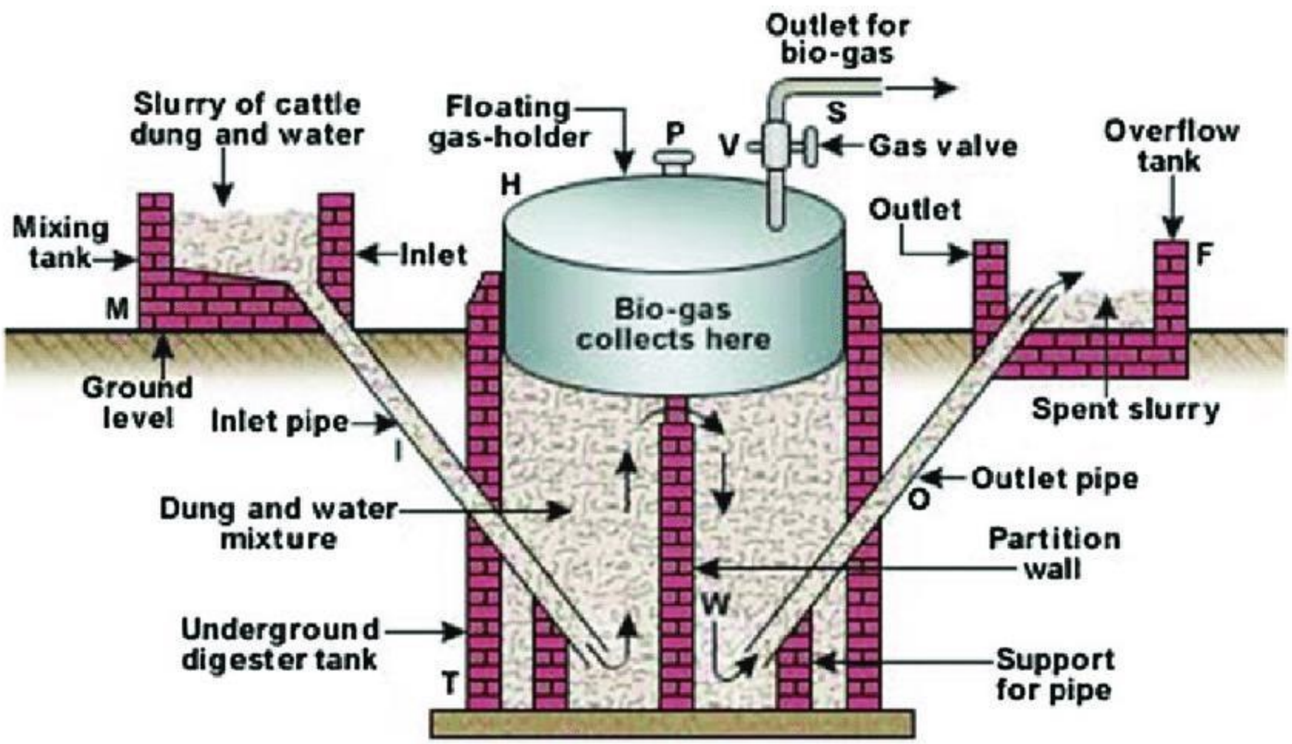
5. **Toxicity:**
   - Though small quantities of mineral ions like *sodium, potassium stimulates the growth of bacteria, the high concentration of heavy metals* and detergents have **negative impact** in gas production rate.
   - Detergents like **soap, antibiotics, and organic solvents are toxic to the growth of microbes** inside the digester.
   - Addition of these substances along with the feed stock should be **avoided.**
6. **pH or hydrogen ion concentration:**
   - To maintain a constant supply of gas, it is **necessary to maintain a suitable pH range** in the digester.
   - pH of the slurry changes at *various stages of the digestion.*
   - In the initial acid formation stage in the fermentation process, the pH is around 6 or less and much of CO_2 is given off.
   - In the latter 2-3 weeks' times, the pH \ increase \ as the volatile acid and N_2 compounds are digested and CH_4 is produced.
   - **The digester is usually buffered if the pH is maintained between 6.5 and 7.5**. In this pH range, the micro-organisms will be very active and digestion will be very efficient.
   - *If the pH range is between 4 and 6 it is called acidic*.
   - *If it is between 9 and 10 it is called alkaline*.
   - **Both these are detrimental to the methanogenic** (Methane production) organisms.
7. **Total solid content:**
   - The raw cow dung contains **80-82% of moisture**. The balance **18-20% is termed as total solids**.
   - The cow dung is **mixed usually in the proportion of 1:1** in order to bring the total solid content to 8-10%.
   - This adjustment of total solid content helps in digesting the materials at the ***faster rate and also in deciding the mixing of the various crop residues as feed stocks in biogas digester***.

8. **Feed rate:**
   - One of the prerequisites of good digestion is the uniform feeding of the digester so that the micro-organisms are kept in a relatively constant organic solids concentration at all times.
   - Therefore, the **digester must be fed at the same time everyday with a balanced feed on the same quality and quantity.**
9. **Diameter to depth ratio:**
   - Studies reveal that gas production per unit volume of digester capacity was maximum, when the **diameter to depth ratio was in the range of 0.66 to 1.00**.
   - One reason may be that because in a simple unstirred single stage digester the *temperature varies at different depths*.
   - The most activity digesting sludge is in the lower half of the digester and this is less affected by changes in night and day temperature.
10. **Nutrients:**
    - The major nutrients required by the bacteria in the digester are C, H_2, O_2, N_2, P and S, of these nutrients N_2 and P are always in short supply.
    - Therefore, to maintain proper balance of nutrients an extra raw material rich in phosphorus (*night soil, chopped leguminous plants*) should be added along with the cow dung to obtain maximum production of gas.
11. **Degree of mixing:**
    - Bacteria in the digester have very limited reach to their food, it is **necessary that the slurry is properly mixed and bacteria get their food supply**.
    - Light mixing improves the fermentation, however a **violent slurry agitation retards the digestion**.
12. **Type of feed stocks:**
    - All **plant and animal wastes** may be used as the feed materials for a digester. When feed *stock is woody or contains more of lignin, then digestion becomes difficult*.
    - To obtain as efficient digestion, these feed stocks are **combined in proportions**.

- **Pre-digestion** and finely chopping will be helpful in the case of some materials.
- Animal wastes are predigested. Plant wastes do not need pre-digestion. Excessive plant material may choke the digester.

STRUCTURE OF BIOGAS PLANTS:

- ✓ In a biogas plant, the feedstock is mixed with water and fed in to a tank, where feedstock goes through number of reaction producing biogas.
- ✓ The mix of dung and water is called slurry. After biogas production, the slurry comes out of the tank and is rich in nutrients and can be used as fertilizer.
- ✓ The biogas produced in the plant is stored in a gas holder.



Biogas Plant Structure

Components of Biogas plants:

Digester:

- This is the fermentation tank and is built partially or fully underground.
- It is generally cylindrical in shape and made up of bricks and cement.
- It holds slurry within it for the period of digestion for which it is designed.

- **<u>Gas Holder:</u>**
  - After release of methane from the digester, it is controlled in a tank called gas holder.
  - It may be a floating drum or a fixed dome.
  - The floating dome is made of steel or iron while the fixed dome is made of cement and concrete.
  - The gas connection is taken from the top of this gas holder.
  - The gas is taken through pipes to the burners.
- **<u>Slurry Mixing (Inlet)</u>**:
  - ✓ Dung is mixed with water and fed into the digester from the inlet.
- **<u>Slurry pit (Outlet)</u>**:
  - ✓ An outlet from the digester, from where slurry is taken out to the field.

<u>CLASSIFICATION OF BIOGAS PLANTS:</u>

Biogas plants are mainly classified as:

- ❖ Based to the process:
  1. Continuous type plant,
     - **(i) Single stage process,**
     - **(ii) Double stage process.**
  2. Batch type plant.
- ❖ Based on dome type,
- ❖ Based on drum type.

1. Continuous Type Plant:

- There is a single digester in which **raw material is charged regularly** and the process goes on without interruption except for repair and cleaning etc.
- It is **thoroughly mixed** with the digesting mass where dilution prevents souring and the biogas production is maintained.
- The continuous process may be completed in a **single stage or separated into two stages.**

(a) Single stage process:

