JUBLI
Journal of Undergraduate Biology Laboratory Investigations

Sucrose increases the emission of CO_2 during yeast (Saccharomyces cerevisiae) fermentation faster than glucose

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The use of certain sugars, such as monosaccharides and disaccharides, have been used in fermentation to increase its rate. Studies have shown that certain types of sugar and yeast have faster rates of fermentation than others. We decided that a monosaccharide's (glucose) rate of fermentation would increase more rapidly than a disaccharide's (sucrose) rate of fermentation. We organized a total of six trials, three for each solution, and compared the emission of CO_2 produced. We anticipated that those interested, such as brewers and distillers, in the use of simple sugars to increase the rate of fermentation would be interested in which sugar type, monosaccharide or disaccharide, increased CO_2 emission as a result of increasing fermentation.

Introduction

Bakers yeast *(Saccharomyces cerevisiae)* are eukaryotic organisms that produce waste products such as carbon dioxide and ethanol when they go through fermentation. A special trait of *S. Cerevisiae* is its ability to convert sugar into energy in both aerobic and anaerobic conditions; however, it is more commonly used in anaerobic conditions for fermentation (Dashko et al, 2014). The purpose of fermentation is to create energy to fuel organisms in the absence of oxygen, also known as anaerobic respiration. During this process, simple sugars are broken down to make ethanol, often using the Crabtree effect. The Crabtree effect, also known as the contra-effet Pasteur, is the opposite of the Pasteur effect and represses aerobic respiration in favor of high fermentation rates and has been shown to effect *S. Cerevisiae* metabolic rates (Deken, 1966).

There are two types of sugars that yeast can feed off to perform anaerobic respiration. Monosaccharides are composed of the simplest of sugars whereas disaccharides are a covalent-bonded form of two monosaccharides. We tested whether yeast ferments at a faster rate with glucose (a

monosaccharide) or with sucrose (a disaccharide). Our hypothesis was that the rate of fermentation would be slower for a solution of yeast with sucrose than one of yeast with glucose since sucrose consists of two units and would take more time to break down. We knew whether our hypothesis would be supported based on the amount of carbon dioxide present during our trials. If the rate of carbon dioxide increased more rapidly during the glucose trials than the sucrose trials, then our hypothesis would be supported. However, if there was less or equal amounts of carbon dioxide in the glucose trial, then our hypothesis would not be supported.

Methods

In order to measure the effect of sugar type on the rate of fermentation, we measured the rate of emission of CO_2 of both glucose-yeast solutions and sucrose-yeast solutions. Since CO_2 is a product of fermentation, we decided this was be the best method for measurement. We began by creating a yeast solution consisting of .6 grams of yeast and 10 mL of distilled water using the process shown in French and Shaw (2018). The first group tested was the glucose-yeast solution. We measured 10 mL of glucose and poured it into the yeast solution. Immediately following, a CO_2 probe was placed inside the beaker. We used LoggerPro to measure and record CO_2 emission for six minutes while collecting data every 10 seconds (LoggerPro3, 2016). This process was completed two additional times using the glucose-yeast solution and three times using the sucrose-yeast solution consisting of 10 mL of raw sucrose.

We fit a trendline to the graph of raw data collection of CO_2 vs. time in order to find a rate of fermentation in ppm/second. The slopes of each trendline for the glucose and sucrose groups were then placed on separate box-and-whisker plots to directly compare the rates of fermentation and sugar type. This type of graph allowed us to display the variability and range of our data in a concise manner. Using PAST3 software, we used an Unpaired t-Test to determine if the difference in values was because of chance or because the sugar type was directly influencing the rate of fermentation. We used an Unpaired t-Test because we found that our data was normally distributed using a Shapiro-Wilk normality test (Hammer & Harper, 2013).

Results

Both groups exhibited a positive rate of fermentation during each trial as shown in Figure 1. The average rate of fermentation of the glucose-yeast solution was 8.212 ppm/second. The average rate of fermentation of the sucrose-yeast solution was 13.731 ppm/second. The range of data for the glucose-yeast solution of 1.8175 ppm/second was lower than the range of data for the sucrose-yeast solution of 4.652 ppm/second. Furthermore, the overall range of data for the glucose-yeast solution was lower than that of the sucrose-yeast solution: the highest rate of the glucose trials (9.1644 ppm/second) was lower than the slowest rate of the sucrose trials (11.466 ppm/second).

An Unpaired t-test was conducted to compare the effect of sugar type on the rate of fermentation in a glucose-yeast solution and a sucrose-yeast solution. There was a significant difference between the two conditions; $t(5) = 2.10$, $p = 0.019$.

