# BIOGAS

# Introduction

- **Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen.**
- **Biogas originates from biogenic material and is a type of biofuel.**
- **One type of biogas is produced by anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste and energy crops.**
- **This type of biogas comprises primarily methane and carbon dioxide.**

# Production

- Biogas is practically produced as landfill gas (LFG) or digester gas.
- A biogas plant is the name often given to an anaerobic digester that treats farm wastes or energy crops.
- Biogas can be produced utilizing anaerobic digesters.
- These plants can be fed with energy crops such as maize silage or biodegradable wastes including sewage sludge and food waste.

# Raw materials

- Raw materials may be obtained from a variety of sources - livestock and poultry wastes, night soil, crop residues, food-processing and paper wastes, and materials such as aquatic weeds, water hyacinth, filamentous algae, and seaweed.
- Different problems are encountered with each of these wastes with regard to collection, transportation, processing, storage, residue utilization, and ultimate use.

## Industrial and food processing waste

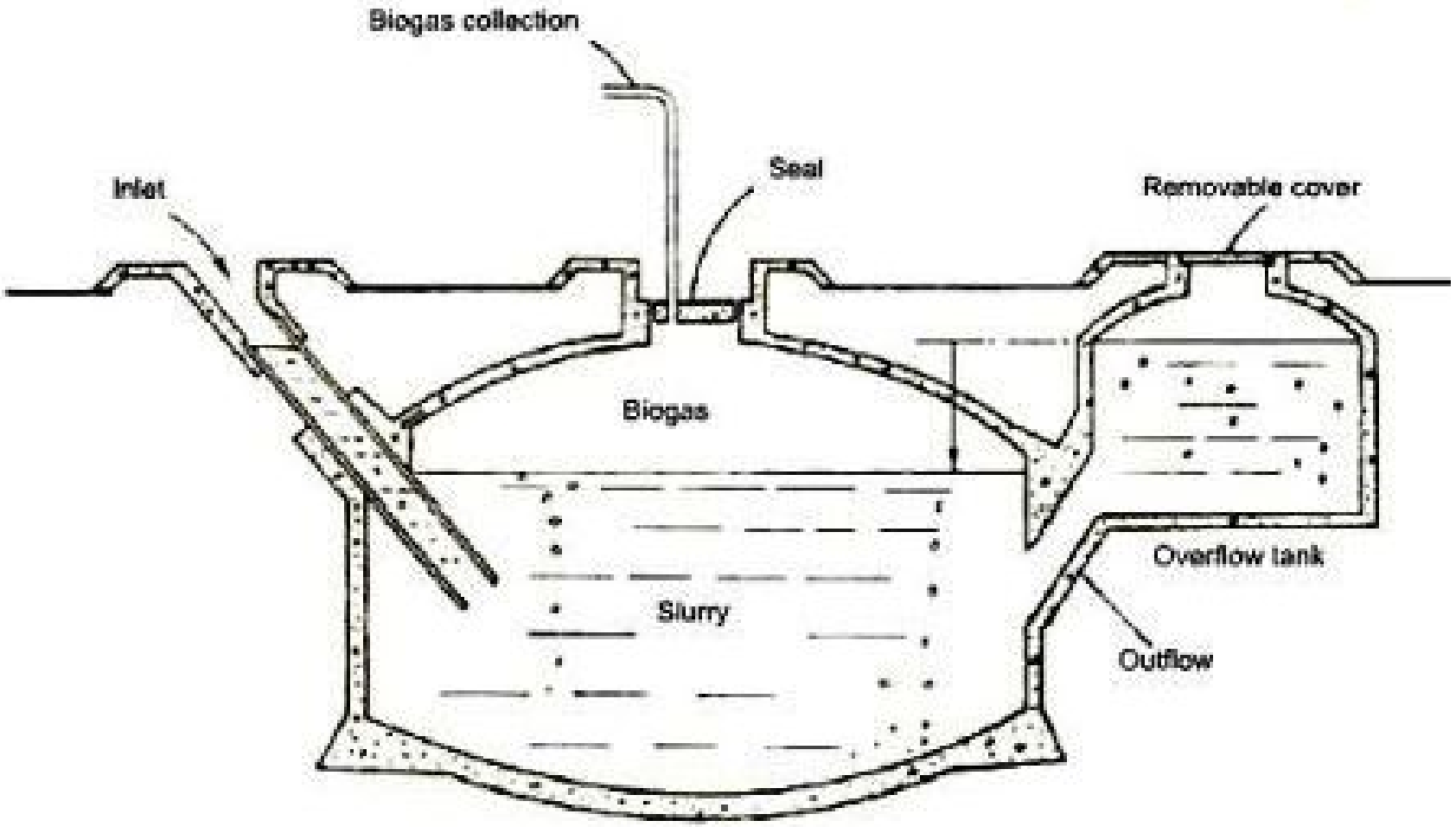
- these arise from sugar, potato, vegetable and fruit processing, brewery and distillery wastes, and whey from cheese production.

