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Glucose Concentrations Effect on Rate of Fermentation in Yeast

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The glucose concentration has been shown to affect the rate of yeast fermentation and carbon dioxide production. We hypothesized if there is a moderate concentration of glucose it will cause fermentation rates to increase and with it an increase production of carbon dioxide. We used the correlation statistical test to confirm there was a strong positive correlation between glucose concentrations and the rate of fermentation. Our results show that 80% glucose concentration in yeast fermentation produced the most amount of carbon dioxide.

Introduction

Sugar aids in fermentation, it acts as an input to cellular respiration. Different studies have been done to explore which types of sugar and/or concentrations of sugar best aids in fermentation. Glucose is the primary input of glycolysis which then continues to fermentation when oxygen is not present, fermentation then produces carbon dioxide. In cellular respiration glucose and oxygen are used to produce ATP, carbon dioxide and water. When oxygen is not present in the cell, cells revert to fermentation as a way to still use glucose to produce ATP and carbon dioxide. Yeast cells are used for their high fermentation rates as an aid in producing alcohol, soy sauce and bread. In a study published in 1992 it reported that moderate concentrations of glucose produced the maximum amount of ethanol, a byproduct of fermentation, therefore it produces the fastest rate of fermentation (D'Amore,1992). Further investigations have found that moderate amounts of glucose when compared to high amounts of glucose have better results in effectiveness of cellular respiration (Verstrepen et al., 2004). Glucose concentration increases fermentation production in yeast, until the saturation gradient is reached causing a stop in carbon dioxide production (Hewitson and Hill, 2018). We chose to study different concentrations of glucose because studies have already shown that glucose is the best sugar for fermentation rates (Deken,D. 1966). Because of this data we decided concentration rates was the best way to study the effects of sugar on fermentation in yeast. Our experiment aimed to answer the question, how do different concentrations of glucose effect fermentation and carbon dioxide production in *Saccharomyces cerevisiae* yeast?

To test the effects of glucose concentration on fermentation rates we added different amounts of glucose concentration to yeast and recorded carbon dioxide production. We hypothesized that if there was a moderate concentration of glucose then fermentation will increase causing an increase production of carbon dioxide because moderate amounts of glucose will create an optimal fuel for

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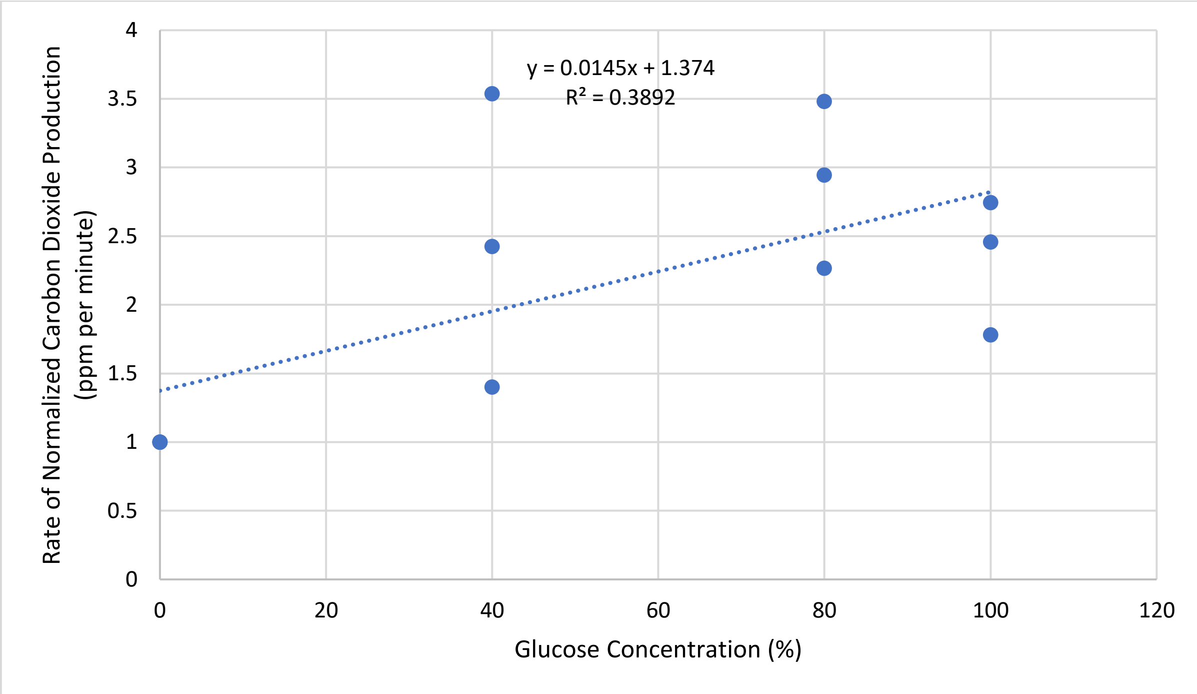

Figure 1: *Figure 1 represents the rate of carbon dioxide production, in ppm per minute, when altered by glucose concentration. Zero percent concentration of glucose remained the most consistent throughout the trials, while in comparison, 100 percent glucose concentration produced the least amount of carbon dioxide compared to the other trials containing glucose.*

cellular respiration. We predicted that the moderate glucose concentration will result in a higher rate of carbon dioxide production due to the balanced input for cellular respiration.