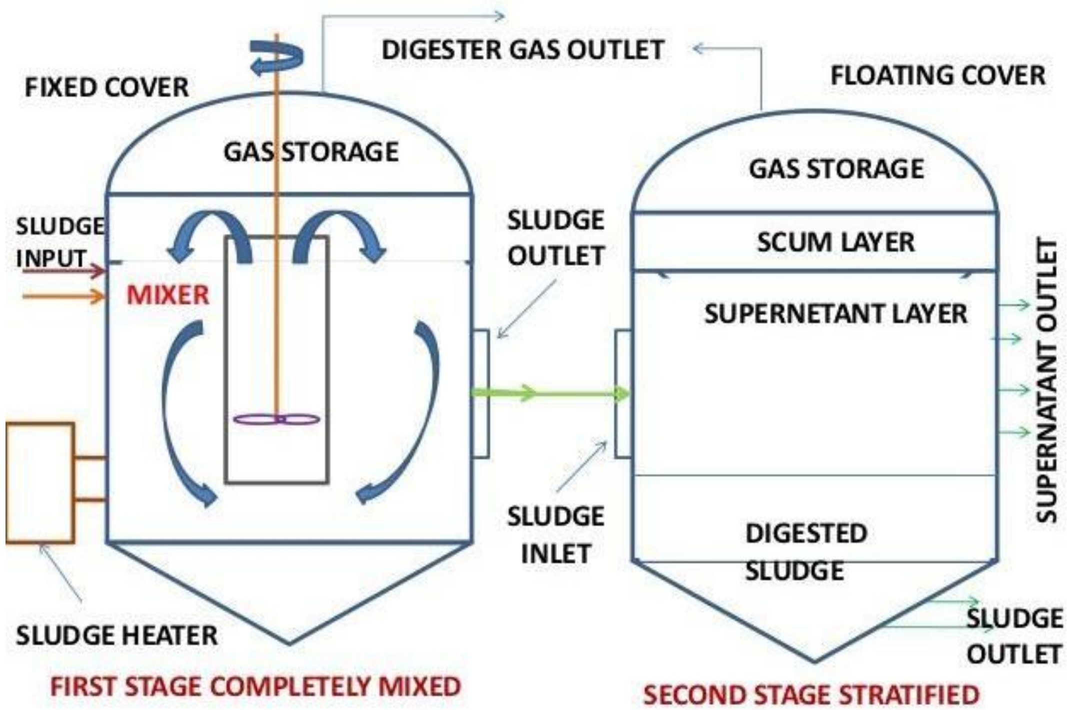
- ✓ The entire process of conversion of complex organic compounds into biogas is **completed in a single chamber**.
- ✓ This chamber is regularly fed with raw materials while the spent residue keeps moving out.

(b) Double stage process:

- ✓ In double stage process, the **first stage of acid production** is carried out in a separate chamber and only the **diluted acids are fed into the second chamber**.
- ✓ Where **bio - methanation takes place** and the biogas can be collected from the **second chamber.**

The main features of continuous plant are that:

- It will produce as **continuously**.
- It requires **small digestion chambers**.
- It needs **lesser period for digestion**.
- It has **less problems** compared to batch type and it is easier in operation.



SCHEMATIC OF TWO-STAGE DOGESTION PROCESS

2. **Batch Type Plant:**

- ✓ The feeding is between intervals, the plant is emptied once the process of digestion is complete.
- ✓ In this type, a battery of digesters are charged along with lime, urea etc., and allowed to produce gas for 40-50 days.
- ✓ The biogas supply may be utilized after 8-10 days.

  The main features of the batch plant are:

  - The gas production is intermittent, depending upon the clearing of the digester.
  - It needs several digesters or chambers for continuous gas production.
  - Batch plants are good for long fibrous materials.
  - This plant needs addition of fermented slurry to start the digestion process.
  - This plant is expensive and has problems.

Demerits:

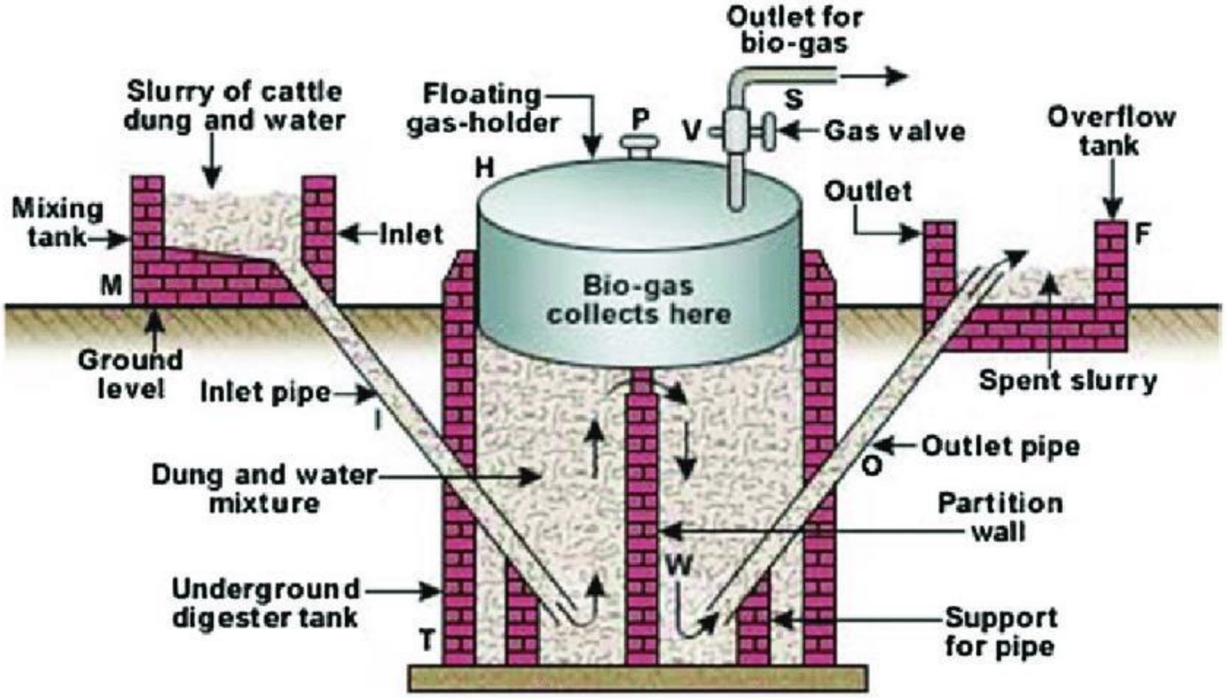
- ➢ **Expensive** to install.
- ➢ Not economical.
- ➢ Installation and operation being **capital and labour intensive.**
- ➢ They are totally unsuitable for Indian conditions.

BASED ON DOME AND DRUM TYPES:

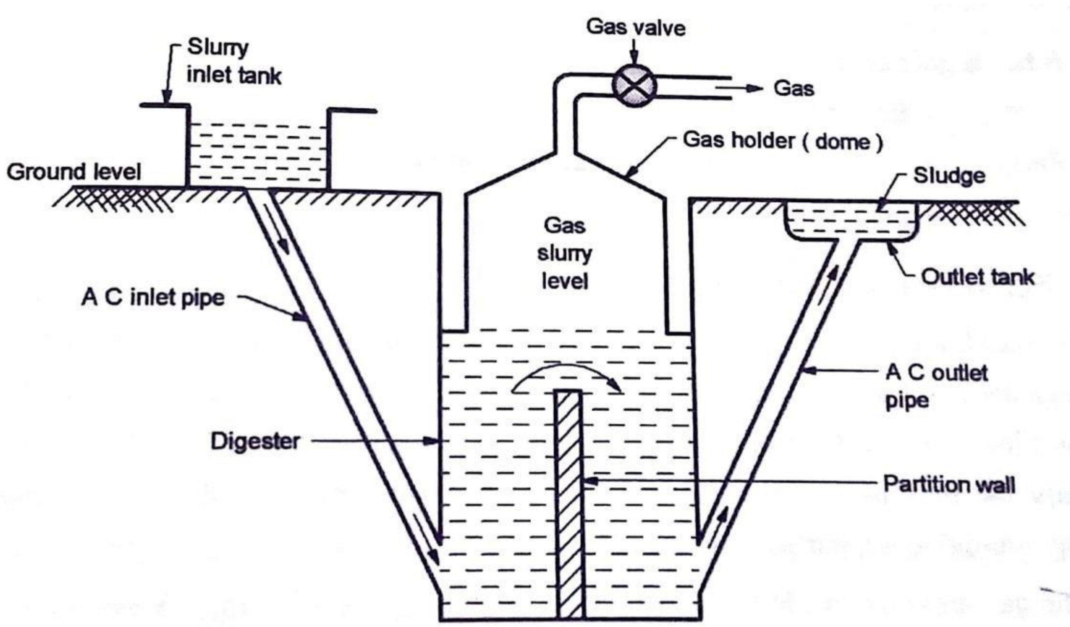
- Floating gasholder digester (KVIC)
- Fixed dome digester.

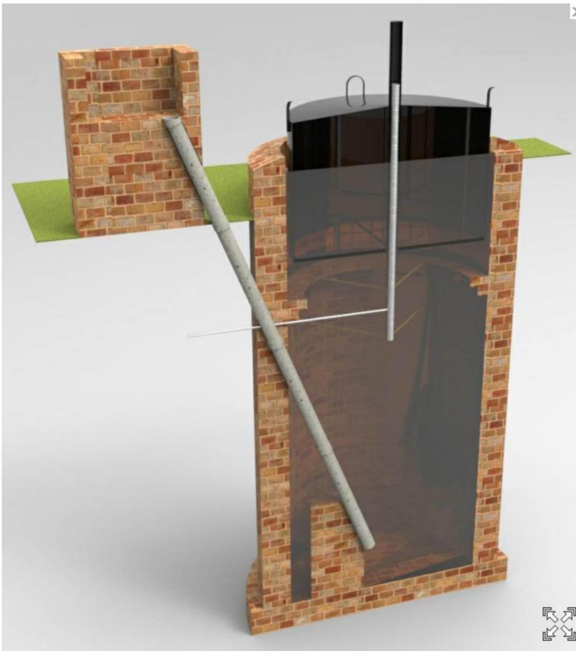
FLOATING GASHOLDER DIGESTER (KVIC):

- ✓ This type was developed in India and is usually made of masonry.
- ✓ It runs on a continuous basis and uses mainly cattle dung as input material.
- ✓ The gasholder is usually made of **steel**, although new materials such as Ferro cement and bamboo-cement have already been introduced.
- ✓ **FRP** materials are also used.