## Animal excreta and agricultural wastes

- these are solid wastes rich on cellulose and lignocelluloses.
- Agricultural biomass like straw, bagasse, etc. show poor digestibility and often high C : N ratio.

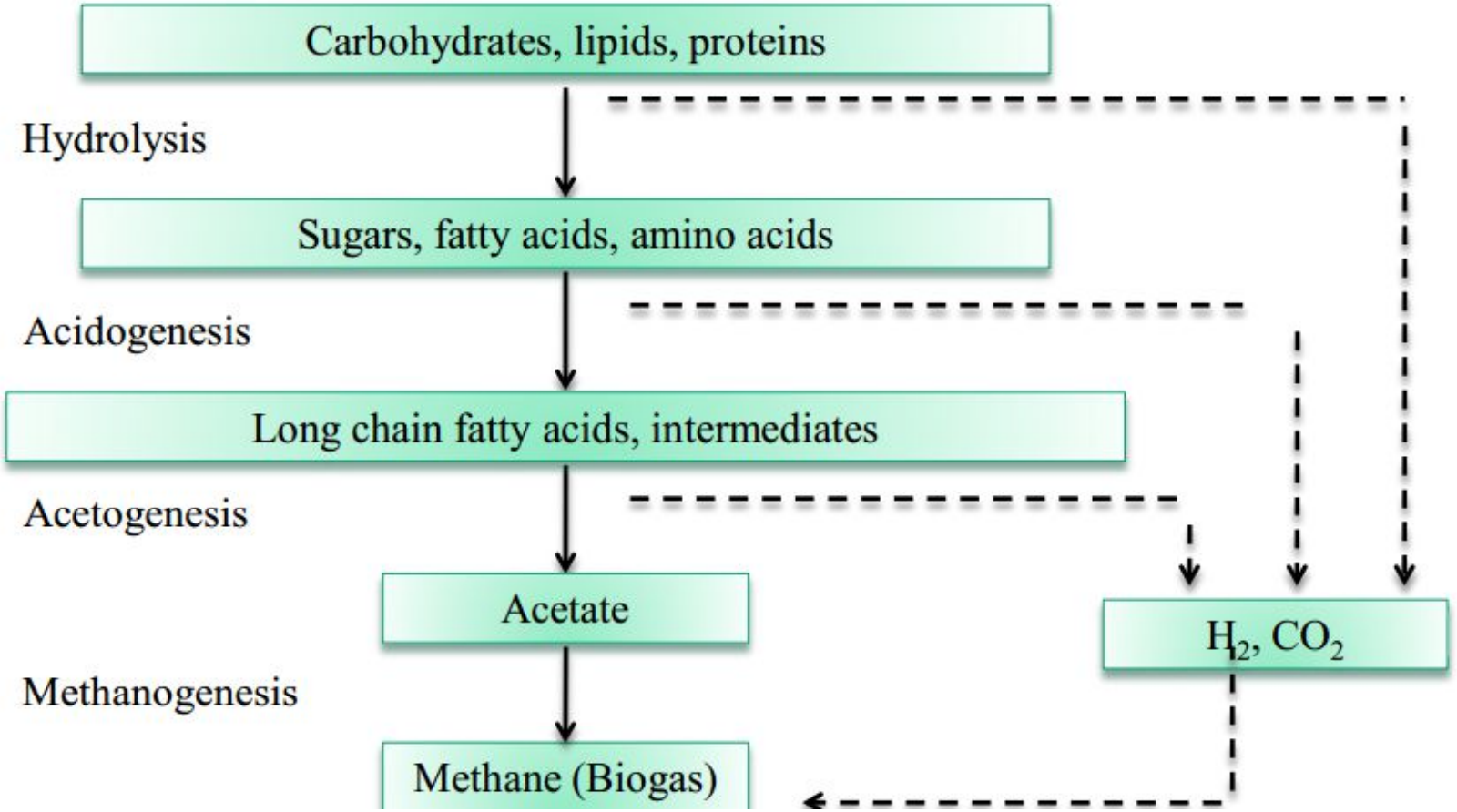
## Domestic and municipal wastes

- these are in the form of solid wastes and sewage respectively.


Biogas collection
Inlet
Seal
Removable cover
Biogas
Overflow tank
Slurry
Outflow

# Digestion

- **Digestion refers to various reactions and interactions that take place among the methanogens, non-methanogens and substrates fed into the digester as inputs.**
- **The breaking down of inputs that are complex organic materials is achieved through three stages.**
  - **Stage 1:** Hydrolysis
  - **Stage 2:** Acidification
  - **Stage 3:** Methanization


Carbohydrates, lipids, proteins
Hydrolysis
