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Comparison of bioreactor systems operated at high bacterial cell density for the production of lactic acid: Batch – CSTR – CSTR cascade – Tubular reactor

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Comparison of bioreactor systems operated with cell recycle and high bacterial cell density for the production of lactic acid: Batch – CSTR – CSTR Cascade – Continuous Tubular Reactor

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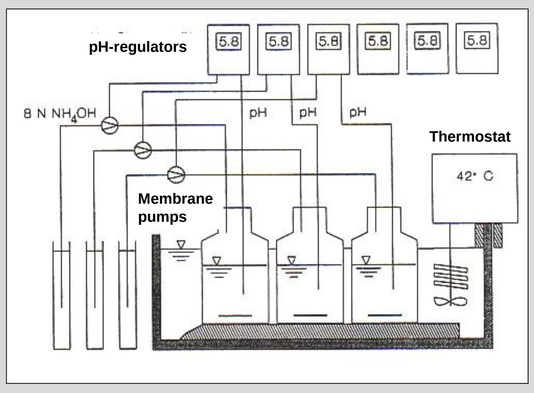
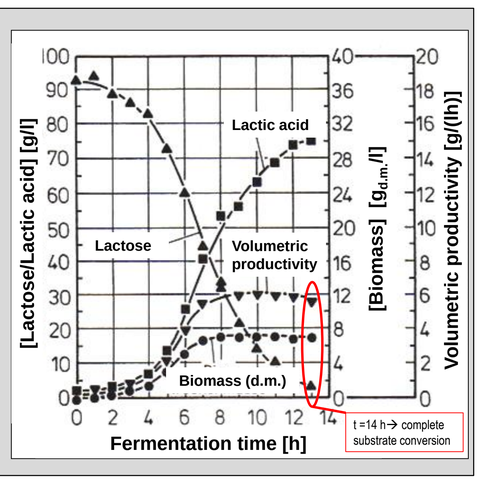
Motivation & Objectives

- Subject was the microbial conversion of lactose, an abundant by-product in the dairy industry, by *Lactobacillus helveticus* to lactic acid as a bulk product.
- Lactic acid serves as an example for bulk products made from renewable resources. It can be applied as a building block for novel technical materials such as biodegradable films for packaging purposes in replacement of materials based on fossile raw materials or as preservative in many industrial sectors.
- Purpose was to compare bioreactor systems with regard to achievable high end product concentration, high volumetric productivity and complete substrate conversion.
- The goal was to quantitatively assess the standard batch stirred tank reactor (STR) versus various alternative continuous reaction systems.
- Emphasis was put on a continuous stirred tank reactor (CSTR), a CSTR cascade with seven stages (N = 7), and a continuous tubular reactor (TR) (d = 50 mm, L = 600 m).
- The continuous systems were equipped with a dynamic microfiltration (MF) cell retention system using rotating membranes to prevent extreme deposit formation or centrifugal separation and cell recirculation to the reactor front.

