Fermenter operation

Technology for biobased products

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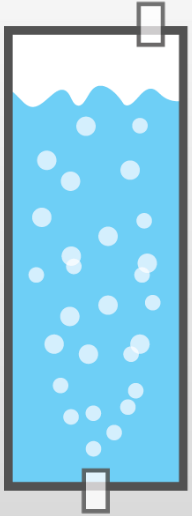
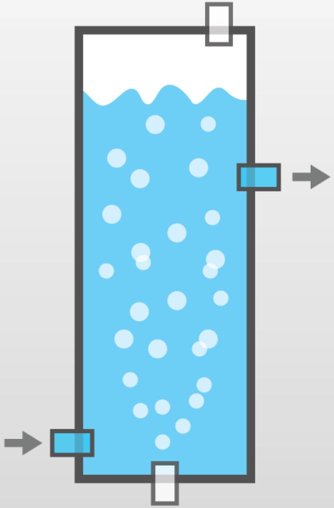
Fermenter operation

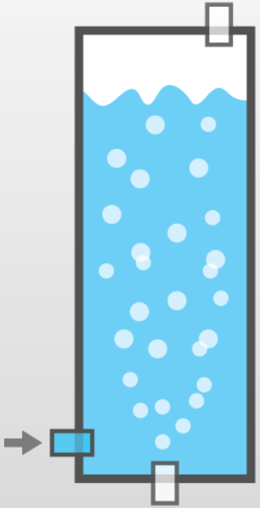
Different modes



Batch

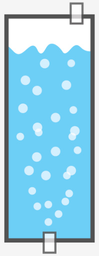


Continuous
(chemostat)