Sugars, fatty acids, amino acids
Acidogenesis
Long chain fatty acids, intermediates
Acetogenesis
Acetate
$H_2$, $CO_2$
Methanogenesis
Methane (Biogas)

# Stage 1: Hydrolysis

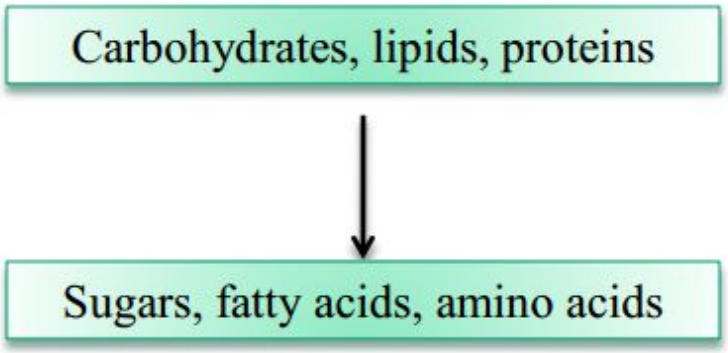
- **The waste materials of plant and animal origins consist mainly of carbohydrates, lipids, proteins and inorganic materials.**
- **Large molecular complex substances are solubilized into simpler ones with the help of extracellular enzyme (cellulase, amylase, protease and lipase) released by the bacteria.**
- **This stage is also known as polymer breakdown stage.**

# Hydrolysis

- Large organic compounds are broken down into monomeric compounds
- Allows cell to assimilate materials
- Performed by many organisms
  - Bacteria, fungi, protists

*Pseudomonas* sp.

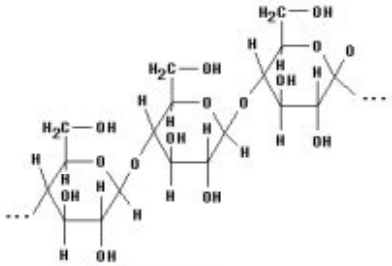
*Hartmanella* sp.