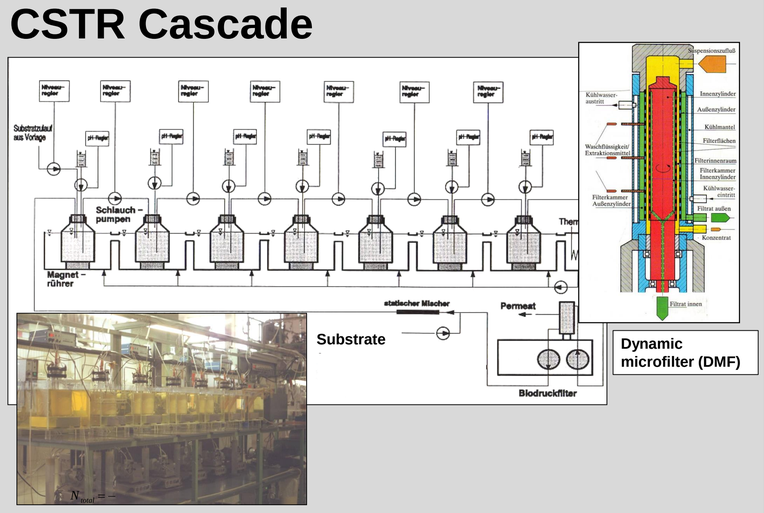
Methods & Results

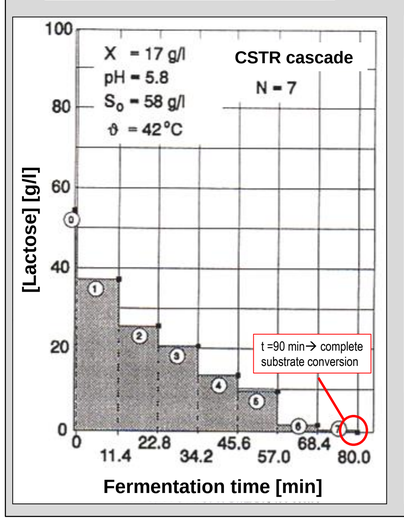
Batch Stirred Tank Reactor

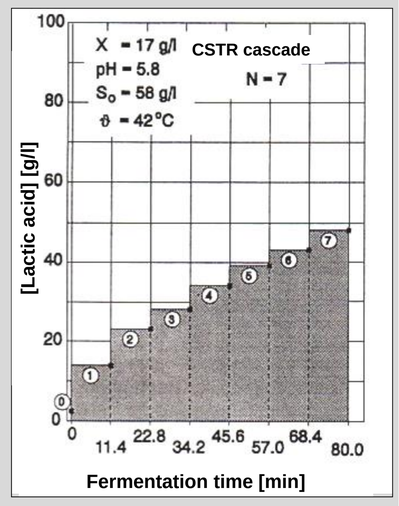




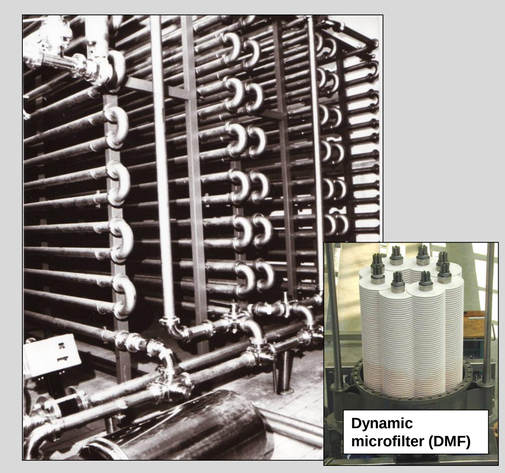
CSTR Cascade

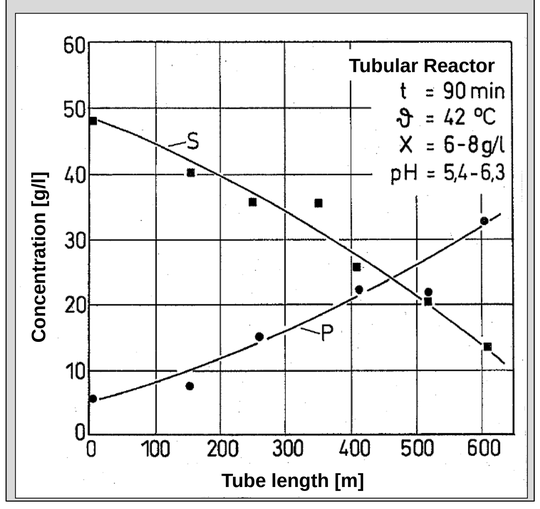




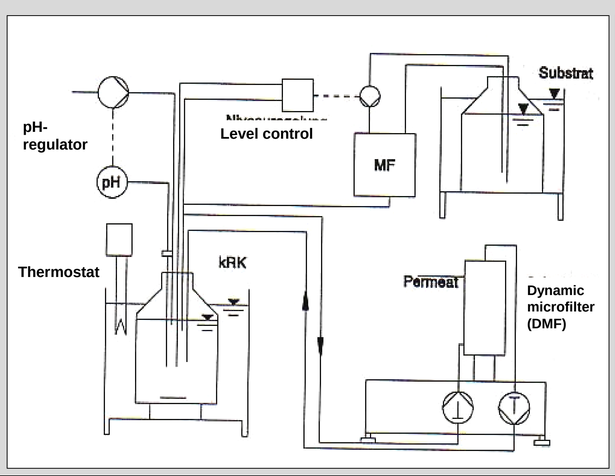


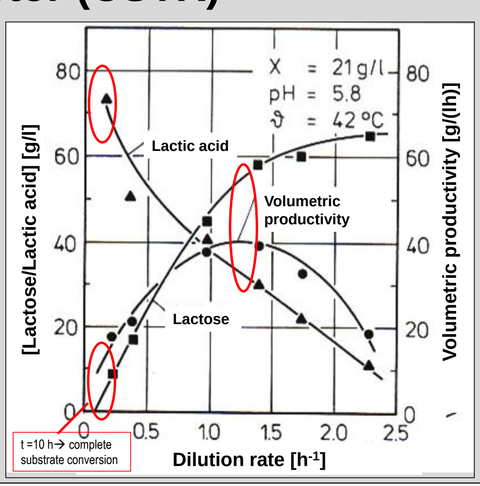
Tubular Reactor





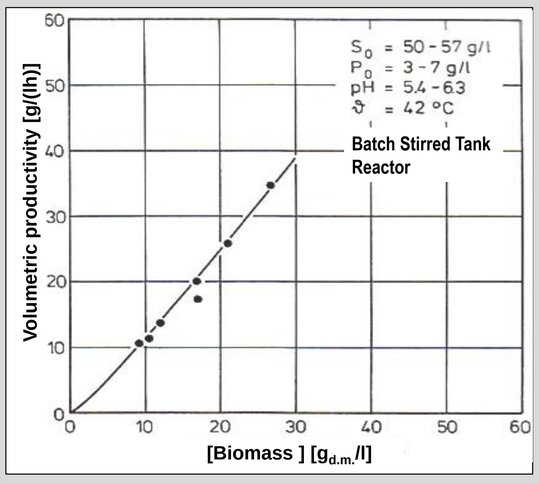
Continuous Stirred Tank Reactor (CSTR)