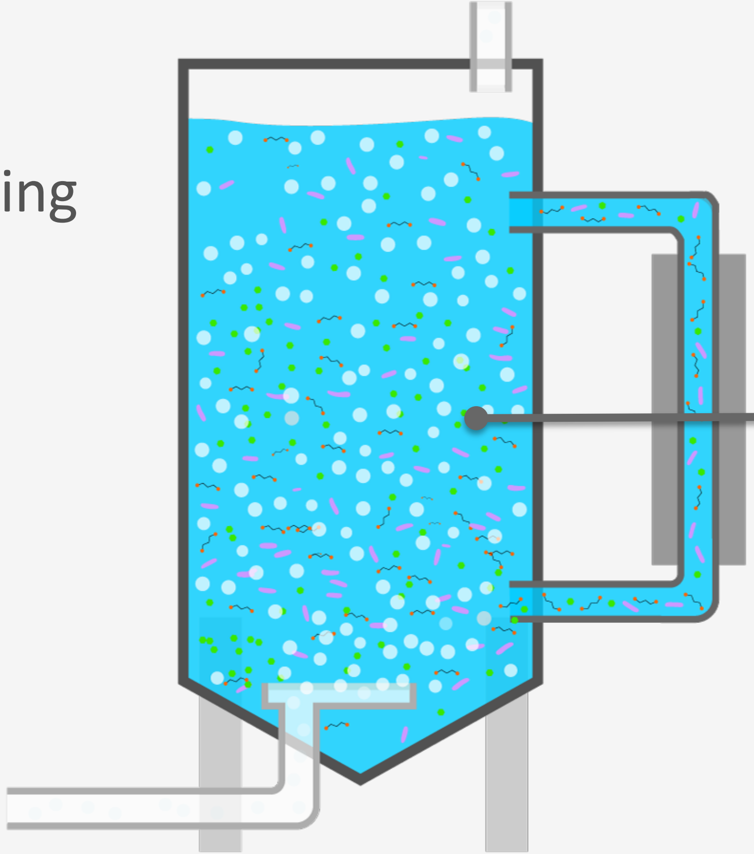


Fed-batch

Batch



No feeding

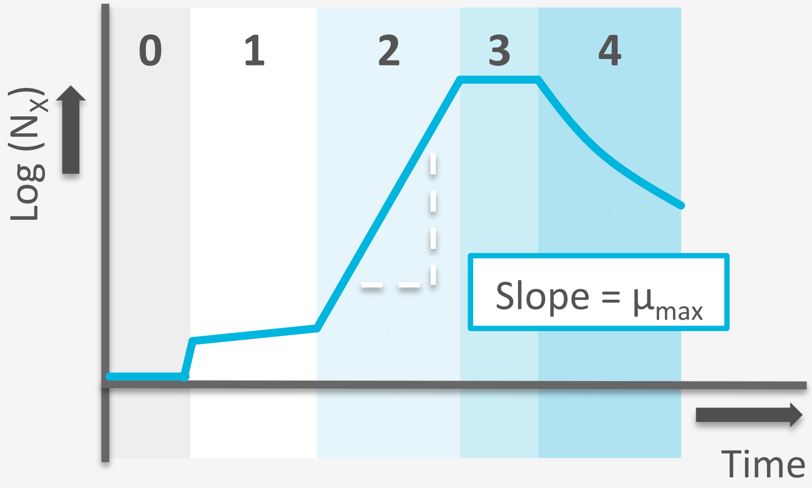


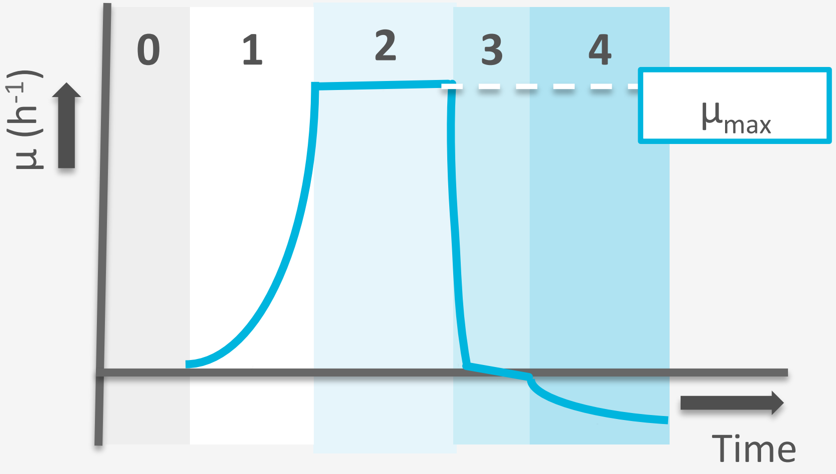
No removal

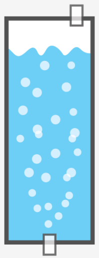
All nutrients in excess

Batch

0	**All nutrients in excess, before inoculum**
1	**Inoculum added, lag phase** Adaptation period, $\mu < \mu_{max}$
2	**Exponential growth phase** Substrate in excess, $\mu = \mu_{max}$
3	**Stationary phase** Substrate depleted, $\mu = 0$
4	**Death phase** Cells start to die, $\mu < 0$







