Scale Up of Fermentation Process

Scale Up of Fermentation Process: Principles

- Scale up of fermentation means increasing the size of a fermentation process from laboratory level to pilot scale and finally to industrial production scale while maintaining the same performance and product quality.

Definition of Scale Up

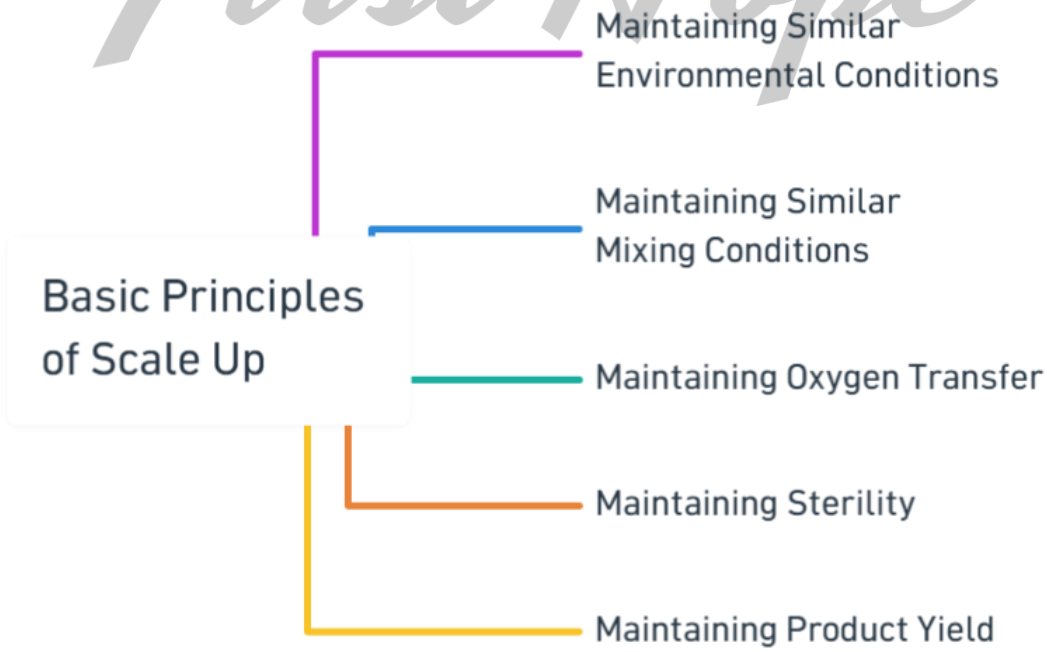
- Scale up is the process of transferring fermentation from small-scale operation to large-scale production.
- It involves increasing the size of equipment and volume of production.
- The aim is to obtain the same results at industrial level as in laboratory scale.

Need for Scale Up

- Laboratory fermentation produces only small quantities.
- Industrial production requires large amounts of product.
- Scale up helps convert research processes into commercial production.

Basic Principles of Scale Up

Scale up is based on maintaining important process conditions similar at all scales.



1. **Maintaining Similar Environmental Conditions**
   - Temperature should remain suitable at all scales.
   - pH should be maintained in the same range.
   - Dissolved oxygen should remain adequate.
   - Similar microbial growth conditions should be preserved.

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2. Maintaining Similar Mixing Conditions

- Proper mixing should be maintained in large reactors.
- Nutrients should remain uniformly distributed.
- Agitation should provide similar performance as small scale.

3. Maintaining Oxygen Transfer

- Oxygen transfer should remain sufficient in large fermenters.
- Similar oxygen availability should be maintained.
- Mass transfer efficiency should be preserved.

4. Maintaining Sterility

- Sterile conditions must be maintained during scale up.
- Risk of contamination increases in large systems.
- Proper sterilization becomes very important.

5. Maintaining Product Yield

- Product quality and yield should remain similar after scale up.
- Large scale production should reproduce laboratory results.

