The Effects of the Rate of Nitrogen Consumption on the Duration of Alcohol Fermentation Remain Unknown

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BIOL398-05/MATH388-01
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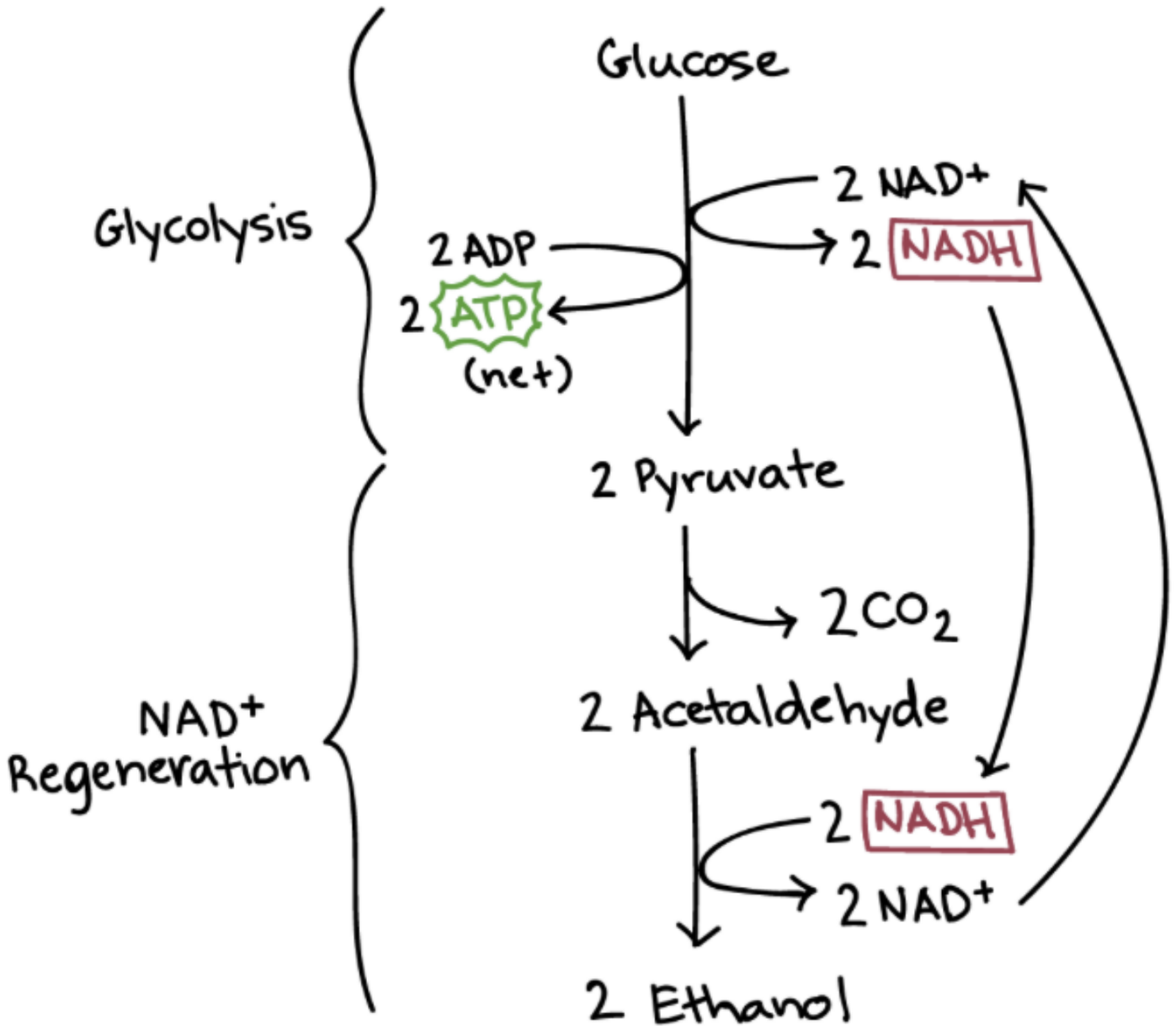
Outline

- **Background Info: Alcohol fermentation in *Saccharomyces cerevisiae***
- **Hypothesis: Rate of nitrogen consumption controls alcohol fermentation time**
- **Multiplicative Nutrient Model: Relating model to ter Schure (1995) and Albertin et al. (2011)**
- **Model fails to support results of ter Schure (1995) and Albertin et al. (2011)**
- **Further research into factors controlling rate and time of alcohol fermentation**