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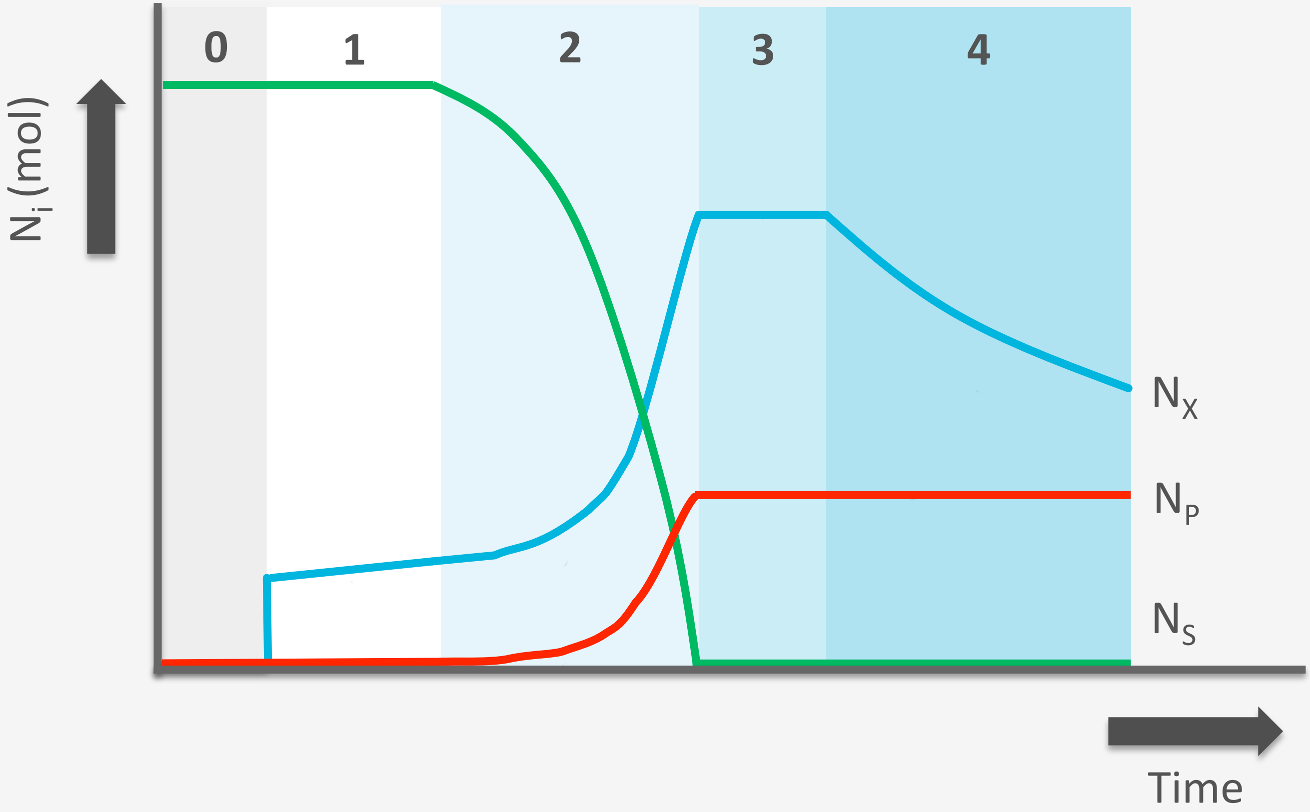

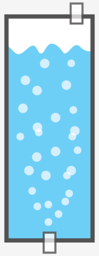

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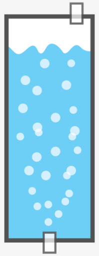

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- Simple
- High growth rate cells
- Short process

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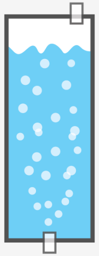
- Limited control environment
- Max growth rate is usually not max production

Batch



Biomass balance:

No in and outflow

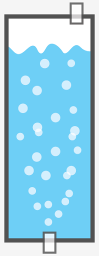
$$\frac{d(V_L(t)c_x(t))}{dt} = \mu(t)V_L(t)\,c_x(t) + F_{in}C_{x,in} - F_{out}C_{x,out}$$

$$\mu(t) = \mu_{max}$$

$$\frac{dN_x(t)}{dt} = \mu_{max}N_x(t)$$

$$N_x(t) = N_x(0)e^{\mu_{max}t}$$

Batch



Biomass balance:

$$\frac{d(V_L(t)c_x(t))}{dt} = \mu(t)V_L(t)\,c_x(t)$$

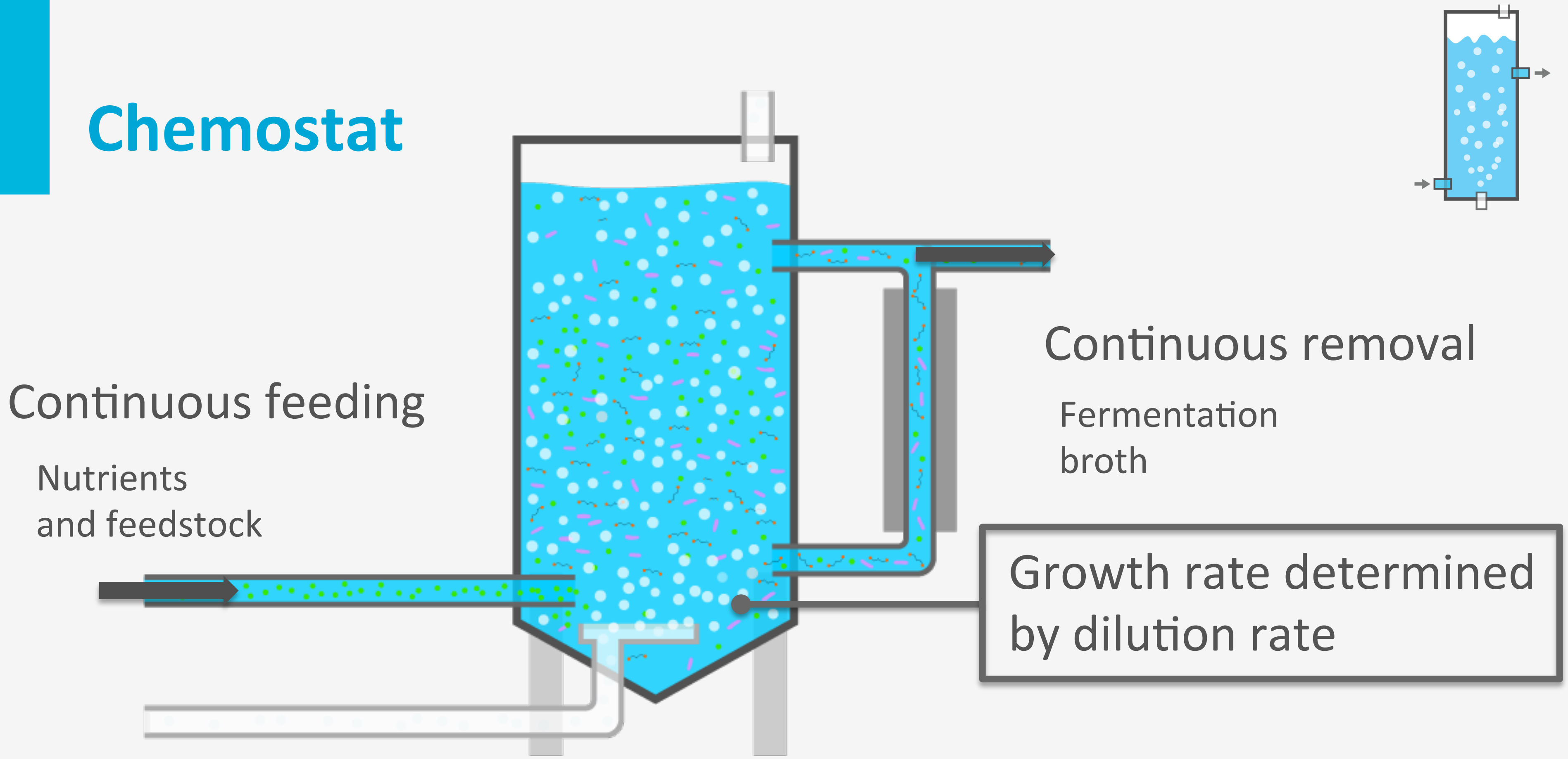
$$N_x(t) = V_L(t)\,c_x(t)$$

$$\mu(t) = \mu_{max}$$

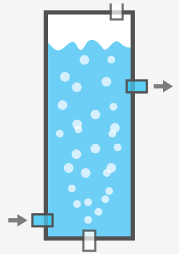
$$\frac{dN_x(t)}{dt} = \mu_{max}N_x(t)$$

