

Mass Transfer

Mass Transfer Theory

- Mass transfer means the movement of substances from one place to another because of concentration differences.
- In fermentation, mass transfer mainly refers to movement of nutrients, gases, and products between different phases.

Definition of Mass Transfer

- Mass transfer is the transport of molecules from a region of higher concentration to a region of lower concentration.
- It is very important in bioreactors because microorganisms need nutrients and gases for growth.
- It affects microbial activity and product formation.

Importance of Mass Transfer in Fermentation

- Microorganisms need oxygen and nutrients.
- Products and waste materials must move away from cells.
- Efficient mass transfer increases productivity.
- Poor mass transfer can limit fermentation performance.

Types of Mass Transfer

1. Molecular Diffusion

- Molecular diffusion occurs when molecules move due to concentration differences.
- It happens naturally without mechanical movement.
- It is common in transfer of dissolved substances.

2. Convective Mass Transfer

- Convective transfer occurs due to bulk movement of liquid or gas.
- Agitation and aeration improve this type of transfer.

Phases Involved in Mass Transfer

Mass transfer in fermentation often occurs between:

1. Gas to Liquid Transfer

- Oxygen moves from air bubbles into liquid broth.

2. Liquid to Cell Transfer

- Nutrients and oxygen move from liquid to microorganisms.

3. Cell to Liquid Transfer

- Products and wastes move from cells into liquid.

4. Driving Force for Mass Transfer

- The driving force is usually concentration difference.
- Greater concentration difference increases transfer rate.

Fick's Law of Diffusion

- Mass transfer by diffusion follows Fick's Law.
- It states that diffusion rate is proportional to concentration gradient.
- Higher concentration difference causes faster diffusion.

Mass Transfer Coefficient

- It shows how efficiently material is transferred.
- It is represented by symbols such as k_L or $k_L a$.
- It is important in oxygen transfer studies.

Factors Affecting Mass Transfer

- Agitation speed.
- Aeration rate.
- Bubble size.
- Temperature.
- Medium viscosity.
- Reactor design.

Role of Mass Transfer in Bioreactors

- **Mass transfer helps in:**
 - Oxygen supply.
 - Nutrient transport.
 - Removal of carbon dioxide.
 - Product recovery.

Diffusional Resistance to Oxygen Requirements of Microorganisms

- Microorganisms require oxygen for respiration in aerobic fermentation.
- Sometimes oxygen movement to cells is slowed by barriers called diffusional resistances.

Definition of Diffusional Resistance

- Diffusional resistance means opposition to movement of oxygen from air to cells.
- It reduces oxygen transfer efficiency.
- It can limit microbial growth.

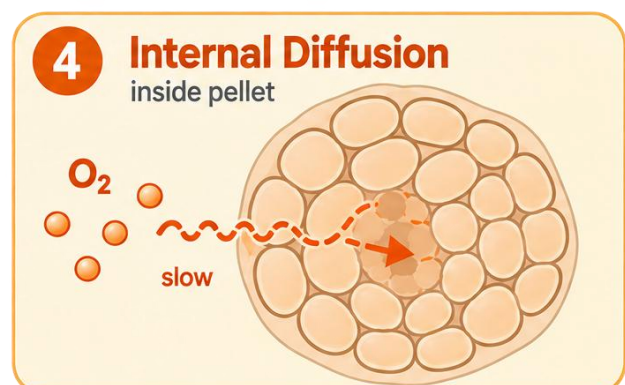
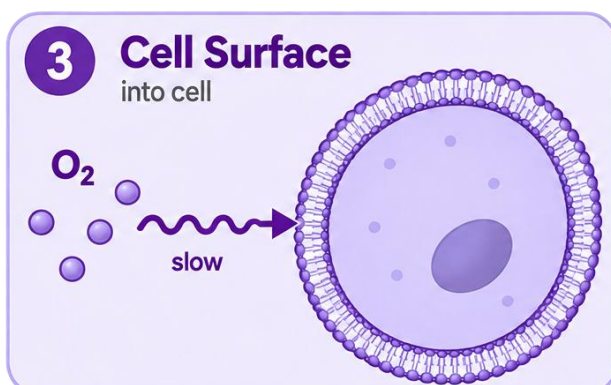
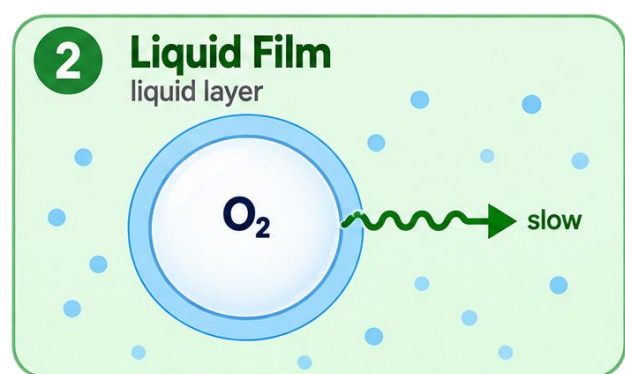
Oxygen Requirement of Microorganisms