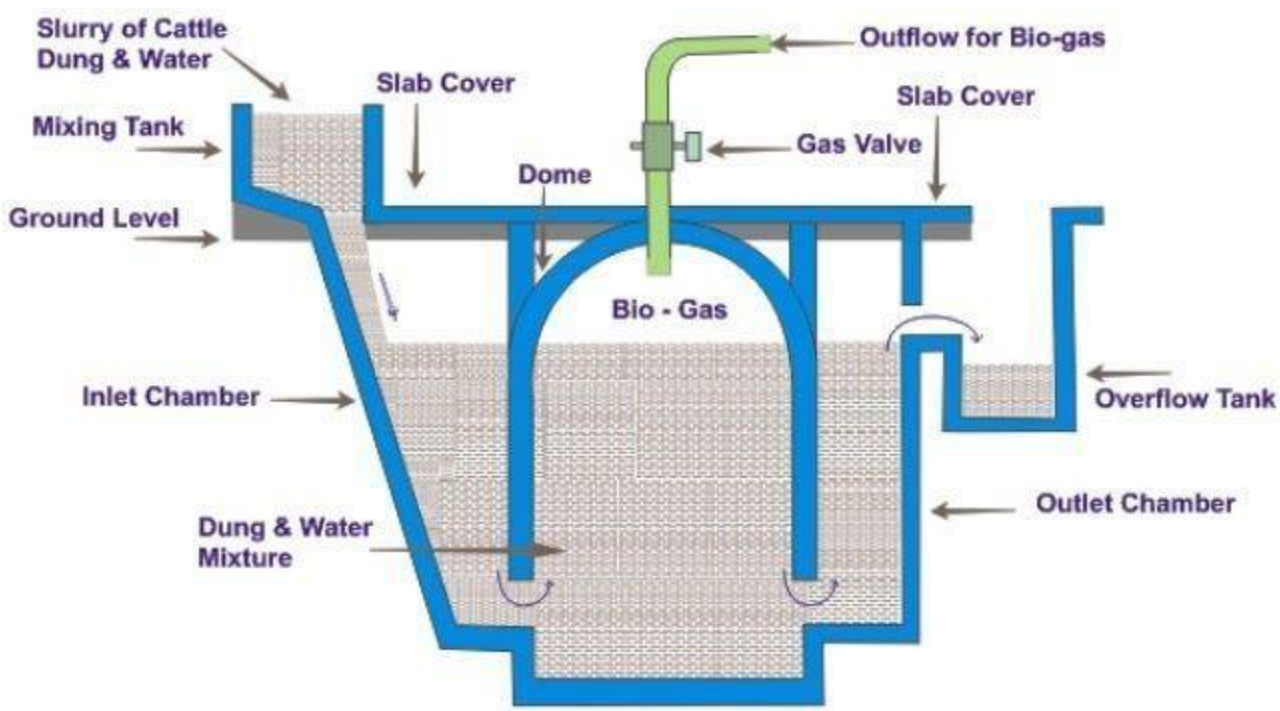


- ✓ The original version of this floating gasholder digester was a vertical cylinder provided with partition wall except for the small sizes of 2 and 3 m^3 of gas per day.
- ✓ The main characteristic of this type is the need for steel sheets and welding skill.
- ✓ Khadi & Village Industries commission model (KVIC).



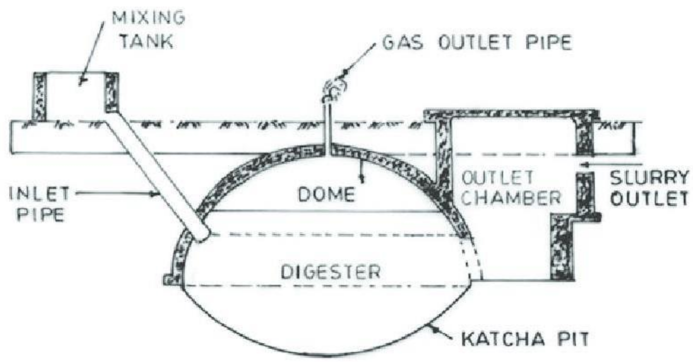


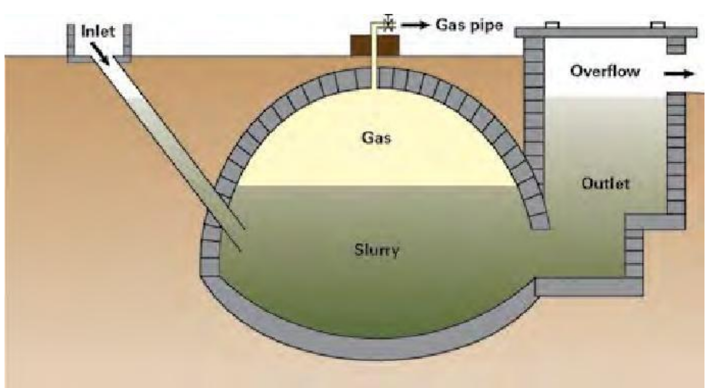
FIXED DOME DIGESTER:

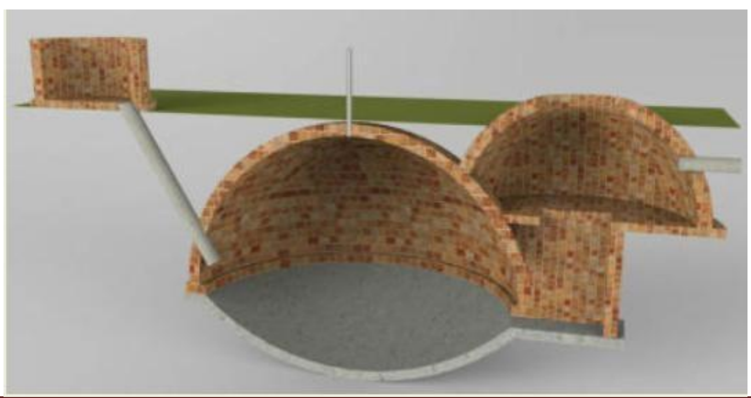


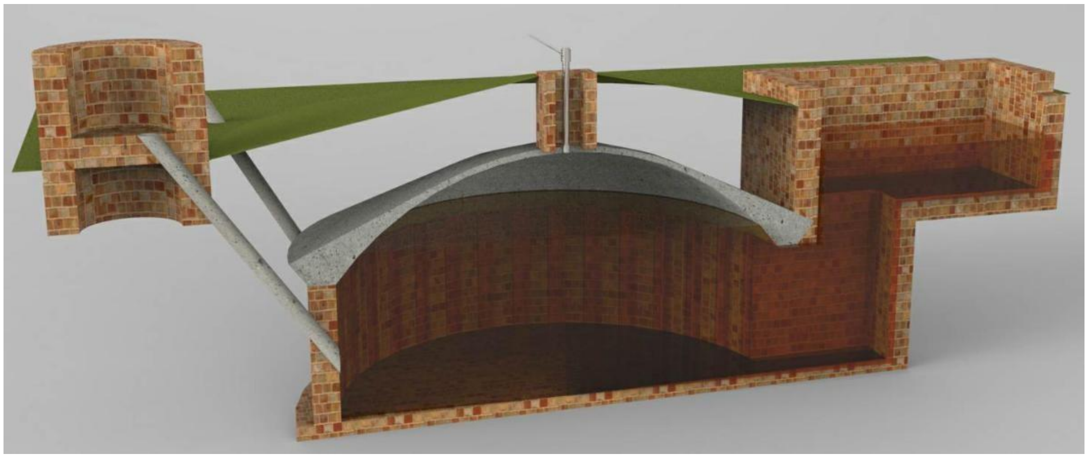
Fixed Dome type Bio-gas Plant

- This digester, which was developed and is widely used in **China**, runs on a continuous batch basis.
- Accordingly, it could **digest plant waste as well as human and animal wastes.**
- It is usually built below ground level, hence it is easier to **insulate in a cold climate**.
- The digester can be built from **several materials**, e.g. bricks, concrete, lime concrete and lime clay.
- This facilitates the introduction and **use of local materials and manpower.**
- The variable pressure inside the digester was found to cause no problems in China in the use of the gas.









Inlet

Biogas Digester

Outlet

Biogas Plant Models in India:

- KVIC (Khadi and Village Industries Commission) design.
- PRAD (Planning, Research and Action Division) design.
- Murugappa Chettiar Research Centre design.
- Tamil Nadu Agricultural University dome type design.
- ASTRA (Application of Science and Technology to Rural Areas) design.
- Himachal Pradesh Capsule design.
- Kacha - Pucca model of Punjab Agricultural University.
- Plug-flow design.
- AFPRO (Action for Food Production) design.
- Roorkee design.
- Deen Bhandhu design.

- Fibre glass fixed dome design (Underground model).
- Mobile biogas plants.
- Plastic emulsion coated, heavily insulated, temperature controlled Switzerland biogas plants.
- IARI (Indian Agricultural Research Institute) design.
- Ganesh Model.
- Ferro-cement Digester Biogas Plant.