Common Scale Up Criteria

Scale up may be based on maintaining:

1. Constant Power Input

- Power supplied per unit volume may be kept constant.

2. Constant Agitation Speed

- Similar mixing intensity may be maintained.

3. Constant Oxygen Transfer Rate

- Oxygen transfer capacity may be preserved.

4. Constant Tip Speed

- Impeller tip speed may be maintained.

5. Constant Reynolds Number

- Flow behavior may be kept similar.

Stages of Scale Up

1. Laboratory Scale

- Used for research and process development.

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2. Pilot Scale

- Intermediate stage for testing scale-up performance.

3. Industrial Scale

- Full production level.

Challenges in Scale Up

- Mixing becomes more difficult in large vessels.
- Heat transfer may change.
- Oxygen transfer may decrease.
- Foam formation may increase.

Importance of Scale Up Principles

- They help achieve successful industrial production.
- They reduce process failures.
- They improve process efficiency.

Scale Up of Fermentation Process: Theoretical Considerations

- Theoretical considerations are scientific and engineering factors that must be considered during scale up to maintain process performance.

Definition of Theoretical Considerations

- These are calculations and principles used to guide scale up.
- They help predict behavior in large fermenters.
- They support proper reactor design.

Important Theoretical Considerations

1. Geometric Similarity

- Fermenters at different scales should have similar shape.
- Height to diameter ratio may be maintained.
- Impeller design may remain proportionally similar.

Importance of Geometric Similarity

- It helps maintain similar flow patterns.
- It supports similar mixing behavior.

2. Kinematic Similarity

- Fluid motion should remain similar at different scales.

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- Circulation patterns should be maintained.

3. Dynamic Similarity

- Forces acting in the system should remain similar.
- This includes inertial and viscous forces.

4. Oxygen Transfer Considerations

- Oxygen transfer rate is very important during scale up.
- Large reactors often have lower oxygen transfer.
- kLa is often used in theoretical analysis.

5. Heat Transfer Considerations

- Heat removal becomes harder in large reactors.
- Temperature control must be considered.

6. Power Consumption

- Agitation power changes with reactor size.
- Power requirement must be estimated.

7. Fluid Flow Behavior

- Flow patterns affect mixing and oxygen transfer.
- Reynolds number is often used to study flow behavior.

8. Mass Transfer Considerations

- Nutrient and oxygen transport must be maintained.
- Diffusion limitations may increase at larger scale.

Mathematical Factors Used in Scale Up

- **Important theoretical parameters include:**
  - Reynolds number.
  - Power number.
  - Oxygen transfer coefficient.
  - Power per unit volume.
  - Impeller tip speed.

Importance of Theoretical Considerations

- They reduce errors during scale up.
- They help predict large-scale performance.
- They improve reactor design.

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Scale Up of Fermentation Process: Techniques Used

- Different techniques are used to perform scale up depending on process requirements and engineering considerations.

Definition of Scale Up Techniques

- Scale up techniques are methods used to transfer fermentation from small to large scale.
- They help maintain important process conditions.

Common Scale Up Techniques

1. Scale Up Based on Constant Power per Unit Volume

- Power input per unit volume is kept constant.
- This helps maintain similar mixing intensity.

Applications

- Commonly used in aerobic fermentations.
- Useful when mixing is very important.

2. Scale Up Based on Constant Tip Speed

- Impeller tip speed is maintained constant.
- It helps control shear forces.

Applications

- Useful for shear-sensitive cells.
- Common in cell culture processes.

3. Scale Up Based on Constant Oxygen Transfer

- Oxygen transfer rate is maintained.
- kLa may be kept similar.

Applications

- Used in oxygen-demanding fermentations.

4. Scale Up Based on Constant Agitation Speed

- Same impeller speed may be maintained.
- Helps preserve mixing conditions.

5. Scale Up Based on Constant Reynolds Number

- Similar fluid flow regime is maintained.
- Useful for studying dynamic similarity.

6. Empirical Scale Up

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