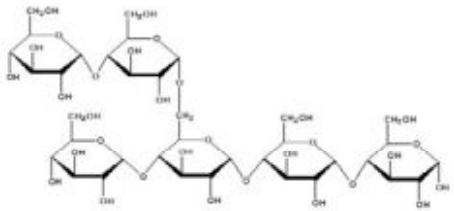
- **For example, the cellulose consisting of polymerized glucose is broken down to dimeric, and then to monomeric sugar molecules (glucose) by cellulolytic bacteria.**
- **For example, polysaccharides are converted into monosaccharides.**
- **Proteins are split into peptides and amino acids.**

# Hydrolysis

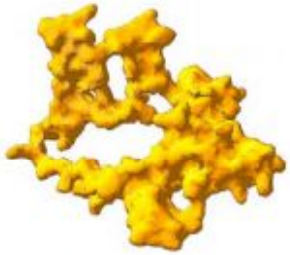
- Accomplished through extracellular enzymes



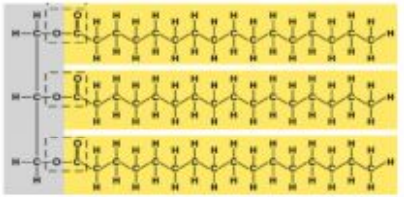
Cellulose



Starch



Casein



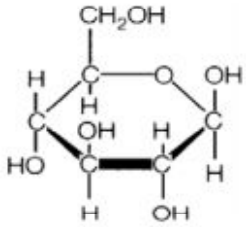
Triglyceride

Cellulases

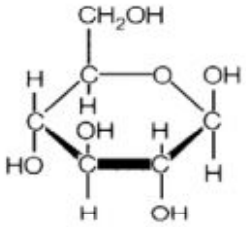
Amylases

Proteases

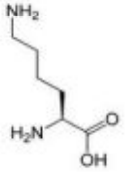
Lipases

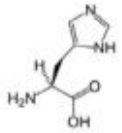


Glucose



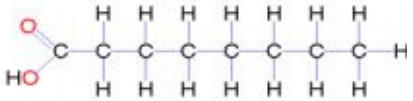
Glucose





Lysine Histidine

Amino Acids



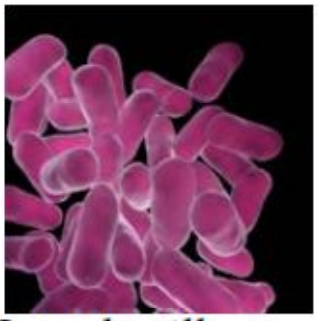
Fatty Acid

# Stage 2: Acidification

- **Acid-producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid ($CH_3COOH$), hydrogen ($H_2$) and carbon dioxide ($CO_2$).**
- **The principal acids produced in this process are acetic acid, propionic acid, butyric acid and ethanol.**
- **Hereby, the acid-producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms.**

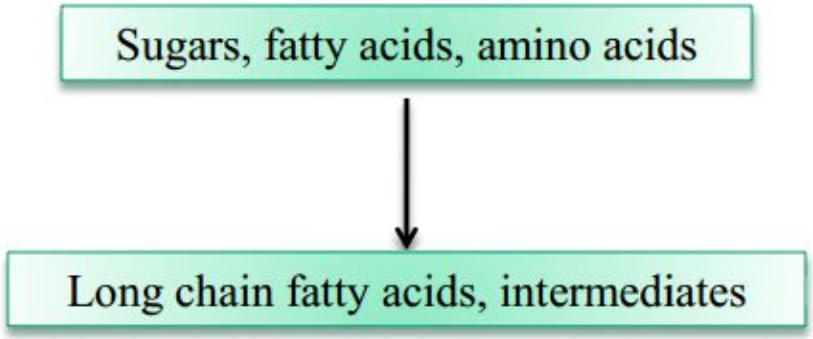
# Acidogenesis

- Monomeric products hydrolysis are fermented into fatty acid intermediaries
- Performed by acidogens
- Generally fastest step in process
- Unbalanced acidogenesis can cause acidification