Comparison between fixed dome and floating drum models:

	Floating gas holder type		Fixed-dome type
(i)	Capital investment is high		Capital investment in the corresponding size of biogas unit is low
(ii)	Steel gas holder is a must which needs to be replaced after few years due to corrosion damage		Steel gas holder is not required
(iii)	Cost of maintenance is high		As there is no moving part, the maintenance cost is minimised
(iv)	Life span of the digester is expected to be 30 years and that of gas holder is 5 to 8 years		Life span of the unit is expected to be comparatively more
(v)	Movable drum does not allow the use of space for other purposes		As the unit is an underground structure, the space above the plant can be used for other purposes.
(vi)	Effect of low temperature during winter is more		Effect of low temperature will be less
(vii)	It is suitable for processing of dung and night-soil slurry. Other organic materials will clog the inlet pipe		It can be easily adapted / modified for use of other materials along with dung slurry

Merits of Floating Gas - Holding Type:

(i)	Release of gas is at constant pressure		Release of gas is at variable pressure which may cause slight reduction in the efficiency of gas appliances. To operate a diesel engine, attachment of a gas pressure regulator in the pipeline is a must.
(ii)	Construction of digester is known to masons but fabrication of gas holder requires workshop facility		Construction of the dome portion of the unit is a skilled job and requires thorough training of masons.
(iii)	Location of defects in the gas holder and repairing are easy		Location of defects in the dome and repairing are difficult
(iv)	Requires relatively less excavation work		Requires more excavation work
(v)	In areas having a high water table, horizontal plants could be installed.		Construction of the plant is difficult in high water table areas

SITE SELECTION FOR BIOGAS PLANTS:

- **Distance:**

The distance between the **plant and the site of gas consumption should be less** in order to achieve economy in pumping of gas and minimizing gas leakage. For a plant of capacity 2 m^3, the optimum distance is 10 m.

- **Minimum gradient:**

For **conveying the gas, a minimum gradient of 1 %** must be available for the line.

- **Open space:**

The **sunlight** should fall on the plant as **temperature between 15 to 30° C is essential** for gas generation at good rate.

- **Water table:**

The plant is normally **constructed underground for ease of charging the feed** and unloading slurry requires less labour. In such cases care should be taken to prevent the **seepage of water** and plant should **not be constructed** if the **water table is more than 3 m**.

- **Seasonal runoff:**

Proper care has to be taken to prevent the **interference of runoff water** during the monsoon. Intercepting ditches or bunds may be constructed.

- **Distance from wells:**

The seepage of fermented slurry may pollute the well water. Hence a minimum of **15 m should be maintained from the wells.**

- **Space requirements:**

Sufficient space must be available for day to day operation and maintenance.

As a guideline **10 to 20 m^2 area is needed per m^3** of the gas.

- **Availability of water:**

Plenty of water must be available as the cow dung slurry with a solid concentration of 7 to 9 % is used.

- **Source of cow dung/ materials for biogas generation:**

The distance between the material for biogas generation and the gas plant (within 5 m) site should be **minimum** to economize the transport cost.

<u>BIO-DIGESTED SLURRY (BDS):</u>

✓ Bio Digested Slurry (BDS) is the **by-product** obtained from the biogas plant after the digestion of the dung and generation of the fuel gas.

✓ The BDS is very **good manure similar to FYM** available in the farm but it becomes very much **different after the digestion process**. The nutrient contents *viz*.

- ✓ **NPK get enriched in the BDS compared to the FYM**. The average macro-nutrient content of some commonly available organic manures are given below.

Advantages:

- Contains 1.5% nitrogen
- Free of flies, mosquitoes
- No smell
- Used as Farm Yard Manure by adding necessary rock phosphate.

Uses of Bio Digested Slurry:

- The slurry after the digestion will be washed out of the digester which is **rich in various plant nutrients such as nitrogen, phosphorous and potash**.
- Well-fermented biogas slurry improves the physical, chemical and biological properties of the soil resulting qualitative as well as quantitative yield of food crops.
- Slurry from the biogas plant is **more than a soil conditioner**, which builds good soil texture, provides and releases plant nutrients.
- Since there are **no more parasites** and pathogens in the slurry, **it is highly recommended for use in farming.**
- The **economic value** of the slurry shows that investment can be **gained back in three to four years' time if slurry is properly used**.

The cow dung slurry after digestion inside the digester comes out with following characteristics and has following advantages:

- ✓ When fully digested, effluent is **odourless** and does **not attract insects or flies** in the open condition.
- ✓ The effluent **repels termites whereas raw dung attracts them** and they can harm plants fertilized with farmyard manure (FYM).
- ✓ **Effluent used as fertilizer reduces weed growth** with about 50%. When FYM is used the undigested weed seeds cause an increased weed growth.
- ✓ It has a **greater fertilizing value than FYM or fresh dung.**
- ✓ The form in which nitrogen available can be easily assimilated by the crops.

Comparison of nutrient content of some commonly available organic manures and bio digested slurry:

S No.	Manure	N (%)	P_2O_5 (%)	K_2O (%)
1	Bio Digested Slurry (BDS)	1.5 - 2.5	1.0 - 1.5	0.8 - 1.2
2	Fresh cattle dung	0.3 – 0.4	0.1- 0.2	0.1 – 0.3
3	Farmyard manure (FYM)	0.4 – 1.5	0.3 - 0.9	0.3 - 1.9
4	Compost	0.5 – 1.5	0.3 - 0.9	0.8 - 1.2

- Like compost and FYM, BDS *improves soil fertility, soil porosity and water holding capacity*.
- It **supports bacterial growth** in soil that facilitates release of vital nutrients, which contribute to increased crop productivity.
- Besides this, **BDS becomes free of weed seeds**, odour etc. and so it is a highly valuable organic manure than the FYM.
- The **digested slurry is fed through the channel**, flowing over a layer of green or dry leaves and filtered in the bed.
- The water from the slurry **filters down which can be reused for preparing fresh dung slurry**.
- The **semi-solid slurry** can be transported easily as it was in the consistency of fresh dung and used for top dressing of crops like sugarcane and potato.
- Bio digested slurry is also used for **fish culture, which acts as a supplementary feed**.
- On an average, **15-25 litre of wet slurry can be applied per day in a 1200 sq. pond.**
- **Slurry mixed with oil cake or rice-bran in the 2:1 ratio increases the fish production remarkably**.

- In general organic manures about 10 tons/ha, in the form of FYM or compost or bio digested slurry is recommended to be applied once in three years to maintain the organic content of soil, besides providing nitrogen, phosphorous and potassium in the form of organic fertilizers to the crop.

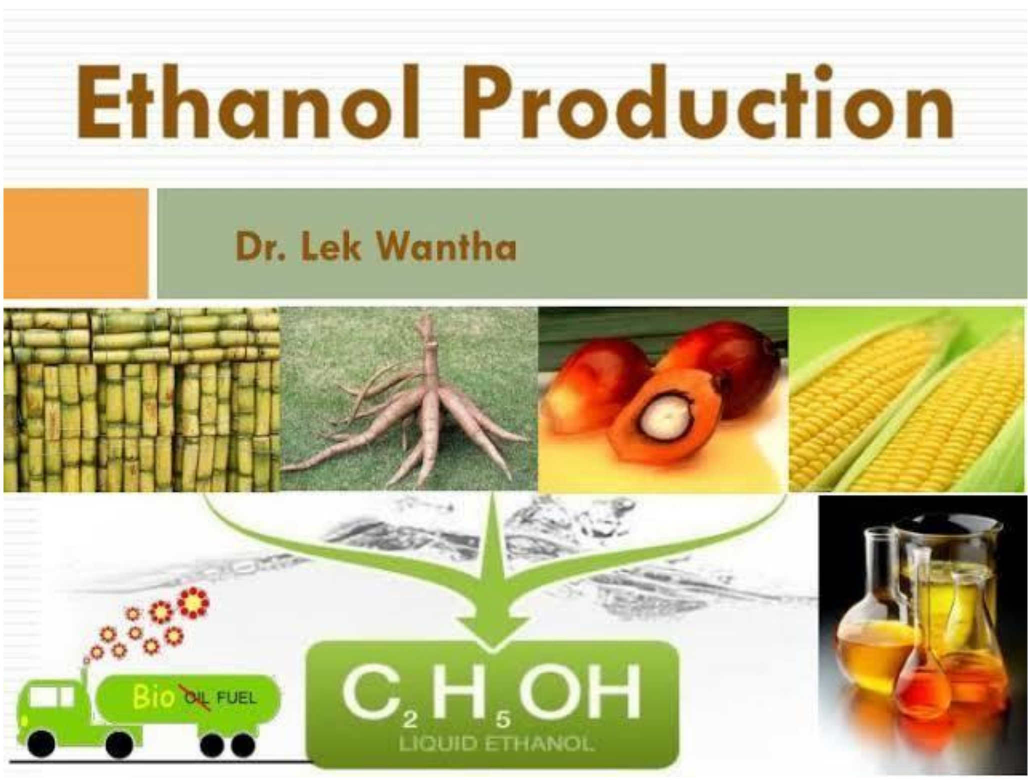
Nutrient contents of organic manures:

	N%	P%	K%	Fe ppm	Mn ppm	Zn ppm	Uu ppm
Biogas slurry	1.60	1.40	1.20	4200	550	150	52
FYM	1.00	0.62	0.80	5700	490	100	45
Compost	1.30	1.00	1.00	4000	530	120	50

ETHANOL PRODUCTION:

What is meant by Ethanol?

- Ethanol is a type of **alcohol** produced by **fermentation** of **sugars and starches or cellulosic biomass**.
- Ethanol is a clean-burning, high-octane fuel that is produced from renewable sources.
- Ethanol is a colourless, flammable, oxygenated hydrocarbon liquid.



- Chemical Formula is C_2H_5OH and has a boiling point of 78.50^0C in the anhydrous state.

