PRAXAIR®

Making our planet more productive℠

Improving Aerobic Fermentation Production Capacity

Praxair's direct oxygen injection technology offers commercial microbial fermentation operations as an efficient, cost-effective means to improve oxygen mass transfer rates and production capacity for a variety of biologic products.

Praxair's Direct Oxygen Technology enables customers to increase the capacity of their oxygen-limited aerobic fermentation vessels while avoiding the capital outlay, electrical infrastructure and power costs associated with new air blowers or expanded agitation systems. Other adverse conditions, such as foaming or gas flooding, can also be reduced.

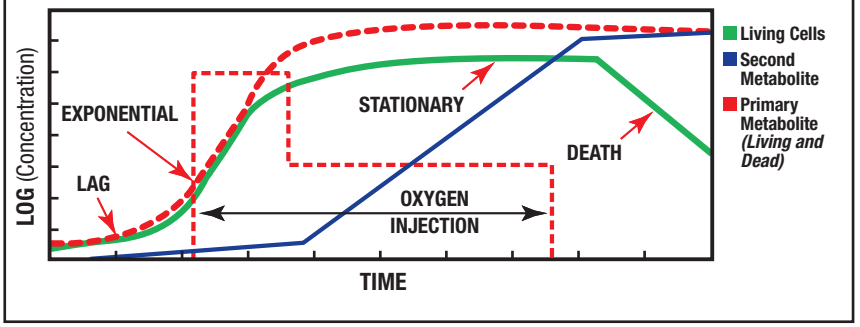
Combining Praxair's Direct Oxygen Injection Technology with existing aerobic fermentors may help customers to:

- Cost-effectively increase the capacity of existing fermentors
- Increase production yields (up to 65% improvement demonstrated to date on some products)
- Provide greater control over dissolved oxygen level and oxygen transfer rate throughout the fermentation cycle
- Enhance oxygen utilization efficiency
- Reduce oxygen consumption and costs
- Avoid capital outlay for additional air blowers or agitation equipment
- Reduce power demand and costs associated with air-only systems
- Reduce vent gas volume and affiliated scrubbing costs
- Lessen stripping potential for desirable reaction by-products

Fermentation Process: Meeting Peak Oxygen Demand

Traditional aerobic fermentors utilize air as the source of oxygen for the fermentation process. However, air only contains 21% oxygen, with the balance comprising nitrogen and other inerts. The low concentration of oxygen in the air stream, coupled with the increasing viscosity of the fermentation media or broth, serve to further inhibit the oxygen mass transfer from air to the liquid broth. This not only reduces the oxygen utilization efficiency but also results in insufficient dissolved oxygen to support organism respiratory function and growth. Prolonged oxygen deprivation can lead to lower biomass yield and premature death of the microorganisms. Oxygen demand varies over the course of the fermentation cycle. As shown in Figure 1, peak oxygen demand occurs during the exponential growth phase of the fermentation process. The related rapid cell growth creates high oxygen demand and increases broth viscosity.

Figure 1: Fermentation Cycle



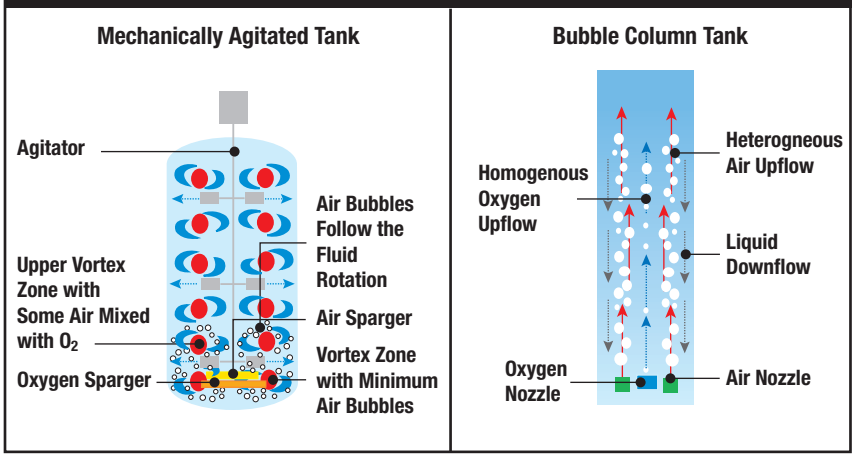
The efficiency of traditional aeration systems may deteriorate with the increase in viscosity, resulting in oxygen limitations even after the exponential growth phase.