Method

In the experiment, we used *Saccharomyces cerevisiae* yeast due to it being easily accessible and well-studied. Since we were interested in the effect of glucose on fermentation, we used different glucose concentrations to study the direct relationship between carbon dioxide production as a byproduct of fermentation and glucose concentrations. To study the effects of glucose on fermentation we followed the protocol for making a yeast solution (Shaw & French, 2018). Three trials for each concentration were conducted, each with different amounts of glucose and deionized water to compare carbon dioxide production (see table 1). To start, we recorded our results in ppm (parts per million) per minute after allowing the carbon dioxide probe to warm up for five minutes.

We used water as a negative control which is used as a baseline of fermentation to compare to our various glucose concentrations All solutions of glucose begin at 0.3 molar as raw value. The glucose solution was added to the respiration chamber and carbon dioxide production was recorded for seven minutes in LoggerPro, sampling 10 samples per minute, (in ppm per minute) while the magnet stirred the solution at a medium rate. A new yeast solution was made for each trial. We covered the graduated cylinder and inverted it several times to mix the solution. All three trials

Sugar solution percentage	0%	40%	80%	100%
Glucose (0.3 M)	0 mL	4 mL	8 mL	10 mL
Water (deionized)	10 mL	6 mL	2 mL	0 mL
Yeast solution	10 mL	10 mL	10 mL	10 mL

Table 1: *solution concentrations*

were completed and recorded three times. We used to excel to create a scatter plot graph because it was the best way to efficiently display our data since our data portrays fermentation rates over several trials. After normalizing our data by dividing all the slopes by the 0 ppm value for that trial, we found that the best fit is a linear model (figure 1). Finally, we used a correlation analysis to test the relationship of glucose and carbon dioxide production in fermentation.

Results

The correlation of the graph is positive. On the normalized graph, the trials that included 40 percent glucose concentration varied the most in relation to carbon dioxide production rates. The trials that included 80 percent glucose concentration provided a CO2 production rate that was generally the highest in most trials. A surprising change happens when 100 percent glucose concentration was mixed with the yeast. The rate of CO2 production dropped, this large drop in the rate of CO2 production is due to the yeast reaching a saturation gradient which means the yeast cannot produce anymore CO2 (see figure 1). We used a correlation statistical test to conclude that there was a relationship between the concentration of glucose and the rate of fermentation. The two groups were positively strongly correlated, $r(11) = .624$, $p = .030$.

Discussion

As stated, we hypothesized that if there was a moderate concentration of glucose then fermentation will increase causing an increased production of carbon dioxide because moderate amounts of glucose will create an optimal fuel for cellular respiration. Based on our results, the hypothesis was supported. Of the various concentrations tested (see table 1), the highest production of carbon dioxide occurred during the tests containing 40% and 80% glucose, as opposed to 100% glucose and water. The concentrations were altered to answer the question, how do different concentrations of glucose effect fermentation and carbon dioxide production in *Saccharomyces cerevisiae* yeast? Our values supported the hypothesis by producing high amounts of carbon dioxide during the seven-minute trial, but the production slowed down significantly after reaching 1322 ppm (see figure 1). The decreased production of carbon dioxide resembled the effects of a cell reaching a saturation gradient, meaning that the transport availability is maximized because all of the solute-binding sites have been filled (Alberts et al., 2002). Several other trials testing the production of both carbon dioxide and ethanol production produced similar results, especially when using *Saccharomyces cerevisiae* yeast specifically (Hagman et al., 2014).

Though there were no outliers and our data showed an overall trend of being positively correlated, we consider the concentration of glucose used as a possible explanation of data. Though the concentrations of 40% and 80% showed the highest productions of carbon dioxide, the 100% solution began to decrease production. This may have occurred due to the 0.3 molar glucose used. If a more concentrated solution of glucose was used, it is probable that the moderate solutions would reach a saturation gradient early on, while the 100% solution would either level out or decrease in carbon dioxide production. In terms of possible errors, we only encountered one situation that could have affected our results. During our first trial, our trial with 100% water was producing carbon dioxide for a short period of time before we began our Logger Pro trial. Though the ppm starting value for that trial was not consistent with the starting range of the following two trials, the overall data showed a consistent trend despite our delayed start time. That being said, we encourage future groups to consistently begin their trial immediately following the insertion of the carbon dioxide probe into the respiration chamber so as to record optimal results.

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