$$N_x(t) = N_x(0)e^{\mu_{max}t}$$

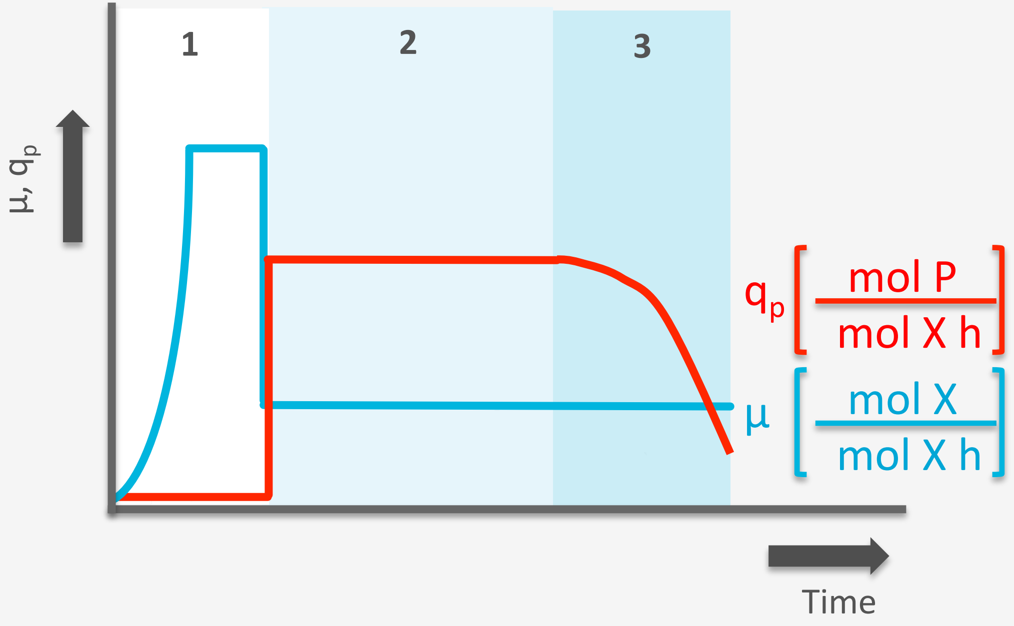
Chemostat


Continuous feeding
Nutrients
and feedstock
Continuous removal
Fermentation
broth
Growth rate determined
by dilution rate

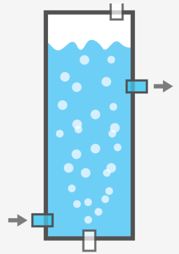
Chemostat



1	**Start-up phase (batch)** $\mu = \mu_{max}$, q_p = low
2	**Steady state phase** $\mu = \mu_{opt}$, $q_p = q_{p,opt}$
3	**$q_{p,opt}$ decreases**



Chemostat



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- Steady state
- Controlled environment
- Optimal production conditions

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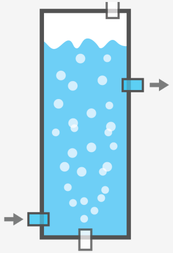
- Takes time to start up
- Loss of production capacity
- Contamination risk

Chemostat



Biomass balance:

Steady state

$$\frac{dV_L(t)c_x(t)}{dt}\left[\frac{mol}{h}\right] = \mu V_L c_x \left[\frac{mol}{h}\right] + F_{in} c_{x,in} \left[\frac{mol}{h}\right] - F_{out} c_{x,out} \left[\frac{mol}{h}\right]$$

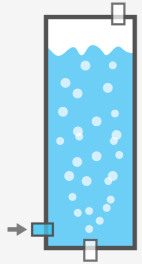
$$V_L c_x \quad [mol\ X\ present\ in\ the\ vessel]$$