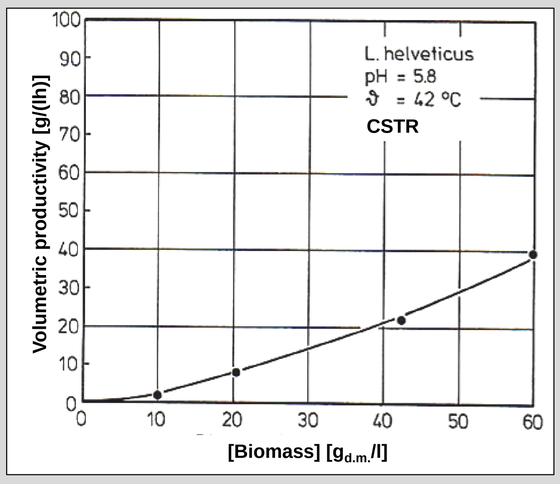


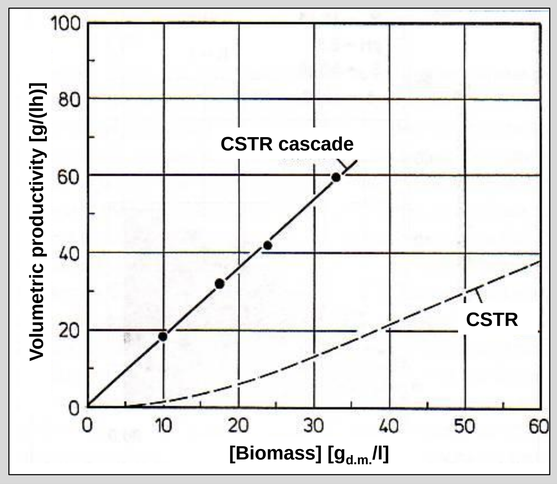


Discussion & Conclusions

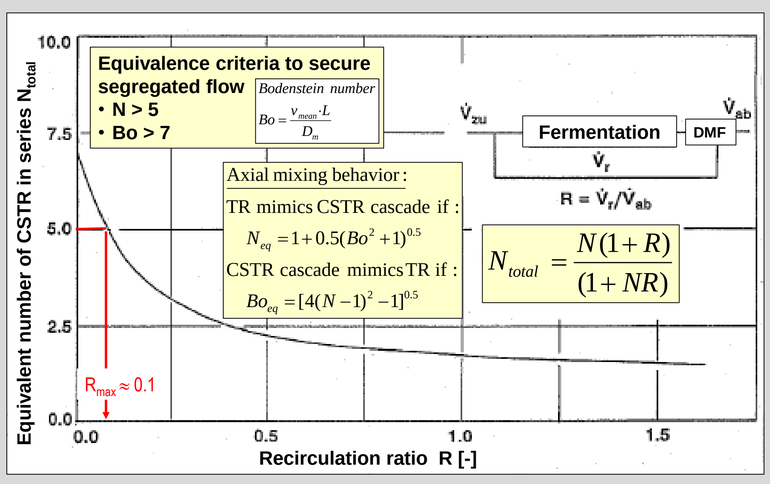
Volumetric productivities of the systems at high cell concentration







Allowed recirculation of serum phase



Evaluation of the systems

- Comparison made in terms of volumetric productivity at same rates of substrate conversion and the same biomass level.
- **Batch:** Relatively high productivity because product inhibition occurs only towards the end of fermentation. However, low productivity only when low in biomass concentration.
- **CSTR**: Adverse effects (substrate limitation and product inhibition) permanently affect the entire reactor volume and time
- **CSTR cascade**: Very high productivity because product inhibition and substrate limitation occur only towards the end of the reactor
- **Tubular reactor**: As for CSTR cascade - Very high productivity because adverse effects occur only towards the end of the reactor

Technical requirements and Summary

- **Cell recirculation**: The challenge for cell retention in reactor systems with spatial distribution of concentrations is to achieve high cell concentration factors. Only small allowed amounts of already fermented medium at the reactor end with exhausted substrate and high reaction product concentration are then recirculated to the reactor front.
- **Cell retention system**: Dynamic membrane systems were found to be capable to achieve this. They do not require high crossflow volume turnover rates and they can cope with high viscosities of the cell concentrates produced for recirculation.
- **Summary**: Volumetric productivities were increased by a factor of 10-20 due to segregation of reactor segments.

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