Industrial Application of Anaerobic Digestion Technology

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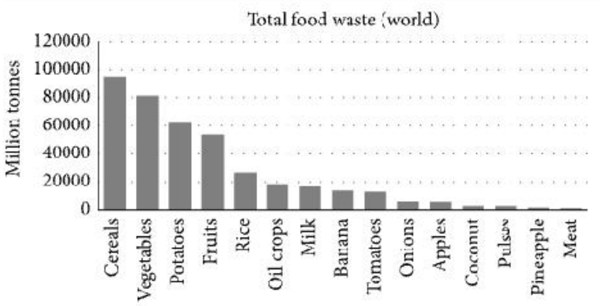
Presentation Outline

- Introduction
- Benefits of anaerobic digestion
- Reaction details
- Process value chain
- Economic relevance
- Factors affecting rate of anaerobic digestion (AD)
- AD design parameters and process configurations
- Deployment of AD for industrial application

Introduction

- Global food waste contribution to env. pollution (Paritosh et al., 2017)



- Industrial organic waste contributors
  - food and beverage industry
  - pulp and mill industry
  - agricultural industry
  - agro-allied industry
  - petrochemical industry
  - leather industry
  - tannery industry

Introduction (Cont'd)

- Techniques for Management of organic wastes
  - Composting
  - Recycling
  - Aerobic digestion
  - Anaerobic digestion

- Anaerobic Digestion (AD): It is a biochemical process involving the breakdown of organic wastes into simpler molecules by the microbial activities of microorganism

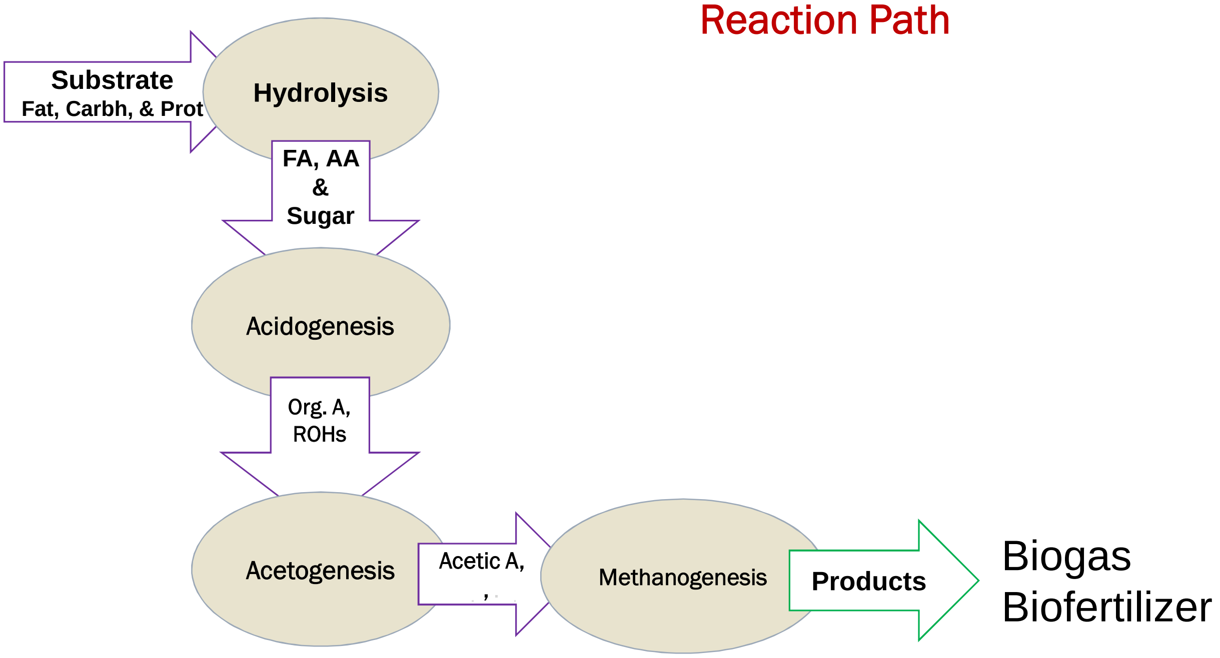
Benefits of Anaerobic Digestion

- Purely a biological process hence it's environmentally friendly
- Reduces release of air and water pollutant into the environment
- Removes harmful pathogens from biological waste
- Reduces carbon footprint thereby serving as potent mitigation against climate change
- Converts waste to wealth
- Low operating costs
- Proven effectiveness

