FDE 328
INDUSTRIAL MICROBIOLOGY

Production Parameters

Yield Coefficients for Cell Mass and Product Formation

- Microorganism growth and product formation are bioconversion processes.
- Chemical nutrients are converted into cell mass and metabolites.
- In order to explain the relationships between nutrients and energy sources, and cell mass and products formed, it is necessary to know the efficiency of the yield.

Yield Coefficients for Cell Mass and Product Formation

- Cell mass and product formation by microorganisms can be described quantitatively by yield coefficients expressed as the mass of cells or product formed per unit mass of substrate consumed, $Y_{X/S}$, and $Y_{P/S}$, for cells and product, respectively.

- With the yield coefficients, the material balance equations for cells, substrate, and product can be straightforwardly formulated.

- **$Y_{X/S}$;** the yield coefficient for cell mass
- **$Y_{P/S}$;** the yield coefficient for product

- The cell mass yield coefficient and the product yield coefficient are $Y_{X/S}$, and $Y_{P/S}$, respectively.

Yield Coefficients

- Yield coefficients are calculated by measuring the substrate consumed, the product and the cell mass formed in a given time period.

$$Y_{x/s} = \frac{\Delta X}{\Delta S}$$

$$Y_{p/s} = \frac{\Delta P}{\Delta S}$$

Yield Coefficients

- These values represent the observed yield coefficients. (experimental determination)
- It is also possible to calculate the theoretical yields of cell mass and products based on the substrate of interest.
- Although the meaning of theoretical cell yield is still debated, these values are valued as a standard measure for organizing experiments and interpreting results.
- There are two commonly used methods for calculating the theoretical cell yield on carbon and energy source.
  - Current electrons
  - ATP's constant yield concept.

Yield Coefficients

- Let's consider the overall stoichiometric equation for growth and production:

$$sS + nN + oO_2 \longrightarrow X + pP + wH_2O + eCO_2$$

- where **S**, carbon source; ***N***, nitrogen source; ***X*** , cell mass; ***P***, product and **s**, *n*, ***o***, ***p***, ***w***, ***e*** are stoichiometric coefficients.

- The theoretical yield coefficients can be determined from the above stoichiometry with known chemical formula for ***S***, ***N***, ***X*** and ***P***.

Yield Coefficients

- Calculation of theoretical product yield requires knowledge of cytoichiometry for product formation.
- For this, let's take the example of the conversion of glucose to ethanol. In the case of ethanol production from glucose, the theoretical yield is determined to be **0.51 g of ethanol/g of glucose** based upon the following stoichiometry:

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

180 → **2x46 (=92)**

From 100 grams of glucose → **51.1 g ethanol**

- Here, the maximum conversion is **2 moles of ethanol / 1 mol of glucose** or **0.51 g of ethanol / g glucose**.
- In practice, this theoretical yield cannot be reached, as some of the substrate is consumed in the formation of cell mass and other by-products. But it may be very close.
- 90-95% of the theoretical yield in ethanol production can be easily reached.

- **Theoretical yield** is calculated based on the stoichiometry of the chemical equation.
- The **actual yield** is experimentally determined.
- The **percent yield** is determined by calculating the ratio of actual yield to theoretical yield.

Productivity in Batch Fermentation

- **Volumetric productivity (V_p);** Volumetric product efficiency (volumetric productivity) is an important index for evaluating the overall performance of the process, and can be defined as product produced per unit volume of fermentation medium per unit time. It is expressed as the product in g per liter volume per hour.

- (V_p; $g.L^{-1}.h^{-1}$).

- The productivity of batch fermentation is calculated by the final concentration of biomass or product being produced divided by the complete time of batch, which includes fermentation time and turnaround time (time for emptying, cleaning, sterilizing, and refilling).

- In the batch process, it is necessary to calculate the productivity for the entire process time.

- This time includes not only the fermentation time, but also the times for unloading, washing, filling and sterilizing the fermentor.

- This time interval can be as short as 6 hours in yeast fabrication and as long as 200 hours in antibiotic production.

Productivity

- In batch fermentation, the process efficiency (**overall productivity**) is expressed by a line extended from the starting point of the fermentation to the end point.

- **Maximum productivity** is indicated by a similar line that is extended tangent to the growth curve from the starting point.

Productivity

- Total time for fermentation;

$$t = \frac{1}{\mu_{max}} \ln\frac{X_f}{X_0} + t_D + t_B + t_L$$

- where;
- *t_D , t_B , t_L are exchange, standby and lag phase (for batch culture and sterilization) times, respectively.

- *X_0 and X_f are the initial and final cell concentrations.