Saccharomyces cerevisiae play a vital role in ethanol production

- **Used in food and biofuel industry to convert sugars to ethanol**
- **Done through the process of alcohol fermentation (AF)**
  - **Main process yeast use to obtain energy (Dombek & Ingram, 1987)**
  - **Occurs in anaerobic conditions**
  - **Results from interaction of various environmental, genetic, and metabolic parameters (Albertin et. al, 2011)**

Alcohol fermentation begins with the breakdown of glucose



Glucose:

- **Important macronutrient**
- **Used as source of sugar**

Glycolysis:

- **Produces ATP**
- **Uses NAD+ as electron acceptor**

Fermentation:

- **Results in ethanol & CO2 production**
- **Regenerates NAD+**

https://www.khanacademy.org/science/biology/cellular-respiration-and-fermentation/variations-on-cellular-respiration/a/fermentation-and-anaerobic-respiration

S. cerevisiae are facultative anaerobes

- **Switch between anaerobic (fermentation) and aerobic (cellular respiration) pathways**
    - **Allows for maximization of ATP production**

- **When glucose scarce —> ethanol used as source of carbon, requiring the shift to cellular respiration**
    - **Converts sugar to ATP and CO_2 (Gasmi et. al, 2014)**

- **Many experiments performed on how to increase the rate of fermentation in yeast**

Population size drives alcoholic fermentation in industrial *S. cerevisiae*

- **Albertin et. al (2011) evaluated relationship between fermentation kinetics and population dynamics**
    - **Used batch reactor model**

Key Results:

- **High fermentation speed (Vmax) significantly correlated with increased population size (K)**
- **K and biomass positively correlated**
- **K and nitrogen consumption positively correlated**

Set of factors that regulate alcohol fermentation time remain unknown

Alcohol Fermentation (AF) time

- **beginning of CO_2 release to the point when CO_2 production rate drops below 0.5 g $liter^{-1}$ h^{-1}** (Albertin et. al, 2011)

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The rate of nitrogen consumption governs alcohol fermentation time

Predictions:

Increase in nitrogen consumption will cause CO2 production rate to reach Vmax sooner then crash

Assumptions:

- **As population size increases, nitrogen consumption increases**
- **As population size increases, glucose decreases—> switch to cellular respiration**

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Nitrogen and glucose both required by yeast for alcohol fermentation

Two Nutrients:

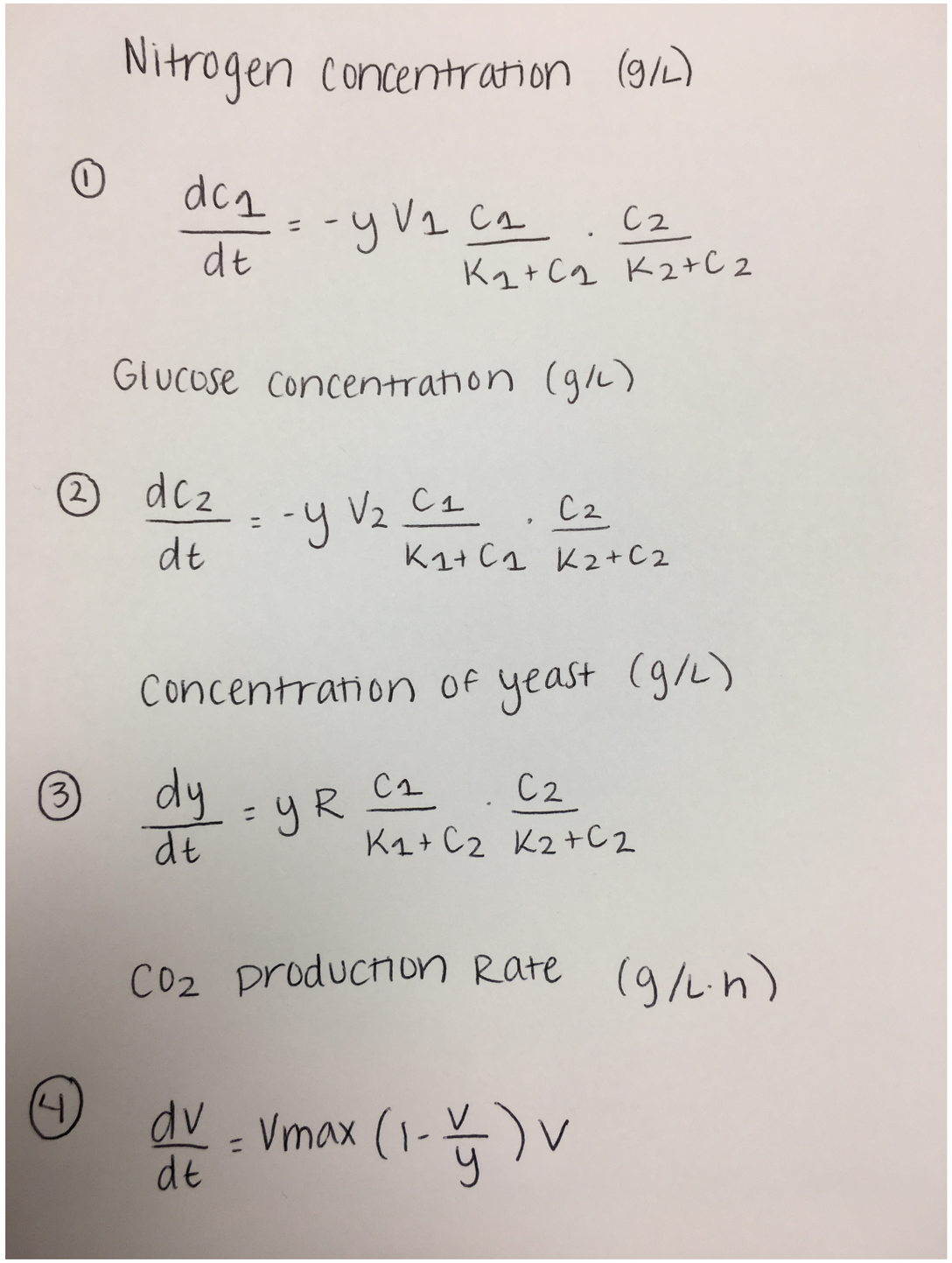
1. Nitrogen:

- **Increase in ammonia concentration in feed from 29 to 61 mM —> increase in biomass, showing ammonia limitation**
- **Ammonium found to be limiting at NH_4^+ concentrations of 29 and 44 mM (ter Schure et. al, 1995)**

2. Glucose:

- **Source of carbon for alcohol fermentation (Albertin et. al, 2011)**

Multiplicative model acts as best representation



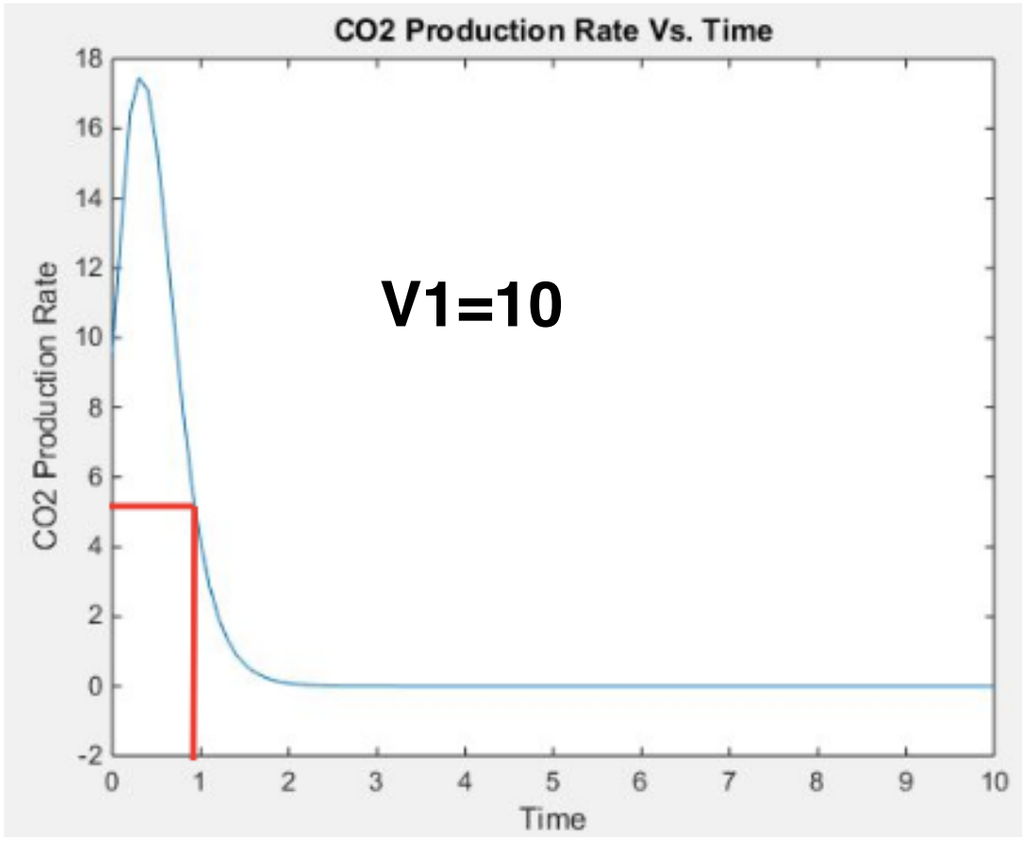
State Variables:

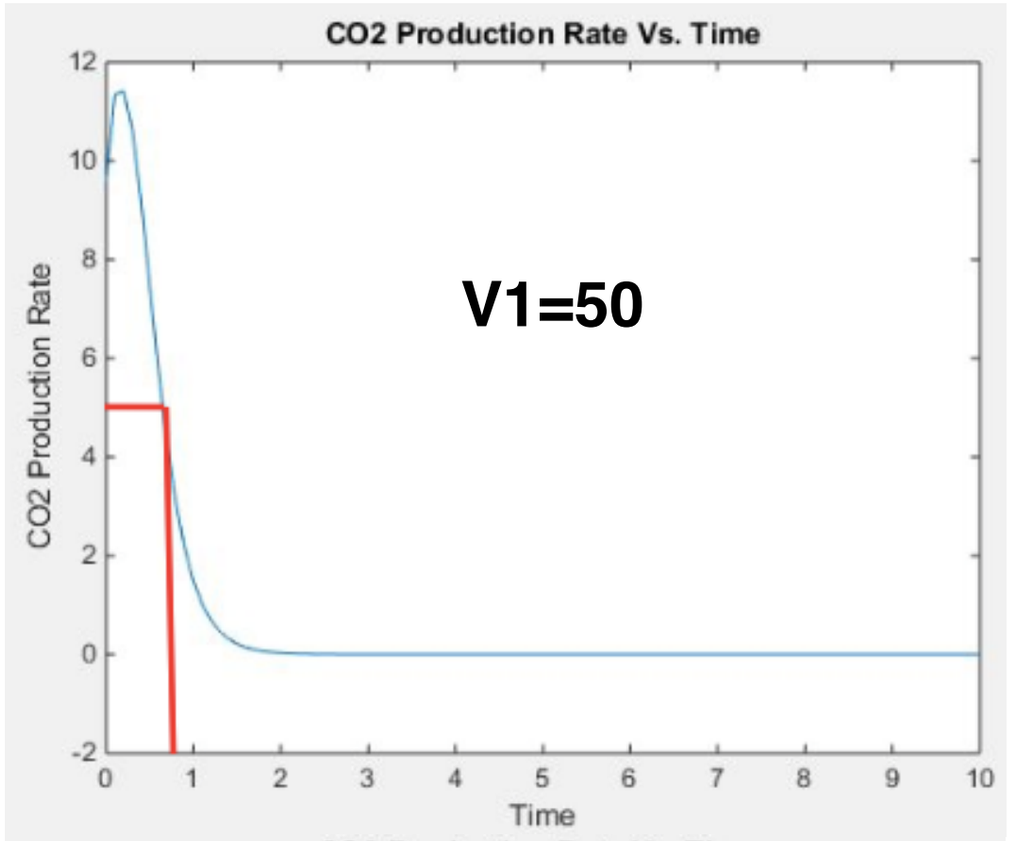
c1= concentration of nitrogen
c2= concentration of glucose
y= concentration of yeast
V= amount of CO2 produced

Parameters:

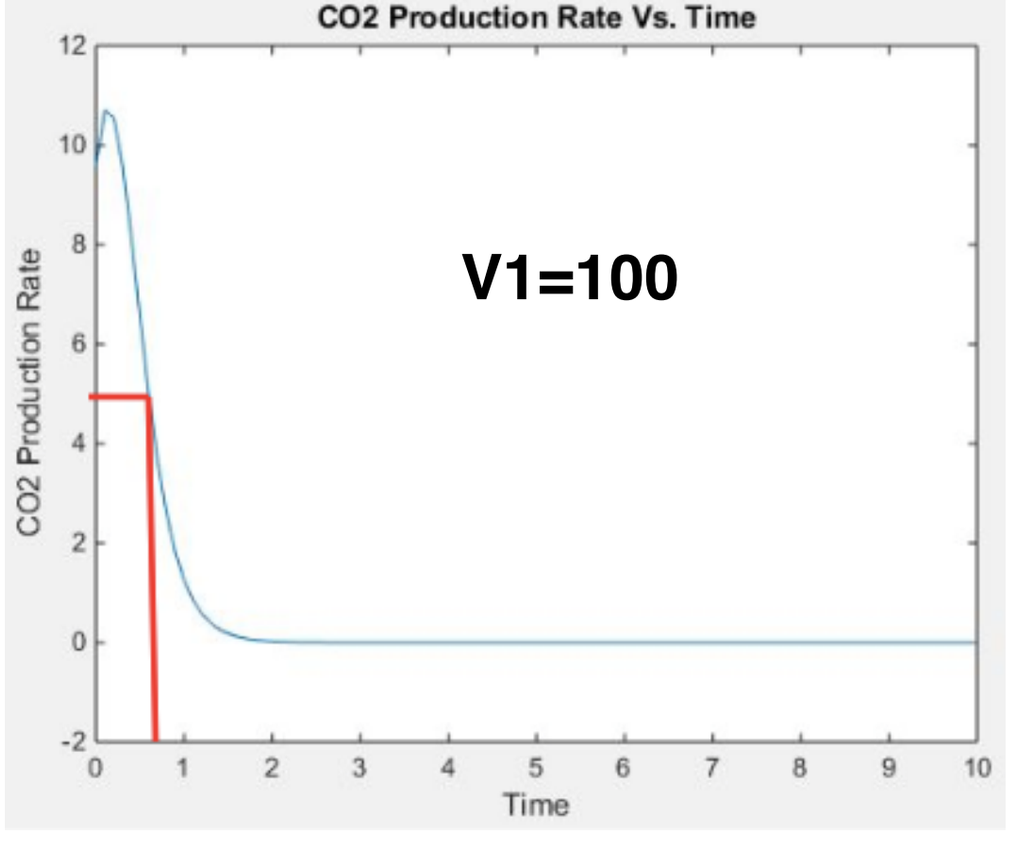
- **V1= rate of nitrogen consumption**
- **V2= rate of glucose consumption**
- **K1= metabolic constant (1/2 Vmax of nitrogen)**
- **K2= metabolic constant (1/2 Vmax of glucose)**
- **R= replaces relative efficiency**
- **Vmax= max rate of CO2 production**

While CO2 production rate seems to crash faster as V1 increases, results remain inconclusive





All parameter values (except V1) remained constant at V2= 10, V3= 4, K1= 2, K2= 2, R= 5



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Unlike model Albertin et. al (2011) and ter schure (1995) findings indicate that rate of nitrogen consumption plays a role in AF time