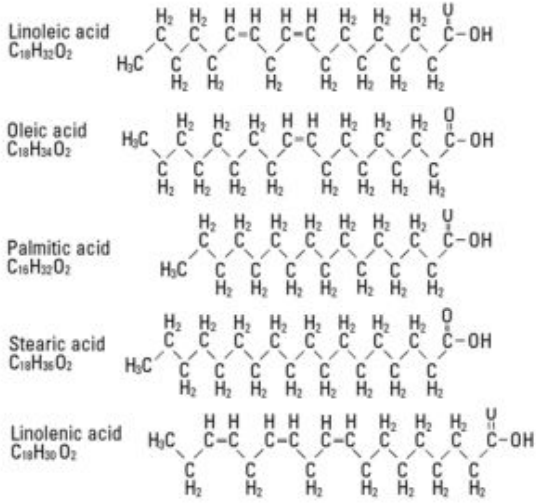
*Lactobacillus* sp.

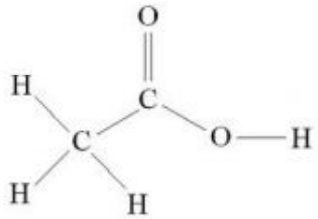
*Propionibacterium* sp.



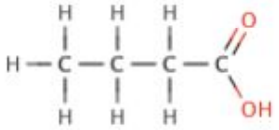
# Acidogenesis

- Many different fatty acids produced
  - Long-chain fatty acids (LCFAs) (generally produced from lipids)
  - Volatile fatty acids(VFAs) (butyric, proprionic, acetic acid)

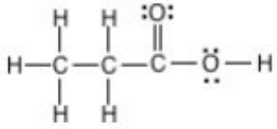


Acetic Acid



Butyric acid



Proprionic acid

# **Stage 3:** Methanization

- The principle acids produced in Stage 2 are processed by methanogenic bacteria to produce methane.
- The reactions that takes place in the process of methane production is called Methanization and is expressed by the following equations.

| | | | | | | |
|---|---|---|---|---|---|---|
| $CH_3COOH$ 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 dioxide | + | $4H_2$ Hydrogen | --> | $CH_4$ Methane | + | $2H_2O$ Water |

