Stoichiometry of Microbial Growth and Product Formation

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• **Topic Outcomes**
  - Describe the importance of stoichiometry in the conversion of substrate into product and cellular material.
  - Perform stoichiometry calculation for the cell growth and product formation.

• **References**
• Introduction
• Stoichiometric Calculation using Elemental Balances
• The law of conservation of mass:
  – Mass can neither be created nor destroyed

Mass in through system boundaries + Mass generated within system
Mass consumed within system − Mass accumulated within system
Conversion of substrate, oxygen and nitrogen for cell growth:

\[ C_xH_yO_zN_i + aO_2 + bHgO_hN_i \rightarrow cCH_{\alpha\beta}O_\deltaN_\delta + dCO_2 + eH_2O \]

If we provide \( X \) kg substrate, how much cell is produced?

How much oxygen is needed to produce \( B \) kg day\(^{-1}\) of cell?

If we provide \( X \) kg C-source substrate and \( Y \) kg N-source substrate, when all the C-source substrate is consumed, will there be N-source substrate left in the broth at the end of the culture?

How much substrate is required to produce \( Z \) tonnes of product per year?
Introduction

• General stoichiometric equation for cell growth is:

\[ C_w H_x O_y N_z + a \, O_2 + b \, H_g O_h N_i \rightarrow c \, CH_\alpha O_\beta N_\delta + d \, CO_2 + e \, H_2 O \]

• \( a, b, c, d, \) and \( e \) are stoichiometric coefficients

• \( C_w H_x O_y N_z \) is the C-source, e.g., \( C_6 H_{12} O_6 \) (glucose)

• \( H_g O_h N_i \) is the N-source, e.g., \( NH_3 \) (ammonia)

• \( CH_\alpha O_\beta N_\delta \) is the molecular formula for cell (based on one carbon)
  – why C, H, O, N ?
  – what are the values of \( \alpha, \beta \) and \( \delta \) ?

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Introduction

• Cellular content: 70% is water, the rest is dry matter.
• Thus, the cell composition is expressed on a dry basis.
• 90% – 95% of cell is accounted for by C, H, O and N.
• Cell composition does not vary much.
• General formula: CH$_{1.8}$O$_{0.5}$N$_{0.2}$
• MW of cell = 24.6 + ash (5% – 10%)
Exercise 1

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Stoichiometric Calculation
- Elemental Balances

- a, b, c, d, and e can be determined by elemental balances:
  - C balance: \( w = c + d \)
  - H balance: \( x + bg = c\alpha + 2e \)
  - O balance: ?
  - N balance: ?

- We have 5 unknown but 4 balance equation. Therefore,

\[
\text{Respiratory quotient (RQ)} = \frac{\text{moles of CO}_2 \text{ formed}}{\text{moles of O}_2 \text{ consumed}}
\]

\[ RQ = \frac{d}{a} \]
Stoichiometric Calculation - Elemental Balances

• Exercise 2

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Stoichiometric Calculation - Elemental Balances

We can now answer

\[ C_w H_x O_y N_z + a O_2 + b HgO_h N_i \rightarrow c CH_\alpha O_\beta N_\delta + d CO_2 + e H_2 O \]

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Stoichiometric Calculation - Elemental Balances

• Exercise 3

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