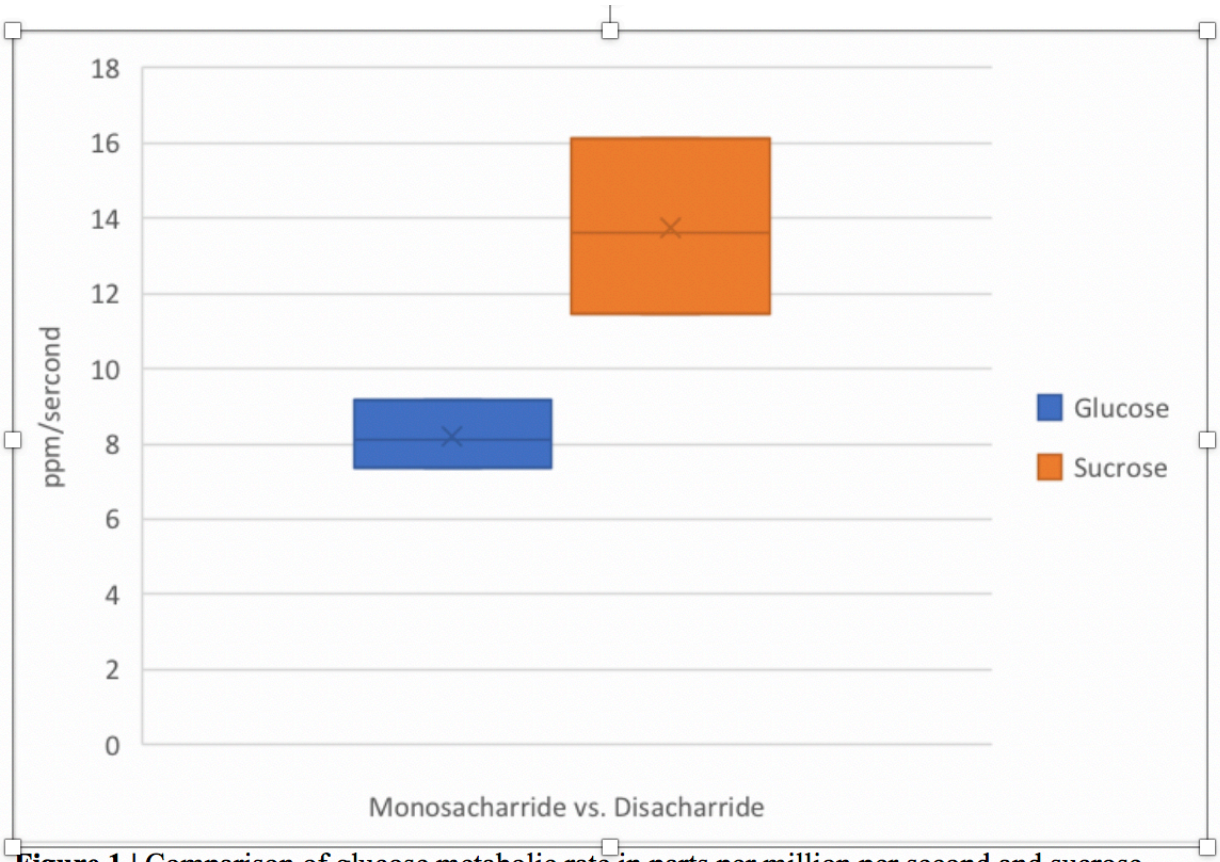

Figure 1 | Comparison of glucose metabolic rate in parts per million per second and sucrose metabolic rate in parts per million per second. The lowest rate for sucrose was greater than the greatest rate for glucose. The average rate for glucose was 8.212 ppm/second, and the average rate for sucrose was 13.731 ppm/sec.

Discussion

After our investigation comparing fermentation rate between monosaccharides (glucose) and disaccharides (sucrose), we found our hypothesis was not supported. Our data showed that CO_2 levels were higher in the sucrose trials than the glucose trials. Although our hypothesis was proven incorrect, statistical analysis showed that sugar-type significantly affected the emission of CO_2 during fermentation.

Our results were not consistent with findings from other papers. Another paper's findings, also comparing monosaccharide and disaccharide in fermentation, showed that the monosaccharide produced more CO_2 than the disaccharide although they used a different variety of sugars (Burnison et al., 2018). Another paper showed that glucose tends to be the faster and higher yielding sugar type compared to fructose, the other monosaccharide in sucrose (Emmerich, 1983).

Sucrose is one of the most commonly used sugars in the industry for fermentation of food and beverages. In *Saccharomyces cerevisiae,* there is an enzyme called invertase that catalyzes the hydrolysis of sucrose into both fructose and glucose which could explain why sucrose produced more carbon dioxide than just glucose (Marques et al., 2016). Some types of yeast lack the ability to properly process glucose in

anaerobic respiration because they lack the enzyme phosphofructokinase (Gancedo, 1971). This could explain why our yeast, *Saccharomyces cerevisiae,* did not perform as we had predicted. Potential errors, such as not effectively rinsing out the bottles in between trials, differing temperatures of sugars, and varying speeds of which the solution was stirred could have affected our results.

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