Gas-Liquid Fermentation Agitation Strategies

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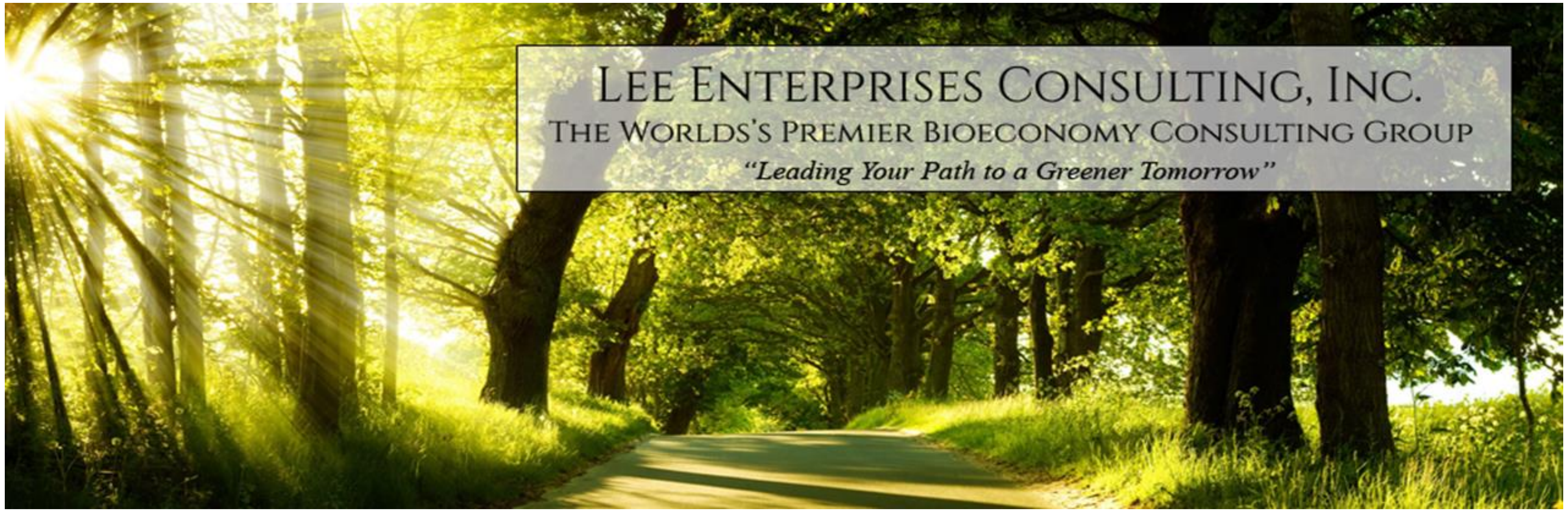
Accredited
Member

LEE ENTERPRISES
CONSULTING, INC.

Background: 40+ years experience in agitation industry

Performing consulting services to developers, operators and investors both in the US and internationally



Expertise: World's largest bioeconomy consulting group - over 100 subject matter experts (SME's)- all areas of the bioeconomy.

Approach: Project interdisciplinary teams to meet exact needs of specific projects.

POC: Handle projects with one agreement and single point of contact.

Cost Advantage: Single POC = lower administrative costs = lower project cost.

Gas-liquid fermentation may be used to make thousands of products by the action of microorganisms. Agitation is often used to aid in gas/liquid mass transfer, as well as promote liquid-phase uniformity

Gas is usually oxygen in air. Other gasses are being used as well:

- Methane
- Carbon dioxide
- Carbon monoxide
- Hydrogen

Basic mass transfer equation

- MTR (mass transfer rate) = $k_l a$*(driving force)
- Simplified driving force = C_{sat}-C
- Gasses vary in terms of solubility
- Next slide compares solubility of a few gasses

Comparative gas solubility

Gas	Solubility Relative to Oxygen
Oxygen	1
Hydrogen	0.039
Carbon monoxide	0.575
Carbon dioxide	35
Methane	0.45