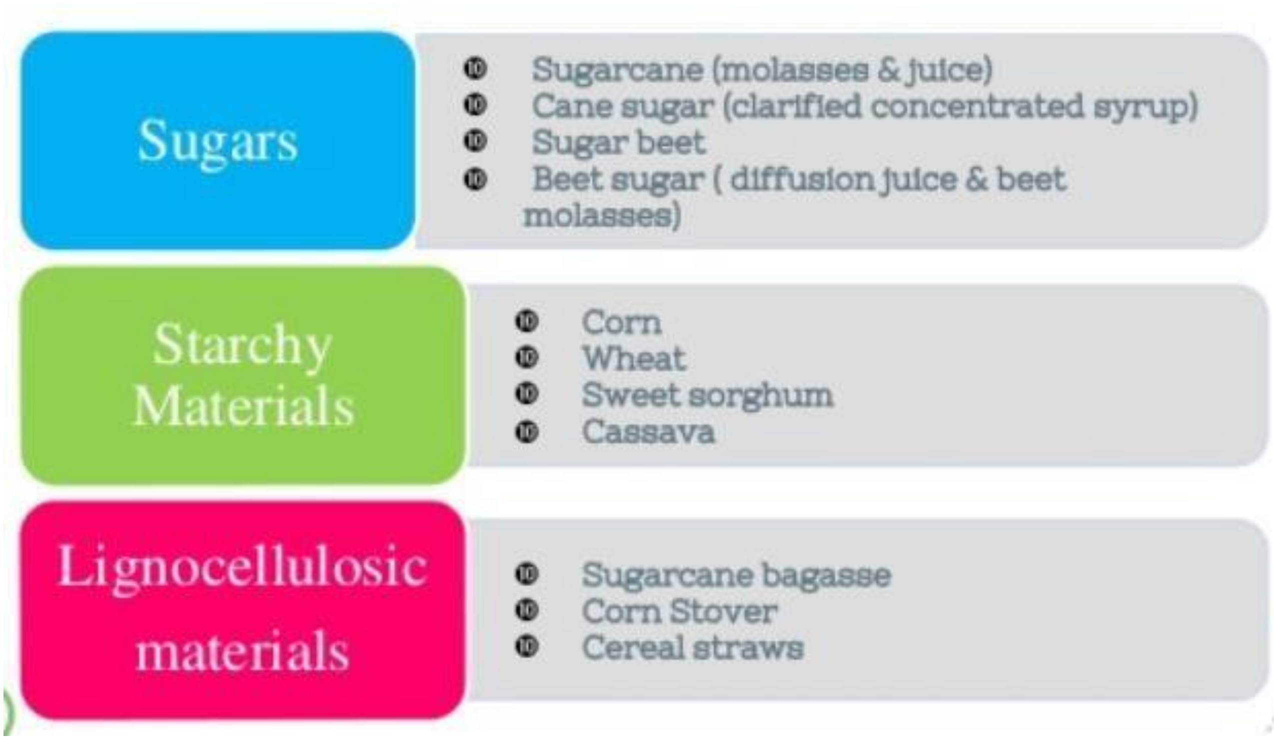
$$\text{glucose} \xrightarrow{\text{yeast}} \text{ethanol} + \text{carbon dioxide}$$

$$C_6H_{12}O_{6(aq)} \xrightarrow{\text{yeast}} 2C_2H_5OH_{(aq)} + 2CO_{2(aq)}$$

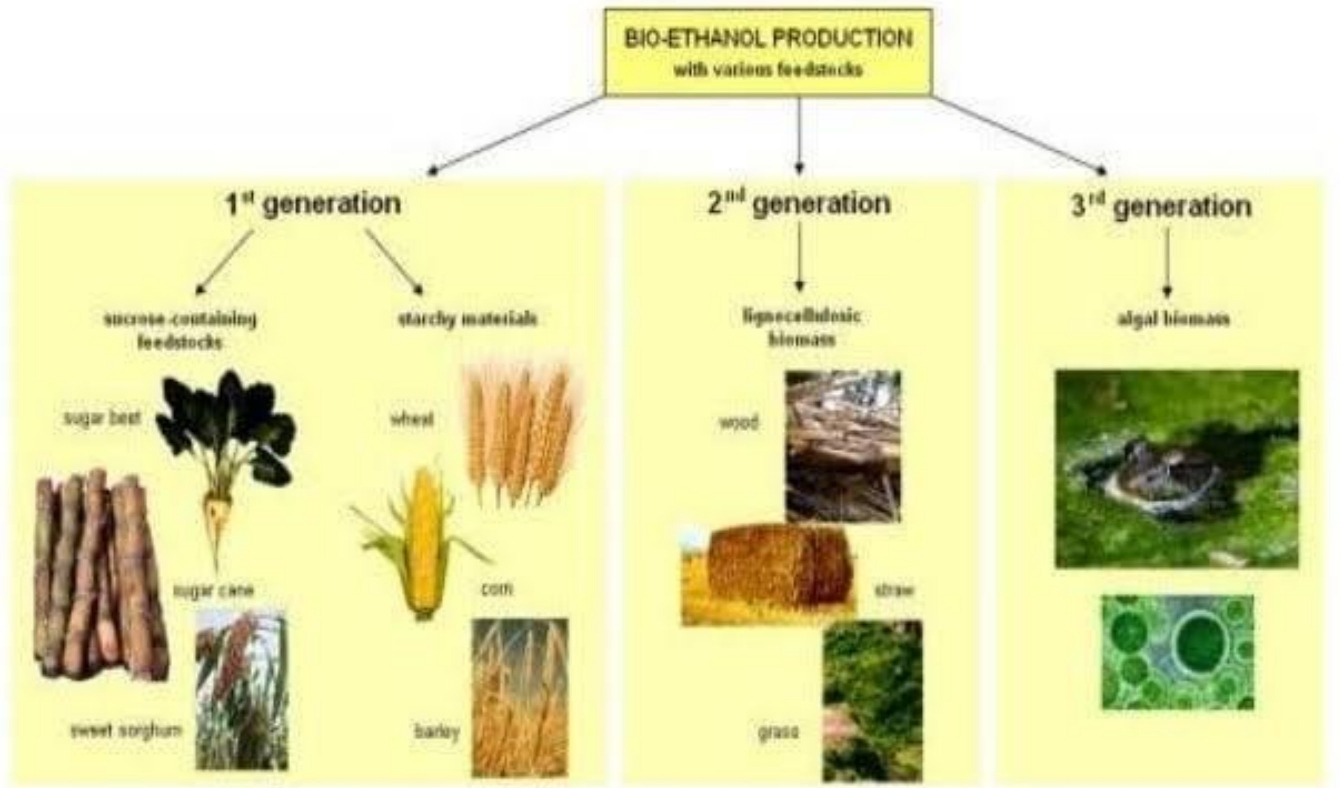
Physical properties of Ethanol:

- ✓ Colorless liquid.
- ✓ Pleasant alcoholic odor detectable at 49 to 716 ppm.
- ✓ Miscible with water and most organic solvents.
- ✓ Melting Point (°C): -114.1
- ✓ Octane 98-100
- ✓ Boiling Point (°C): 78.3
- ✓ Specific Gravity: 0.789
- ✓ Vapor Density: 1.6

Raw materials for Ethanol Production:



SUBSTRATES AND MEDIA FOR ETHANOL PRODUCTION

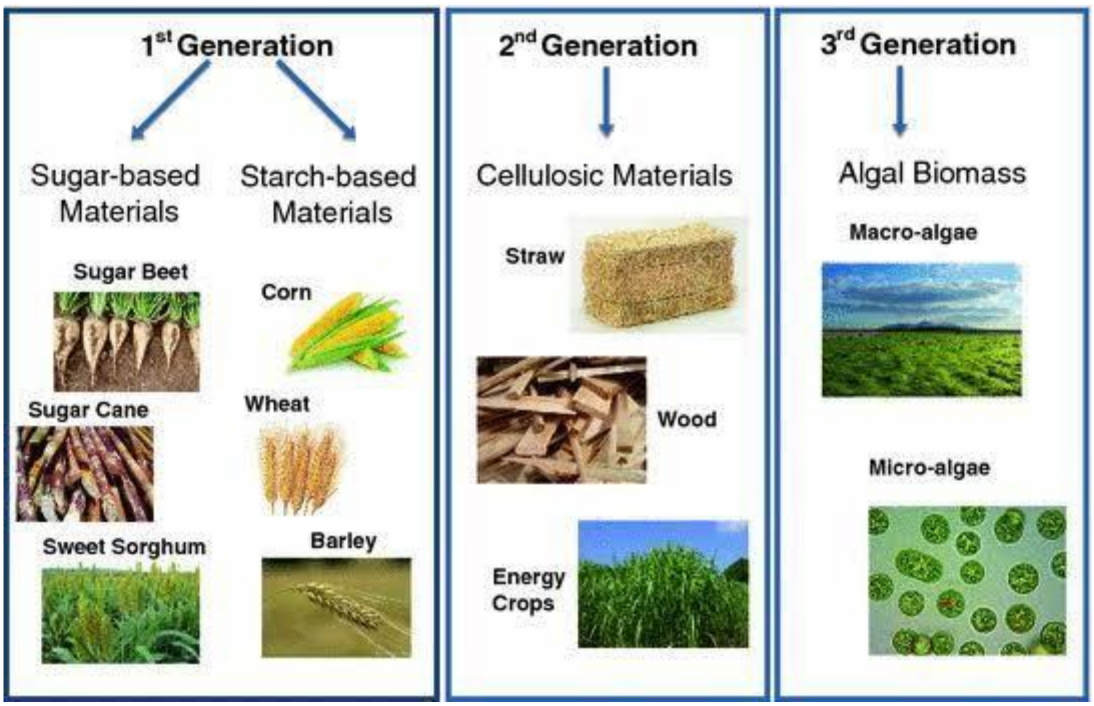


Raw materials (Sugar):

- Materials containing sugar require the least costly preparation, as the sugars are already available in the degradable form.
- Sucrose occurs in free form in sugarcane, and clarified can juice may be used directly for ethanol production.
- However, molasses is used rather than the corresponding juices for various reasons.
- This class of raw materials is relatively the most expensive to obtain since it has other markets.
- Sugar beets and sweet sorghum also have potential for ethanol production, but sweet sorghum juice contains some starch and aconitic acid that cause difficulties in sugar crystallization.