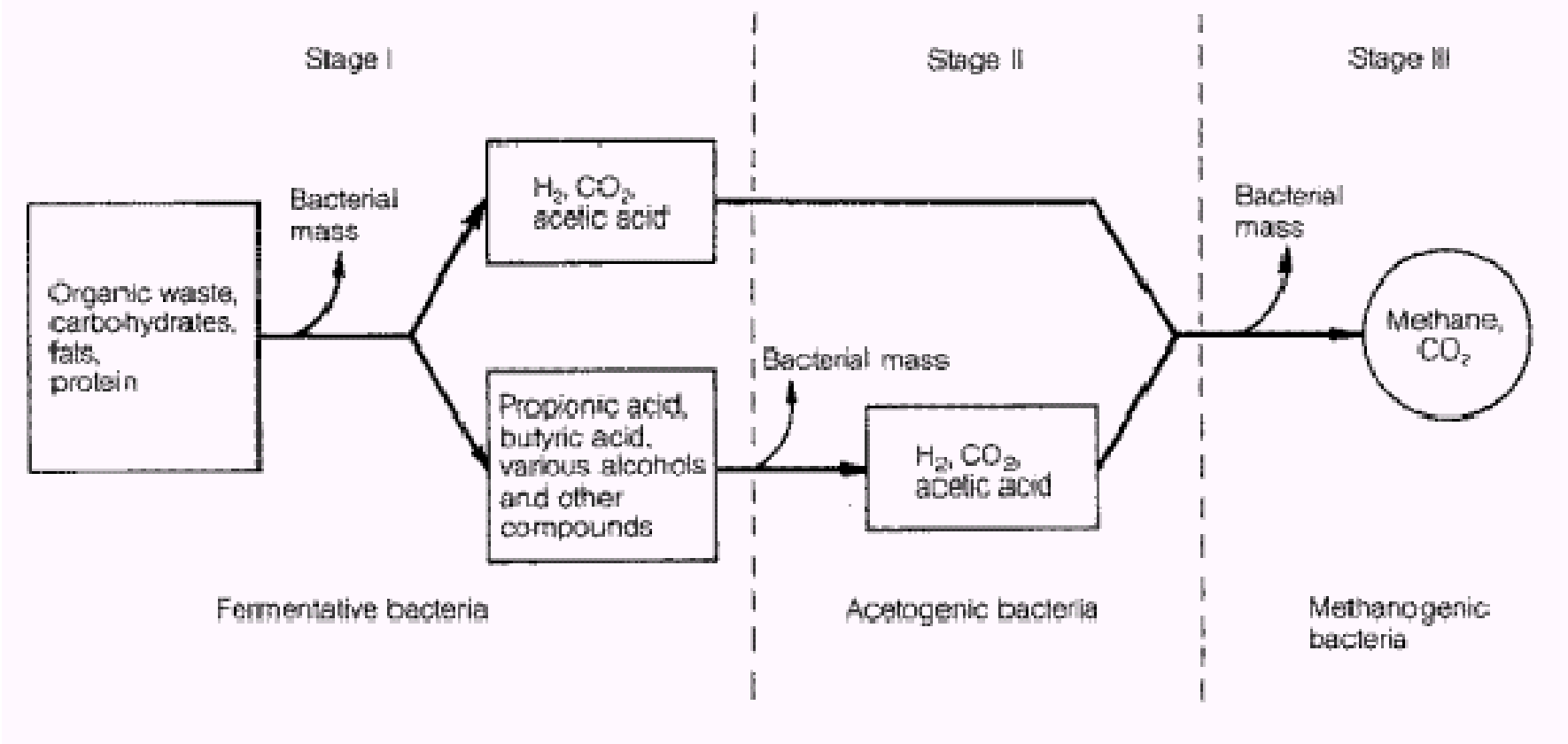



**Figure 2: The three-stage anaerobic fermentation of biomass**

*from: Production and Utilization of Biogas in Rural Areas of Industrialized and Developing Countries, Schriftenreihe der gtz, No. 97, p. 54; after: Märkl, H.: Mikrobielle Methangewinnung; in: Fortschritte der Verfahrenstechnik, Vol. 18, p. 509, Düsseldorf, FRG*

The process of biogas production involves three stages. The different organisms involved in each stage are listed below in the table: - See more at:

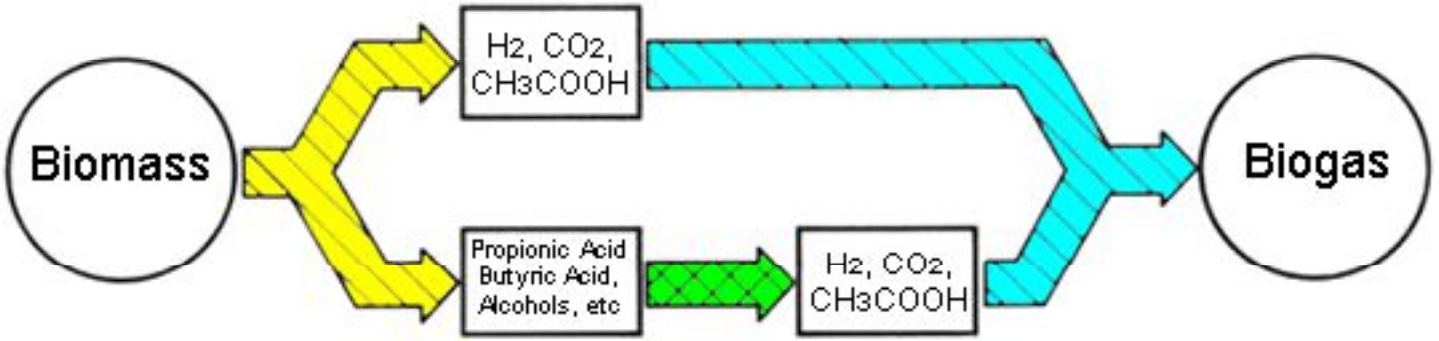
| | Name of the stage | Organisms involved |
|---|---|---|
| 1. | Solubilization | *Facultative anaerobic bacteria including Cellulomonas, Eubacteria, Clostridium, Ruminococcus* |
| 2. | Acidogenesis | Facultative anaerobic acidogenic bacteria such as *Escherichia coli, Clostridium, Actinomyces, Corynebacterium* |
| 3. | Methanogenesis | Methanogens i.e. Methane producing anaerobic bacteria like *Methanobacterium, Methanococcus, Methanosarcina* |