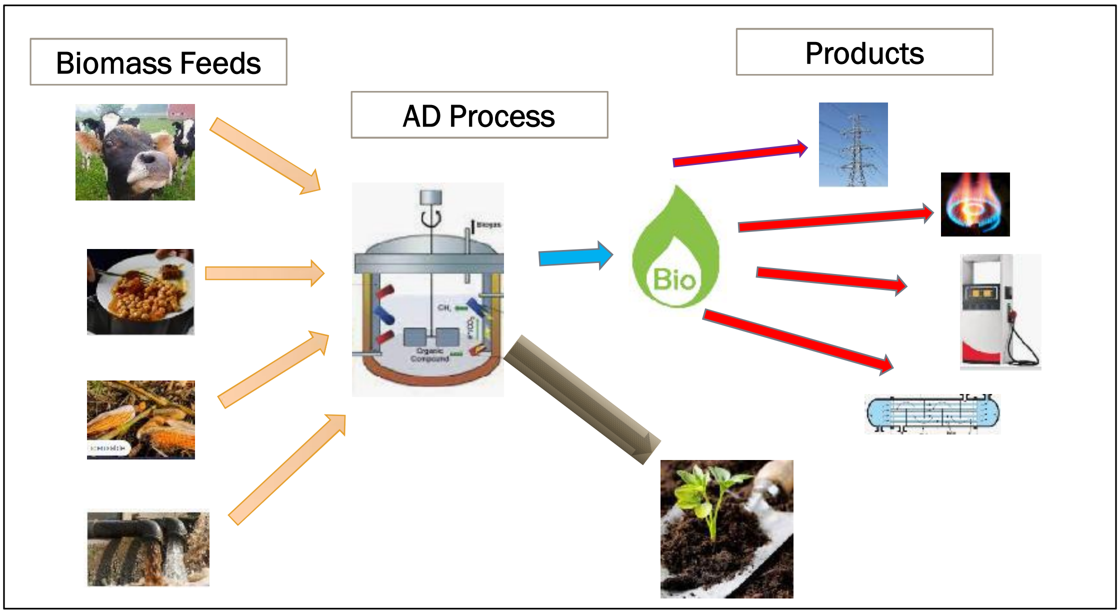
Reaction Details

- The reaction proceeds via a four-stage mechanism
  - hydrolysis,
  - acidogenesis,
  - acetogenesis
  - methanogenesis
- Products of anaerobic digestion
  - biogas (50% – 75% C)
  - carbon dioxide
  - Nitrogen gas
  - hydrogen sulfide
  - water vapour
  - biofertilizer
  - traces of other gas such as hydrogen

Reaction Path



Process Value Chain



Global Relevance and Economic Potentials

- AD has been adopted worldwide, ranging from small-scale household digesters to large-scale systems
- Globally Europe is leading in AD technology deployment their leading role is mainly driven by strict environmental regulations for waste disposal
- Zaks et al., 2011 reported that AD systems in USA have the potential to generate 5.5% of USA annual electricity generation
  - This is equivalent to about 231 TWh
  - At energy cost of 10.42 cent/kWh; this is worth $104 billion/annum

Factors Affecting Rate of Anaerobic Digestion

- Absence of oxygen
- Dynamic of microbial population
- pH; best at 6.8 – 7.2
- Reaction temperature
  - Psychrophilic; 10 – 20ºC
  - Mesophilic; 20 – 48ºC
  - Thermophilic; > 48ºC

AD Design Parameters and Process Configurations

- Selection of process configuration
  - Reactor type
    - Batch reactor
    - Sequencing Batch [anaerobic sequencing batch reactor (ASBR)]
    - Continuous reactor; continuous stirred tank reactor (CSTR)
    - Semi-Continuous reactor
  - Reaction kinetic rate order
    - 1^{st} order
    - 2^{nd} order
    - Fractional order
  - Reaction rate constant (k)
    - Overall rate constant is determined or adopted
  - Reaction stages
    - single stage or multiple stage

Reactor Design Equations

- For a reaction involving reactant A, rate of consumption of A is;

  $- \quad = k$ (i)

  Where k = the rate constant which is dependent on the reaction temperature and the activation energy