Raw materials (Starchy):

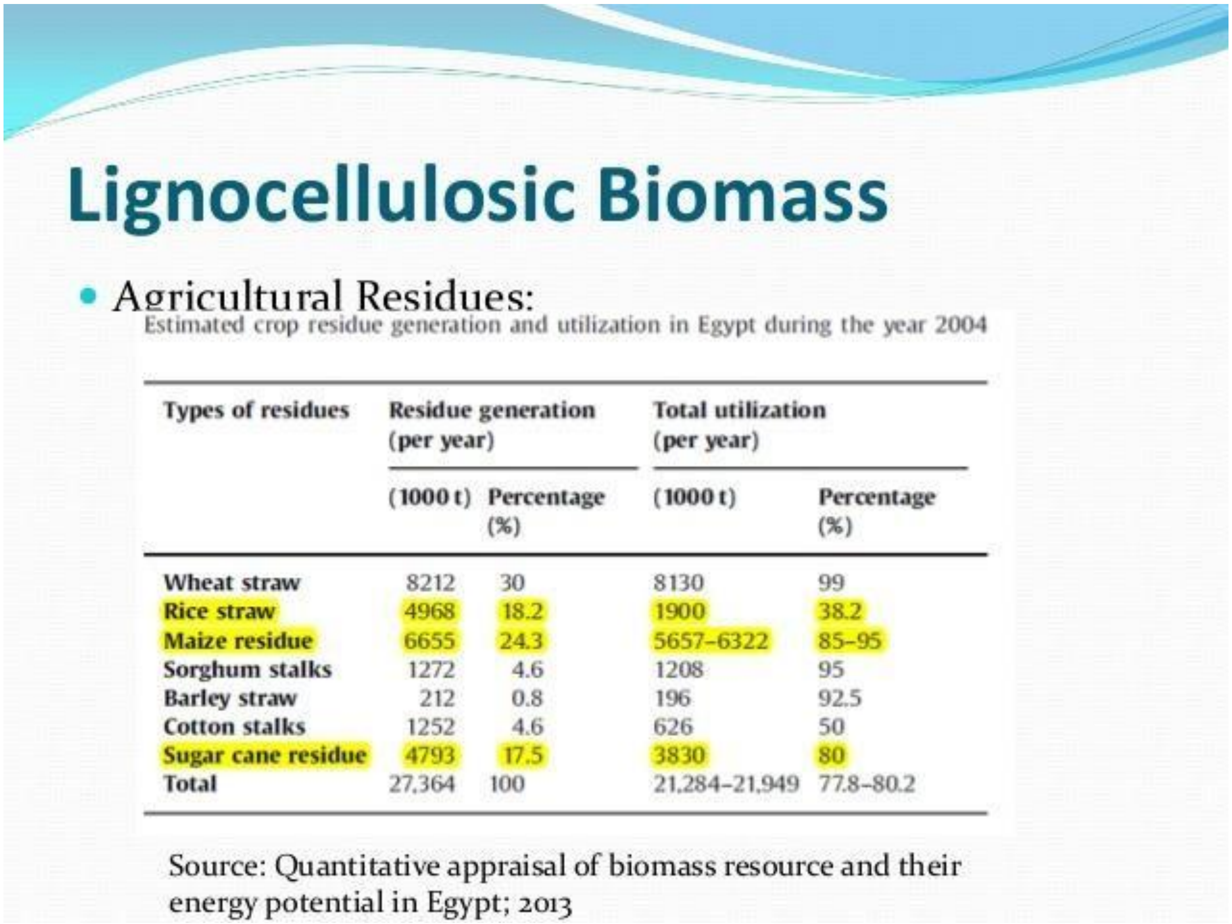
- Starch or carbohydrate is an attractive feedstock for many fermentation processes.
- High yields and starch content (50-60 percent) give corn an advantage.
- Spoiled and low-quality starches, not suitable for food or animal feed, can be effectively used for the production of alcohol.
- Even if food-grade starch is used, the resulting biomass byproduct represents an excellent, protein-fortified human or animal food.
- **Potatoes and cassava offers a high yield of starch per hectare of cropland**, but the problem of storage to allow year-round ethanol production has not been overcome.
- Cassava, one of the most efficient photosynthetic plants, contains 20-35 percent starch and 1-2 percent protein.



Raw materials (Lignocellulose):

- **Lignocellulose refers to the materials constituting the essential part of the cell wall of plants**, i.e. cellulose, hemicellulose, and lignin.
- Lignocellulose refers to plant dry matter, so called lignocellulosic biomass. It is the most abundantly available raw material on the Earth for the production of biofuels, mainly bio-ethanol. It is composed of carbohydrate polymers, and an aromatic polymer.

- Lignocellulose is the **major renewable from the carbohydrate in the world. It has been estimated that about 100 GT cellulose is produced worldwide each year**, a significant fraction of this occurs as municipal and agricultural waste.
- The energy crisis of the 1970's created renewed interest in the use of cellulose, **but it is still difficult to convert it efficiently to its degradable monomer sugar units**.
- A substantial **improvement in cellulose hydrolysis technology is required** before this resource material can be used on a large scale as a biomass feed stock for ethanol production.
- While there are great quantities of urban and industrial wastes which require processing for environmental reason, these materials are so widely distributed that only a few isolated sources have economic potential.
- The **collection, transportation, concentration and storage** of these materials present technological difficulties.