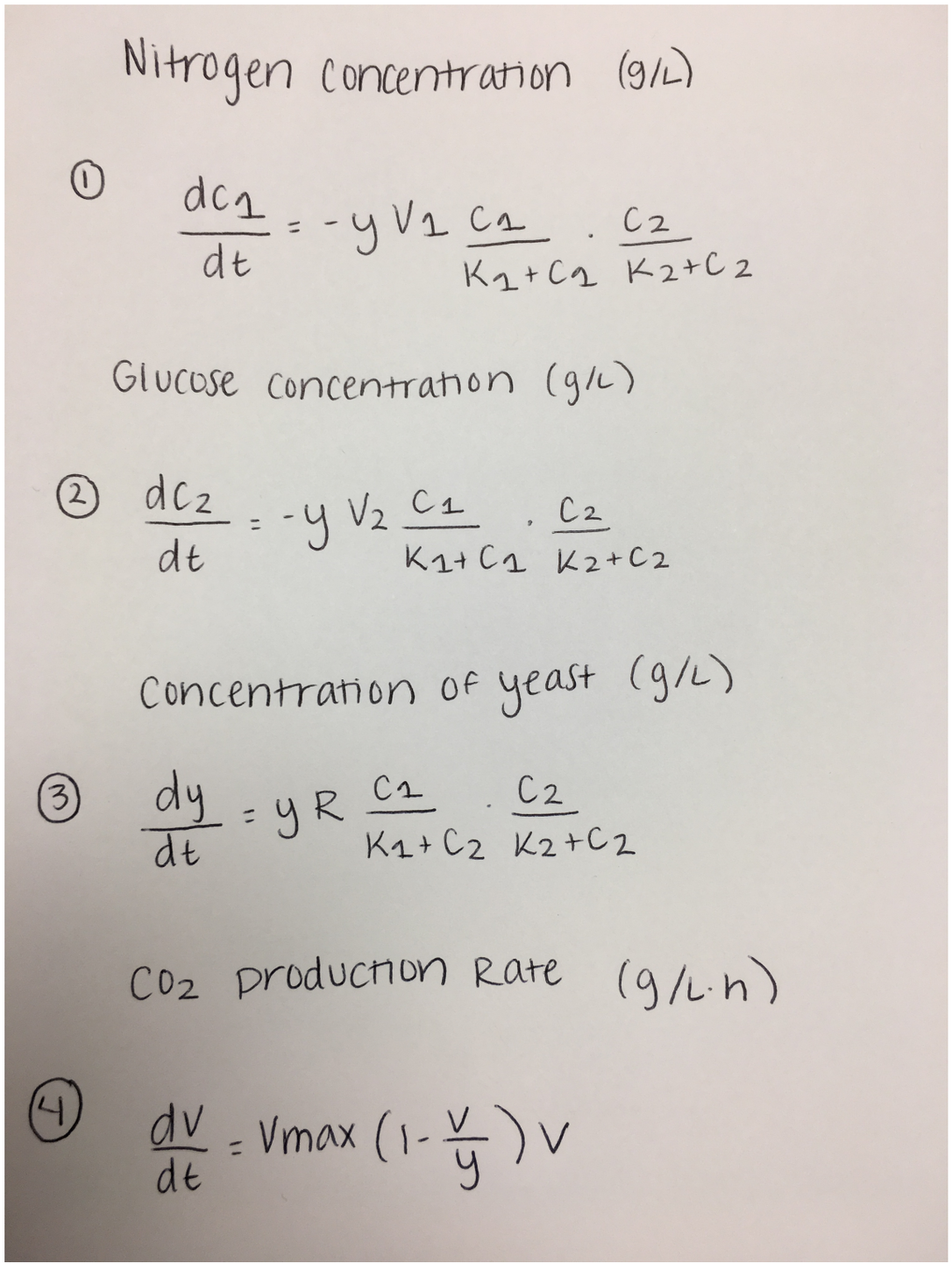
- **Nitrogen consumption and population size positively correlated**

- **Population size drives alcohol fermentation** **(Albertin et. al, 2011)**

- **Increase in ammonia related to increase in biomass** **(ter Schure et. al, 1995)**

- **Biomass positively correlated to population size** **(Albertin et. al, 2011)**

Rate of nitrogen consumption is not the only factor that governs AF time



Changes in the rate of glucose consumption will have similar effects as changes in the rate of nitrogen consumption.

Summary

- **Identifying the factors that control the rate and duration of alcohol fermentation in *S. Cerevisiae* important issue**
    - **main source of energy production in yeast**
    - **allows for ethanol production for food and biofuel industry**

- **Set of factors that regulation the rate and time of alcohol fermentation remain unknown**

- **While model fails to support results of papers, possible rate of nitrogen consumption may still influence AF time**

- **Rate of glucose consumption may play a role as well**

Further study into the factors that affect AF needed

- **Results of model need verification**
    - **rate of nitrogen consumption may not be only factor affecting AF time —> verify by testing changes in rate of glucose consumption**
- **If rate of nitrogen consumption does influence AF time**
    - **further study into factors controlling rate of nitrogen consumption needed**
    - **since rate of nitrogen consumption can’t be set by experimenter**

Acknowledgments

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References

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