Ideal broth outflow: $c_{x,out} = c_x$
Biomass concentration inflow: $c_{x,in} = 0$

Dilution rate:

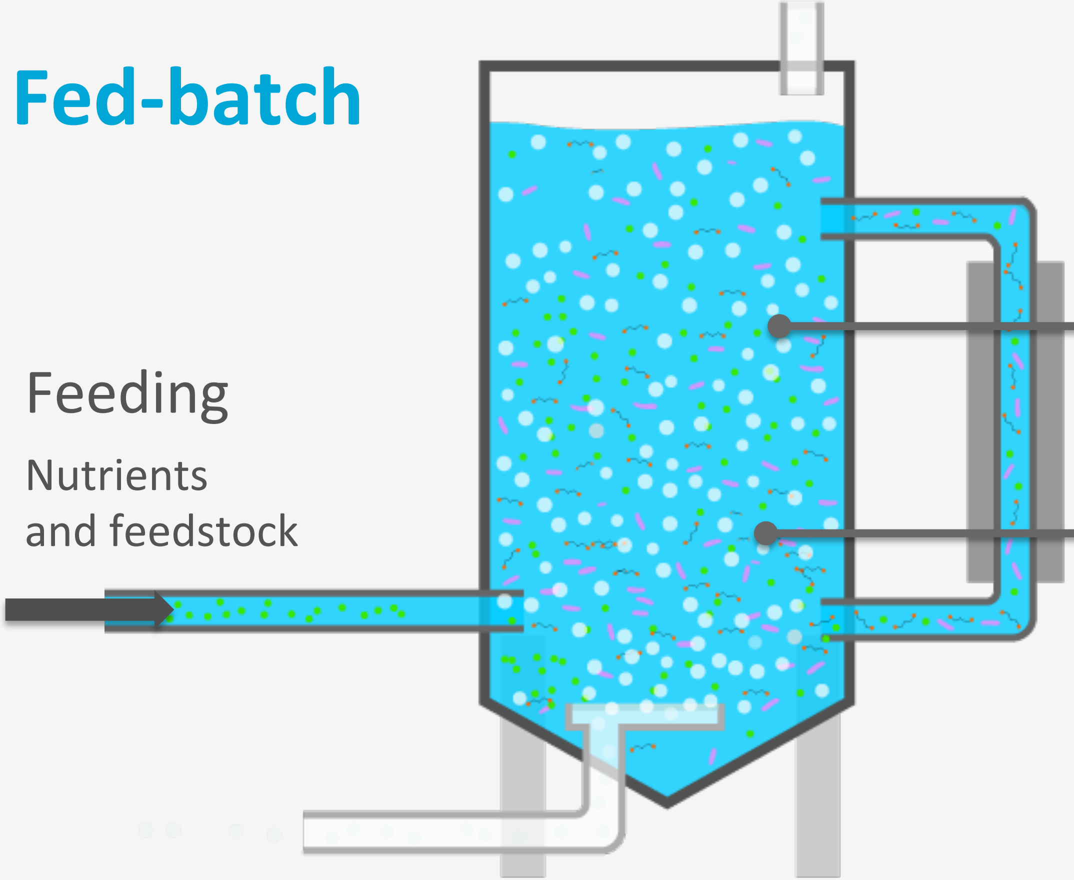
$$\mu_{ss} = D = \frac{F_{out}}{V_L}\left[\frac{m^3/h}{m^3}\right]$$