Typically when cells reach the stationary phase, the production of secondary metabolite is initiated and cell growth slows down drastically. Therefore, maintaining adequate oxygen levels during the exponential growth period is critical to overall optimum cell growth and yield of products. However, traditional aeration systems often provide insufficient dissolved oxygen to meet the peak demands of the cells.

The simple method of mixing pure oxygen into the air stream increases the average oxygen concentration of the stream but provides only modest improvement to the oxygen mass transfer rate.

Improving Aerobic Fermentation Production Capacity and Costs

Figure 2: Types of Fermentors with Direct Oxygen Injection Technology



Improving Aerobic Fermentation Production Capacity and Costs

Simple air enrichment inefficiently utilizes the oxygen as it does not adequately increase the driving force for oxygen transfer, thus reducing the cost-effectiveness of the oxygen supplementation technique. Significant portions of the added oxygen remain undissolved and pass unused through the broth and out the vent from the fermentor. Praxair offers a more sophisticated means of introducing the oxygen to improve its dissolution efficiency and improve process economics.

Improved Oxygen Injection Methodology

Praxair's proprietary direct oxygen injection process supplements the existing air injection system and provides controlled dissolution of high-purity oxygen into the fermentation broth. Air and pure oxygen are injected separately into the fermentor, fulfilling vital, distinct functions. The air strips the broth of carbon dioxide and other undesirable reaction by-products that adversely affect the metabolic activity of the organisms. The high purity oxygen, used with Praxair's direct injection technology, provides superior control of dissolved oxygen levels while supporting the production of primary and secondary metabolites.

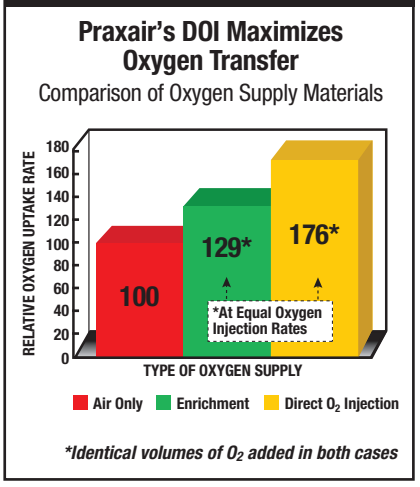
The patented high-efficiency oxygen injection process and related injector are both the results of Praxair's extensive experience in developing mass transfer and dissolution technologies. The injector is sized and located so as to introduce finely-sized oxygen bubbles at low velocity into the stationary vortex within the mechanically agitated fermentor.

This strategic injector location minimizes the coalescence with air bubbles as they travel through the fermentation broth, enhancing mass transfer efficiency. The site of introduction, coupled with oxygen bubble size and velocity, are key to expanding oxygen's dissolution rate and fermentation productivity. The system, once installed, operates efficiently with most mechanically agitated or air-lifted systems *(See Figure 2)*.

Increase Oxygen Utilization

As illustrated in Figure 3, Praxair's direct oxygen injection process provides a more effective means to dissolve oxygen within the broth. The oxygen utilization efficiency increases by as much as 50% and process yields may expand up to 65% relative to traditional air-based fermentation processes. This increase is accomplished without additional power input.

Figure 3: Relative Oxygen Transfer Rates



By reducing the overall throughput of unconsumed oxygen and inert gases, this process also reduces foaming and gas flooding associated with running an air-based system at peak air rates.

To determine if Direct Oxygen Injection Fermentation is right for you, please contact Praxair at 1-800-PRAXAIR or visit us on the web at www.praxair.com.

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