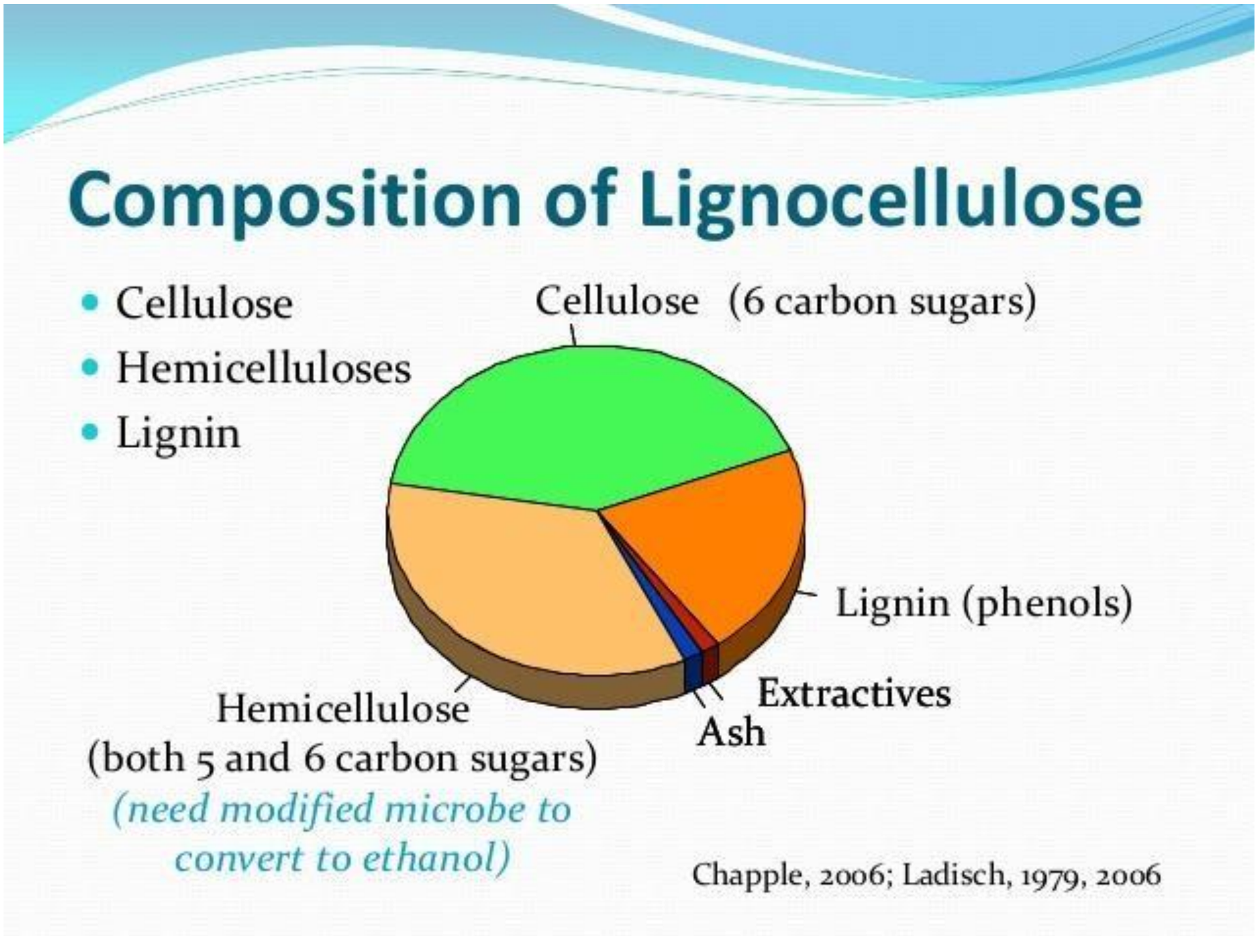
Lignocellulosic Biomass

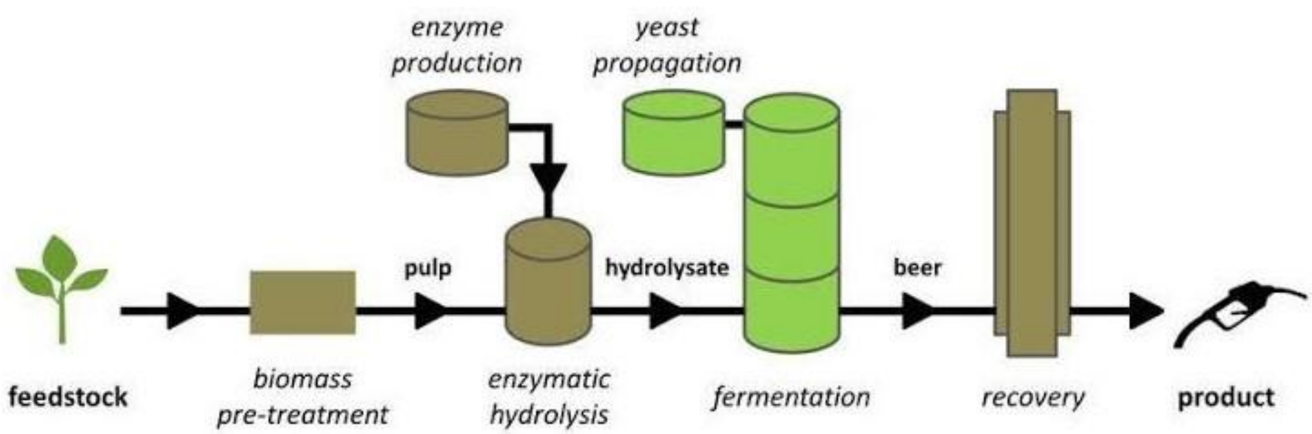
- Agricultural Residues:

Estimated crop residue generation and utilization in Egypt during the year 2004

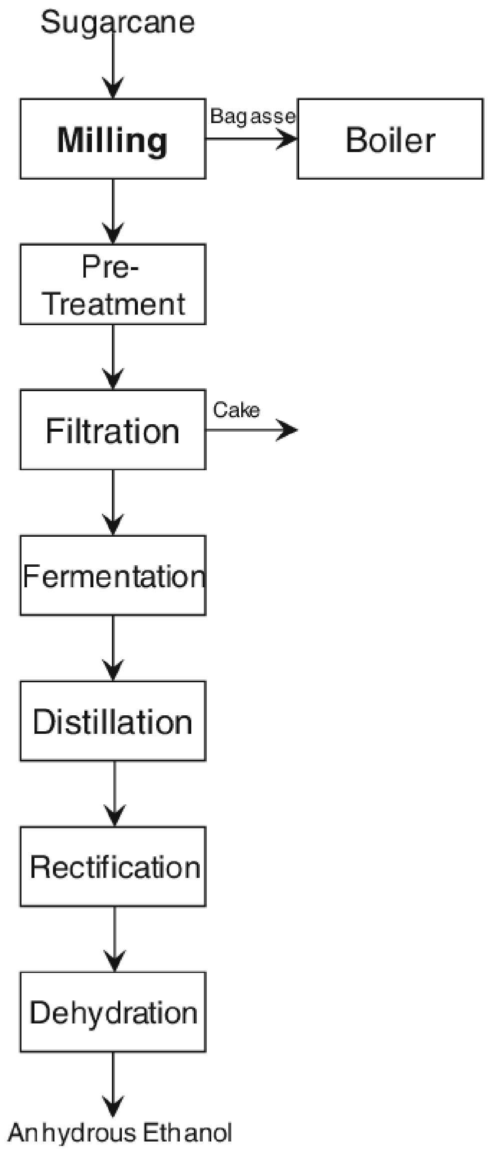
Types of residues	Residue generation (per year)		Total utilization (per year)	
	(1000 t)	Percentage (%)	(1000 t)	Percentage (%)
Wheat straw	8212	30	8130	99
Rice straw	4968	18.2	1900	38.2
Maize residue	6655	24.3	5657–6322	85–95
Sorghum stalks	1272	4.6	1208	95
Barley straw	212	0.8	196	92.5
Cotton stalks	1252	4.6	626	50
Sugar cane residue	4793	17.5	3830	80
Total	27,364	100	21,284–21,949	77.8–80.2

Source: Quantitative appraisal of biomass resource and their energy potential in Egypt; 2013


Composition of Lignocellulose
Cellulose
Hemicelluloses
Lignin
Cellulose (6 carbon sugars)
Lignin (phenols)
Extractives
Ash
Hemicellulose
(both 5 and 6 carbon sugars)
(need modified microbe to
convert to ethanol)
Chapple, 2006; Ladisch, 1979, 2006

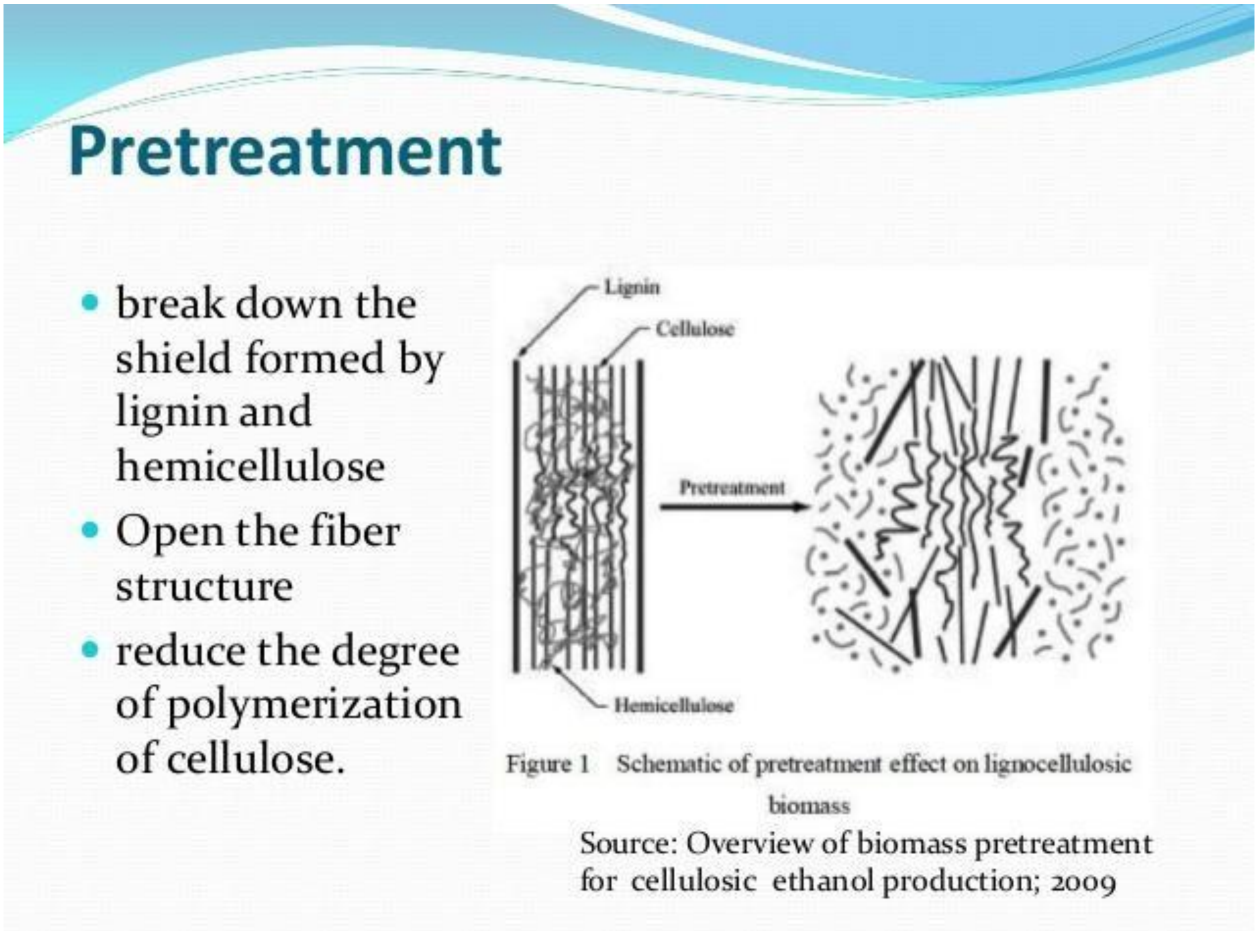

enzyme
production
yeast
propagation
pulp
hydrolysate
beer
feedstock
biomass
pre-treatment
enzymatic
hydrolysis
fermentation
recovery
product

ETHANOL PRODUCTION FROM SUGARCANE:



- **Milling:**
  - ✓ Mechanical crushing of the cereal grain to release the starch component.
  - ✓ The feedstock passes through a hammer mill which grinds it into a fine powder called meal.
- **Pretreatment:**
  - The fibre component of cellulosic biomass, hemi cellulose and cellulose, can be hydrolyse, but the **structural features of cellulose, such as the degree of crystalline, the degree of polymerization, the degree of water swelling and surface area, make it less amenable to hydrolysis**.