# *Biogas - The Characteristics*

The product of digestion is Biogas, a combination of methane and carbon dioxide, typically in the ratio of 6:4 (55-80 % methane). In addition, there are small quantities of hydrogen sulfide and other trace gases.

**Typical composition of biogas**

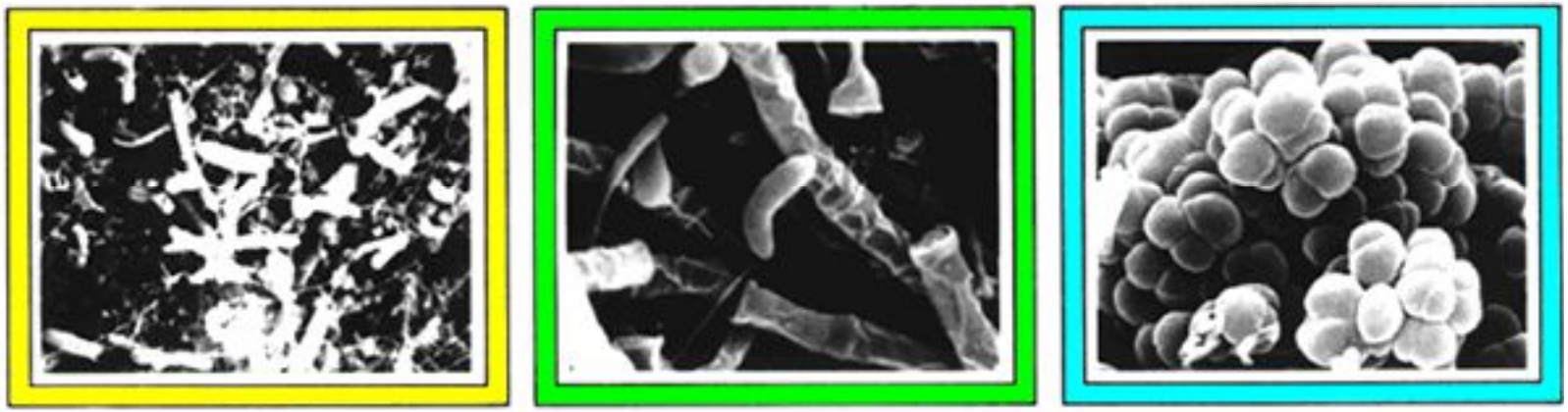
| | |
|---|---|
| Methane | 50-80 % |
| Carbon dioxide | 25-50 % |
| Nitrogen | 0-10 % |
| Hydrogen | 0-1 % |
| Hydrogen sulphide | 0-3 % |
| Oxygen | 0-2 % |