Basic $k_l a$ equation:
$k_l a = A(P/V)^B(U_S)^C$

- P/V is agitator power input under gassed conditions, per volume of liquid
- U_S is gas superficial velocity
- A, B and C are broth-specific constants that should be empirically determined
- A well-designed experimental protocol can aid in developing these constants
- Next slide shows rough comparative k_l values for different gasses

Comparative k_l values for various gasses

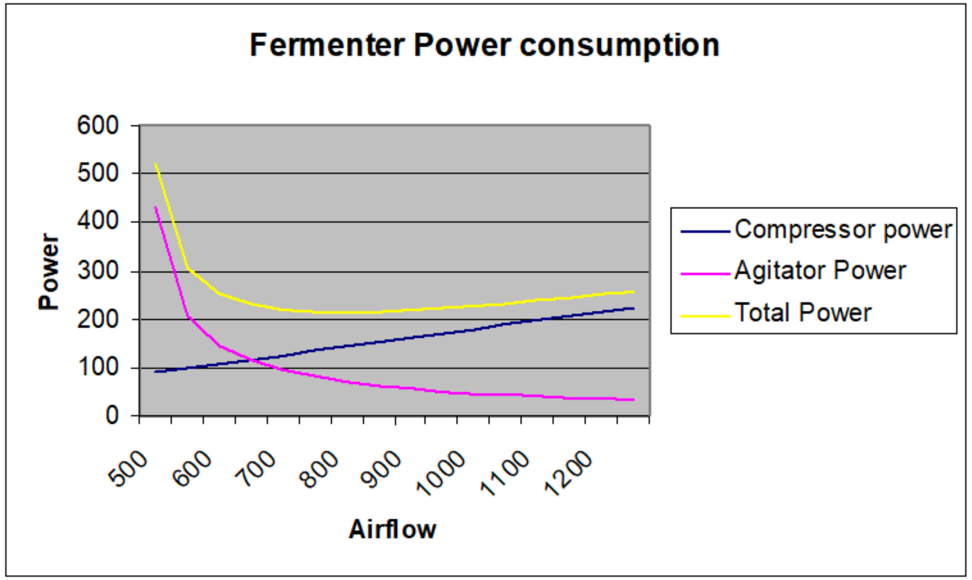
Gas	Diffusivity Relative to Oxygen	k_l Relative to Oxygen
Oxygen	1.00	1.00
Hydrogen	1.93	1.39
Carbon monoxide	0.97	0.98
Carbon dioxide	0.91	0.96
Methane	0.71	0.84

What can be done with a broth-specific mass transfer correlation?

- More accurate design for a target mass transfer rate
- Minimize power consumption for peak mass transfer
- Minimize energy consumption for whole batch process

Minimize power consumption for peak mass transfer rate

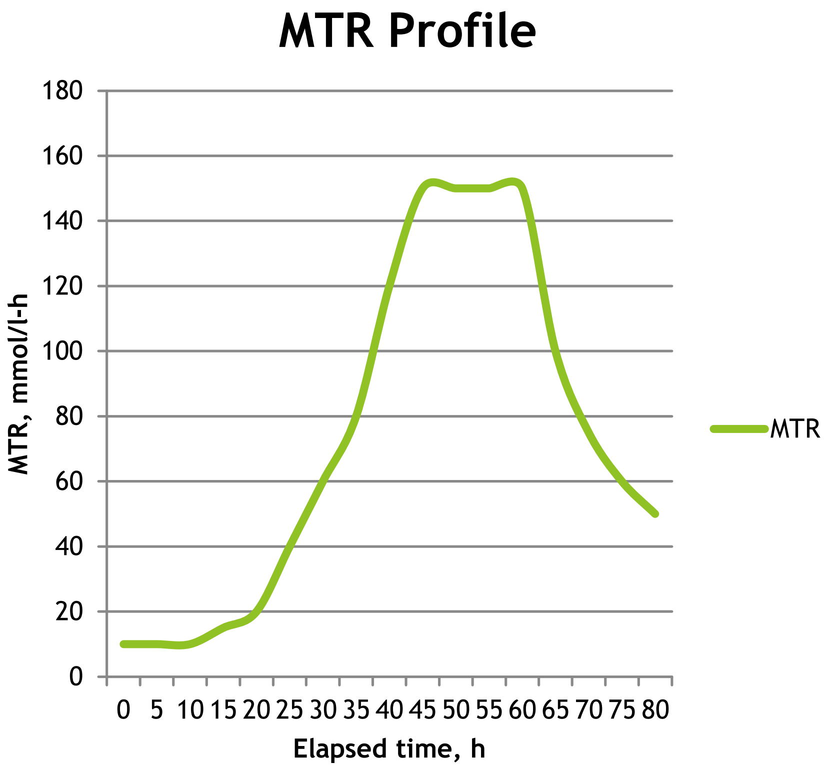
- Combinations of gas flow and agitator power can produce same mass transfer rate
- Total power goes through a minimum