- Some form of pretreatment is, therefore, necessary to obtain high yields of monosaccharides.
- Several techniques have been proposed to enhance the degree of hydrolysis of lignocellulosic to sugars.
- These techniques are generally classified as **physical, chemical, biological or a combination of these**, according to their mode of action.



- The **physical pretreatment involves particle reduction to very small mesh sizes**.
- The shearing and compressive forces involved in **milling cause a reduction in crystallinity, a decrease in the mean degree of polymerization and an increase in bulk density**.
- The milled material also allows for a high slurry concentration, thereby reducing the reactor volume and hence, capital cost.

- In general, the **power requirements for these grinding or milling methods are so large** as to make them quite expensive.
- **Chemical treatments with strong acids or bases, such as sulphuric acid** or sodium hydroxide, or with other cellulose swelling or dissolving agents also effectively increase hydrolysis.
- These **chemicals are generally quite corrosive and expensive and must be recovered for reuse**.
- Furthermore, they are often toxic or inhibitory to microorganisms (or their enzymes) so that their removal from the pretreated cellulosic materials must be almost complete.
- All these factors combine to increase the expense and difficulty of such chemical treatment methods.
- Another technique of current interest is the **steam explosion process** (Muzzy et al. 1982).
- Lignocellulosic materials (usually wood chips) are saturated with water under pressure of 2000-3400 KPa (21-35 kg/cm^2) at elevated temperatures (215-260°C).
- When the **pressure is released, the water evaporates rapidly and the wood fibres tend to separate**.
- In addition, the moisture and high temperature liberate acetic acid which catalysis the hydrolysis of the hemicellulose.
- Although this process is very effective, **it requires considerable thermal energy and some of the sugars are inevitably degraded by the high temperatures involved**.

Fermentation:

- ✓ Fermentation of the mash using yeast.
- ✓ Yeast is added to the mash to ferment the sugars to ethanol and carbon dioxide.
- ✓ Using a continuous process, the fermenting mash is allowed to flow through several fermenters until it is fully fermented and leaves the final tank.
- ✓ In a batch process, the mash stays in one fermenter for about 48 hours before the distillation process is started.

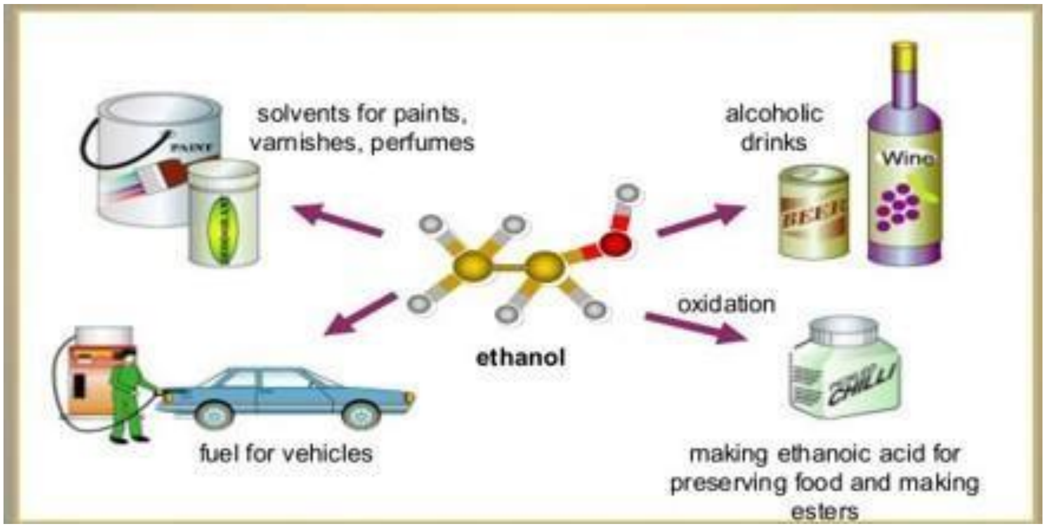
Principle of fermentation:

- Summarizing chemical equation for ethanol fermentation:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

- One glucose molecule is converted into two ethanol molecules and two carbon dioxide molecules.
- The most common microorganism, the yeast ***Saccharomyces cerevisiae***.
- Higher concentrations up to 95% are produced by **distilling and fractionating**.
- When distilled, the remaining constant boiling point mixture is 95% ethanol, 5% water.
- Anhydrous ethanol is produced commercially with azeotropic removal of water by **co-distillation** with solvents such as benzene.
- Only about 0.5% of the energy potential of the sugars is lost during fermentation, but significant amounts of process heat are required for the concentration and separation processes.
- This process heat may be provided by the combustion or gasification of otherwise waste biomass.

Applications of Ethanol:



Fuel Application

- ✓ Transport fuel to replace gasoline.
- ✓ Fuel for power generation by thermal combustion.
- ✓ Fuel for fuel cells by thermo chemical reaction.

- ✓ Fuel in cogeneration systems.
- ✓ Feedstock in the chemicals industry.

- Blending of ethanol with a small proportion of a volatile fuel such as gasoline -> more cost effective
  - Various mixture of bio ethanol with gasoline or diesel fuels.
  - E5G to E26G (5-26% ethanol, 95-74% gasoline)
  - E85G (85% ethanol, 15% gasoline)
  - E15D (15% ethanol, 85% diesel)
  - E95D (95% ethanol, 5% water, with ignition improver)
- Exhaust gases of ethanol are much cleaner:
  - ✓ It burns more cleanly as a result of more complete combustion.
- Greenhouse gases reduce:
  - ✓ Ethanol-blended fuels such as E85 (85% ethanol and 15% gasoline) reduce up to 37.1% of GHGs
- **Positive energy balance**, depending on the type of raw stock:
  - ✓ Output of energy during the production is more than the input.
- **Any plant** can be used for production of bio ethanol:
  - ✓ It only has to contain sugar and starch.
- **Carbon neutral**
  - ✓ The CO_2 released in the bio ethanol production process is the same amount as the one the crops previously absorbed during photosynthesis.
- Decrease in **ozone formation:**
  - ✓ The emissions produced by burning ethanol are less reactive with sunlight than those produced by burning gasoline, which results in a lower potential for forming ozone.
- Renewable energy resource:
  - ✓ Result of conversion of the sun's energy into usable energy.
  - ✓ Photosynthesis -> feed stocks grow -> processed into ethanol.

- **Energy security:**
    - ✓ Countries that do not have access to crude oil resources grow crops for energy use and gain some economic freedom.
- Reduces the **amount of high-octane additives:**
    - ✓ Fuel spills are more easily biodegraded or diluted to non-toxic concentrations.

Disadvantages and Concerns:

- **Biodiversity:**
    - A large amount of arable land is required to grow crops, natural habitats would be destroyed.
- **Food vs Fuel debate:**
    - Due to the lucrative prices of bio ethanol some farmers may sacrifice food crops for bio fuel production which will increase food prices around the world.
- **Carbon emissions (controversial):**
    - During production of bio ethanol, huge amount of carbon dioxide is released.
    - Emission of GHGs from production of bio ethanol is comparable to the emissions of internal-combustion engines.
- **Not as efficient as petroleum:**
    - Energy content of the petrol is much higher than bio ethanol.
    - Its energy content is 70% of that of petrol.
- **Engines made for working on Bio ethanol cannot be used for petrol or diesel:**
    - Due to high octane number of bio ethanol, they can be burned in the engines with much higher compression.
- **Transportation:**
    - Ethanol is hygroscopic, it absorbs water from the air and thus has high corrosion aggressiveness.
    - Can only be transported by auto transport or railroad.
- **Many older cars unequipped to handle even 10% ethanol.**

AI 8007- AGRICULTUR WASTE MANAGEMENT

IMPORTANT QUESTIONS:

UNIT-1 Introduction

1. What are the types of agricultural wastes? Explain in detail.
2. Explain classification of agro wastes (agro industrial waste) based on their characteristics.
3. Explain the concept of agricultural waste management systems.
4. Explain about recycling techniques and utilization potential in detail.
5. Current constraints in collection and handling of agro wastes.

UNIT-2 Composting

1. Brief about solid waste suitable for composting.
2. Explain in detail Heap method of composting with procedure.
3. Brief about (i) Coimbatore Method, (ii) Indore Method (iii) Bangalore Method.
4. Explain with the neat sketch NADEP method.
5. Explain in detail vermin composting process and roll of vermin composting in agriculture.
6. Explain factors affecting composting.

UNIT-3 Biomass Briquetting

1. Explain potential agro residues and their characters in detail.
2. Brief about fundamental aspects of briquetting.
3. Explain types of briquetting with neat sketch.
4. Compare piston press screw press technologies.
5. Procedure for setting of briquetting plant.
6. Cost analysis of briquetting plant.

UNIT-4 Biochar Production

1. Explain biomass Pyrolysis techniques.
2. Brief about characteristics of biochar & bio oil.
3. Explain with the neat sketch pilot scale Pyrolysis reactors.
4. Explain role of biochar in soil nutrient and carbon sequestration.

UNIT-5 Biogas and Bio Ethanol Production

1. Brief about biomass characterization.
2. Explain microbiology of biogas production.
3. Types of biogas digesters with neat sketch.
4. Brief about factors affecting biogas production.
5. Explain the concept of Bio Digested Slurry (BDS).
6. What are the raw materials suitable for ethanol production? Explain.
7. Explain the procedure for ethanol production from sugarcane.