Acidogenic bacteria

Acetogenic bacteria

Methanogenic bacteria



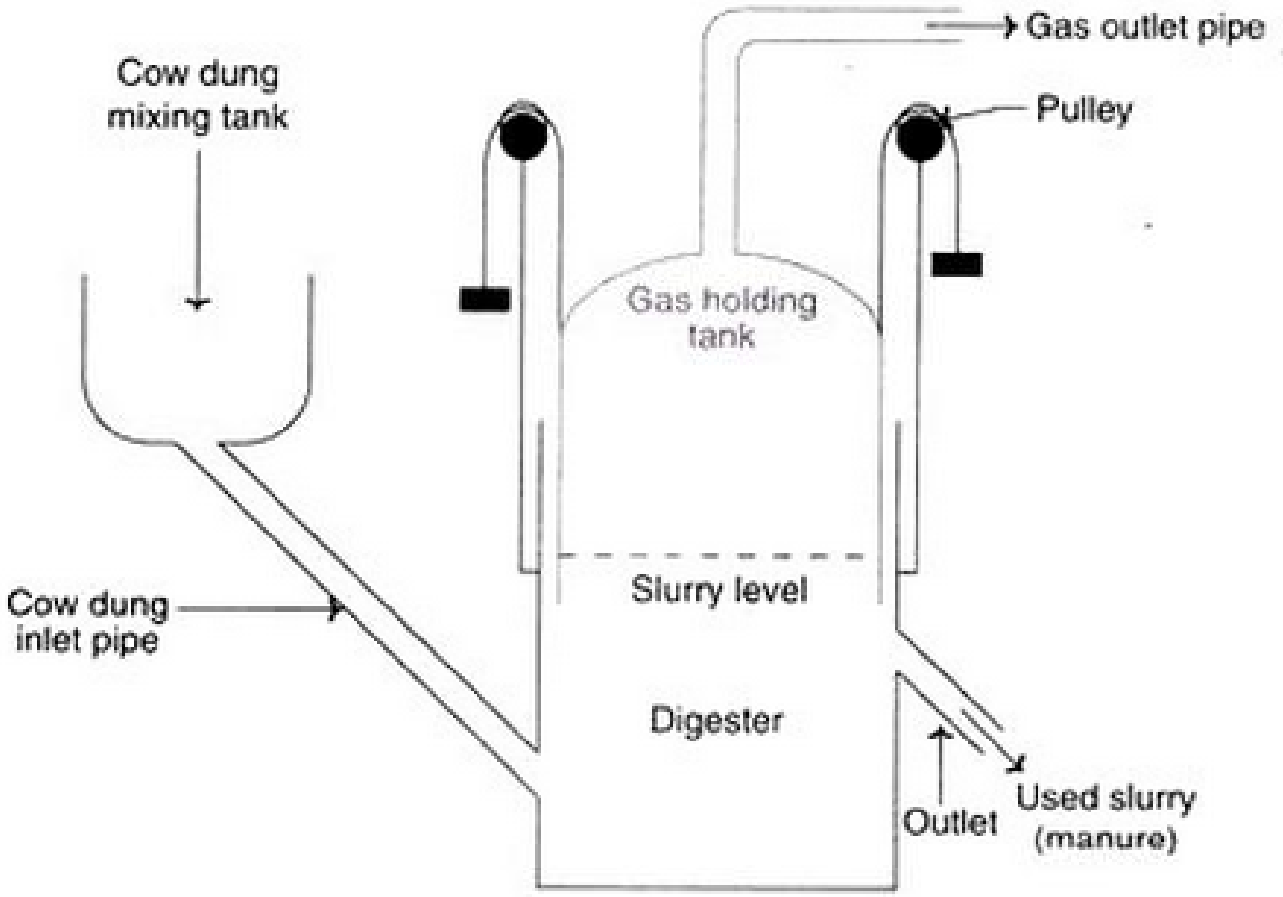



*Fig. 31.3 : Diagrammatic representation of a biogas plant (gobar gas plant).*

# Advantages

- Cheaper and simpler technology than other biofuels.
- Recovery of the product is spontaneous
- Aseptic conditions are not needed for operation.
- Any biodegradable matter can be used as substrate.
- Anaerobic digestion inactivates pathogens and parasites.

# Disadvantages

- **The product value is rather low.**
- **The process is not very attractive economically on large industrial scale.**
- **The biogas yields are lower due to the dilute nature of substrates used.**
- **Biogas contains some gases as impurities, which are corrosive to the metal part of internal combustion engine.**