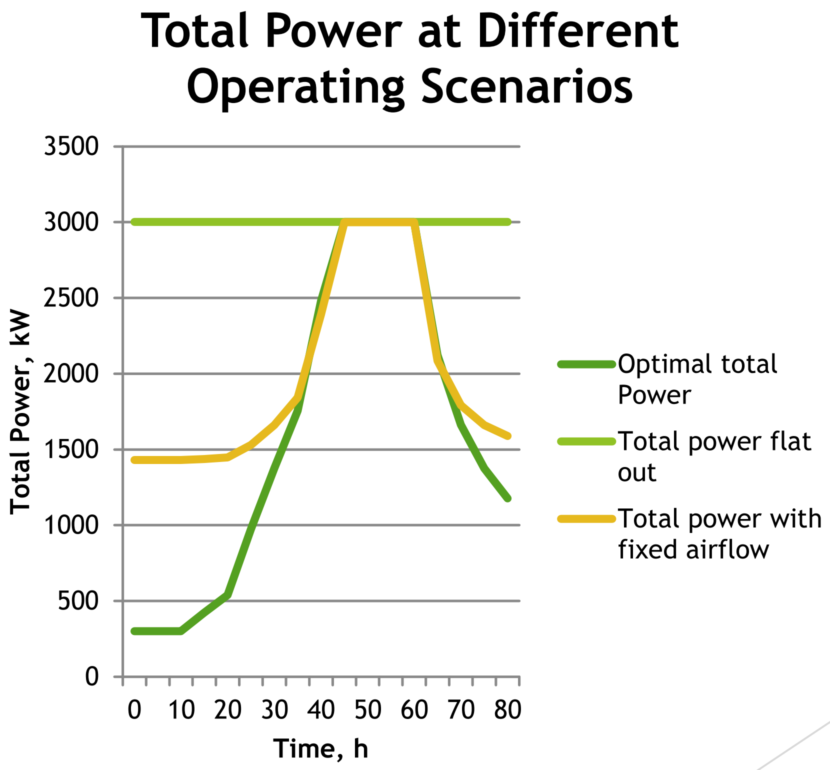


Minimize total energy per batch

- Mass transfer rate is not constant in a batch process
- Gas flow and agitation can be optimized at each stage in process to minimize total energy consumed

Mass transfer and power profile





How much does this save compared to fixed speed and airflow?

- For this assumed scenario, running fixed airflow, variable agitator speed saves 33% energy per batch
- Varying airflow and agitator speed saves 46%
- Monetary savings can be hundreds of thousands of dollars per year per fermenter

What can Lee Enterprises and Benz Technology International do to help you design fermentation facilities?

- Design pilot protocol for developing broth-specific mass transfer correlations
- Optimize energy consumption
- Heat transfer studies
- Process economics: material costs, capex, operating protocol, upstream and downstream operations
- Market studies
- Feasibility studies

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