- **Aerobic microorganisms need oxygen for:**
 - Energy production.
 - Cell growth.
 - Product formation.
 - Metabolic reactions.

Path of Oxygen Transfer

- **Oxygen moves through several steps:**
 - From air bubble to liquid surface.
 - Through liquid film around bubble.
 - Through fermentation broth.
 - Through liquid film around cells.
 - Into microbial cells.
- Resistance may occur at any step.

Types of Diffusional Resistance



1. Gas Film Resistance

- Resistance may occur at the gas-liquid interface.
- It slows oxygen transfer from bubble to liquid.

2. Liquid Film Resistance

- Thin liquid layer around bubbles may resist oxygen movement.
- This is often a major resistance.

3. Cell Surface Resistance

- Oxygen may face resistance while entering cells.

4. Internal Diffusion Resistance

- Oxygen movement inside cell aggregates may be slow.
- This is common in pellets or biofilms.

Oxygen Transfer Limitation

- If oxygen transfer is slower than oxygen demand, limitation occurs.
- Microbial growth may decrease.
- Product formation may be affected.

Factors Increasing Diffusional Resistance

1. High Viscosity

- Thick broth slows oxygen movement.

2. Large Cell Aggregates

- Oxygen may not reach inner cells easily.

3. Poor Agitation

- Reduces mixing and oxygen distribution.

4. Low Aeration

- Decreases oxygen availability.

Reducing Diffusional Resistance

- **Resistance can be reduced by:**
 - Increasing agitation.
 - Increasing aeration.
 - Using better impeller designs.
 - Reducing broth viscosity.

- Improving reactor design.

Importance in Fermentation

- Understanding oxygen resistance helps improve productivity.
- It is very important in aerobic industrial fermentation.

Measurement of Mass Transfer Coefficient and Factors Affecting Them

- Mass transfer coefficient indicates how efficiently substances, especially oxygen, are transferred to a bioreactor.

Definition of Mass Transfer Coefficient

- It measures the rate of transfer of a substance between phases.
- In fermentation, oxygen transfer coefficient is very important.
- It is often represented as kLa .

Meaning of kLa

kLa consists of:

kL

- It is liquid film mass transfer coefficient.
- It indicates oxygen transfer through liquid film.

a

- It is interfacial area between gas and liquid.
- More bubble surface means larger value of a .

kLa

- It combines both factors.
- It represents overall oxygen transfer ability.

Importance of kLa

- It shows efficiency of oxygen supply.
- It helps in reactor design.
- It is important in scale-up.
- Higher kLa usually means better oxygen transfer.

Measurement of Mass Transfer Coefficient

1. Sulfite Oxidation Method



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