  = concentration of A at any given time t, after commencement of the reaction

  n = kinetic rate order of the reaction

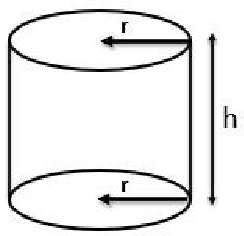
- 1^{st} order batch reactor (using MTR)
  - $t = \int \frac{}{} = -\int \frac{}{}$ (ii)
- For 1^{st} order kinetics; $t = -\int \frac{}{k} = - - \ln\left(\frac{}{}\right)$ (iii)
  - But, $t = -$ (iv)
  - Therefore, $V = -\ln\left(\frac{}{}\right) = -\ln\left(\frac{}{}\right)$ (v)

- 1st order continuous/semi-continuous reactor (using CSTR)
  - V = (vi)
- For 1st order kinetics; V = $\frac{}{k}$ (vii)
  - But, = 1 − (viii)
  - Also, = (ix)
  - Therefore, V = $\frac{(\quad)}{k}$ = $\frac{(\quad)}{k}$ (x)

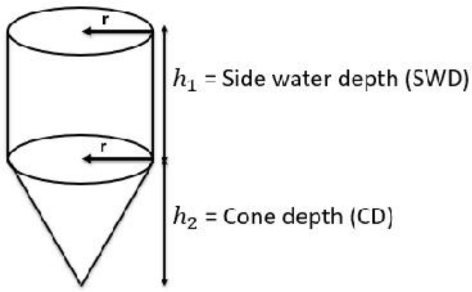
2nd Order Kinetic Design Equations

- Batch reactor (using MTR)
  - V = − (− −) = $\frac{(\quad)}{}$ (xi)
  - Therefore, V = $\frac{(\quad)}{}$ x (xii)
- Continuous or semi-continuous reactor (using CSTR)
  - V = = $\frac{}{k}$ = $\frac{(\quad)}{k}$ (xiii)
  - Therefore, V = $\frac{(\quad)}{}$ x (xvi)

Sizing of Reactor



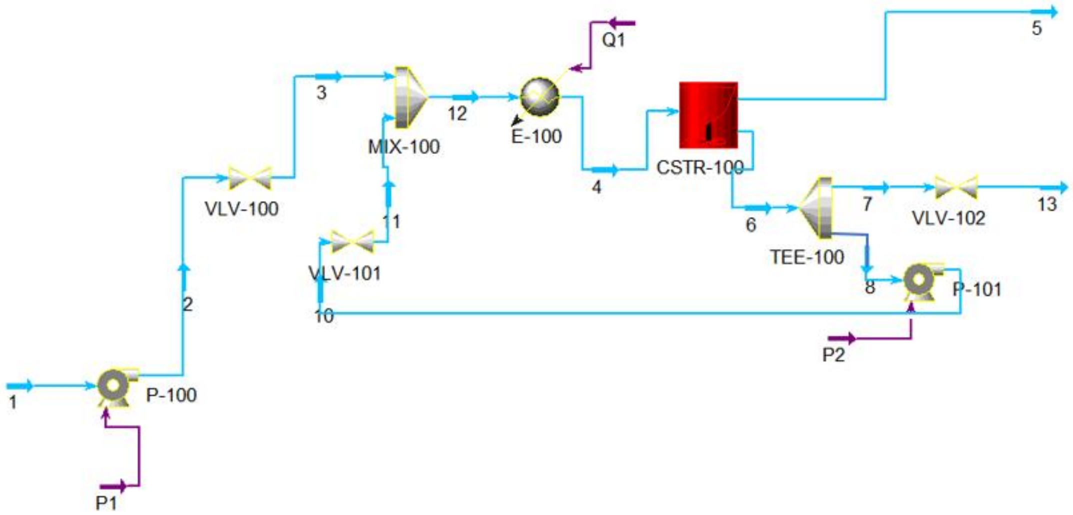
Or



- d = $\sqrt{\text{—}}$ (xv)
- h = xd (xvi)

- d = $\sqrt{\quad (\quad)}$ (xvii)
- h = xd (xviii)
- h = — (xix)

Typical Process Flow Diagram of An AD System



Stage by Stage Steps for Deployment of AD for Industrial Application

- Determining design parameters
- Design of the digester (reactor)
- Design of the auxiliary unit operations such as;
  - pumps
  - mixer
  - heat exchanger etc
- Generation of process flow diagram (PFD) using computer simulation;
  - Hysys
  - Aspen plus
- Fabrication of the various unit operations
- Installation
- Commissioning of the AD plant


THANK YOU :)
for Listening