Fed-batch



Feeding

Nutrients
and feedstock



Cell growth is limited by the supply of substrate

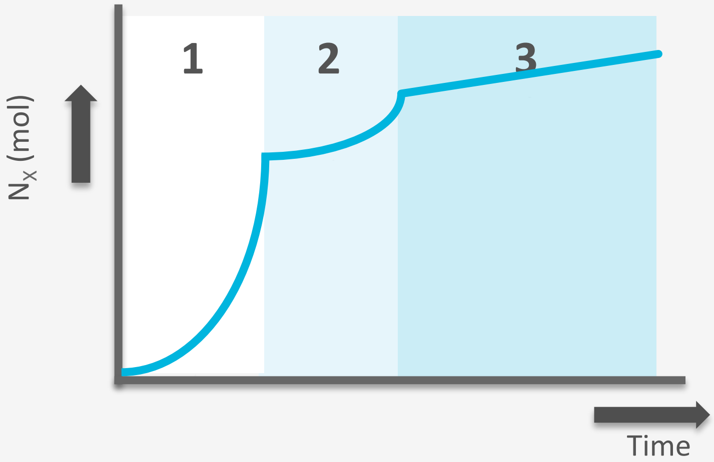
All nutrients in excess

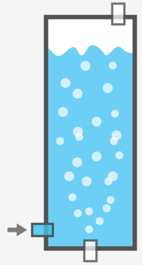
Stopped when production rate much

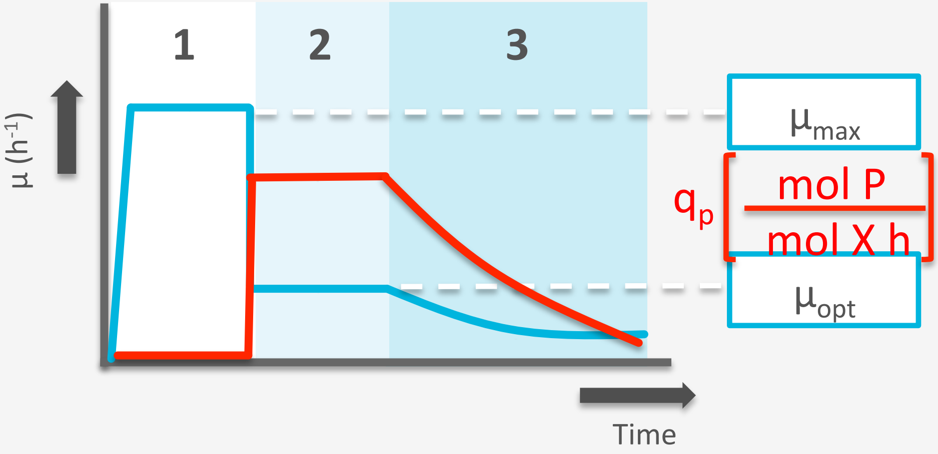
Fed-batch phase

Fed-batch

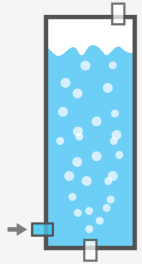
1	**Start-up phase (batch)** $\mu = \mu_{max}$
2	**Feed phase** $\mu = \mu_{opt}$
3	**Transport limitation** $\mu < \mu_{opt}$







Fed-batch



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Simple set-up

Long cycles

Good conditions for production

High product titer

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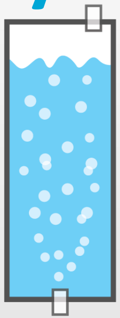
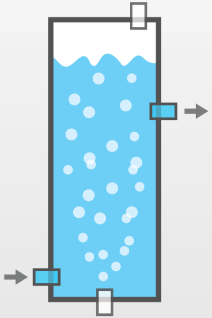
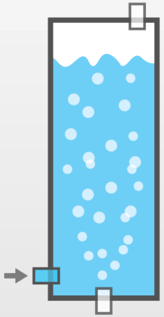
Not as optimal as chemostat

Operation in industry







	Batch	Chemostat	Fed-batch
Operation time	+	+++	++
Maintaining sterility	+++	+	++
Product titer	+	++	+++
Productivity	+	+++	++
Employed in industry	++	+	+++

See you in the next unit!