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Disaccharide Sugar, Sucrose, Results in Greater CO_2 Production in *Saccharomyces cerevisiae* Yeast Than

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Abstract

When fermentation occurs in the yeast *Saccharomyces cerevisiae*, sugar is broken down to produce products, such as carbon dioxide. A real-world application of this, winemaking, led us to believe that the type of sugar would affect the rate of production of carbon dioxide. Therefore, we hypothesized that monosaccharide sugars would initially produce carbon dioxide at a faster rate than disaccharide sugars, given that monosaccharide sugars have a lesser number of bonds needing to be broken. An experiment to test this hypothesis was then developed by measuring the carbon dioxide production rate between a monosaccharide sugar, glucose, and a disaccharide sugar, sucrose, when each were placed separately in a yeast solution. After three trials, we found that disaccharide sugars produce carbon dioxide at a faster rate than monosaccharide sugars, meaning the increased number of bonds in disaccharides results in a greater production of carbon dioxide.

Introduction

In most modern human delicacies, sugar can be considered commonplace. On average, a person consumes 53 pounds of sugar per year (World Health Organization, 2015). Sugars, which fall under carbohydrates, are essential for life because they are broken down into glucose, a necessary component for cellular respiration (Zhao et al., 2009). Sugars come in various forms, such as monosaccharides and disaccharides. Disaccharides consist of two monosaccharides connected by a covalent bond, whereas monosaccharides are simple sugars that cannot be hydrolyzed. In *Saccharomyces cerevisiae* yeast, fermentation occurs—meaning sugar is metabolized without oxygen present—resulting in the production of carbon dioxide, alcohol ethanol, and energy. This is a common process in winemaking.

This leads to the question of whether using monosaccharide or disaccharide sugars will result in a greater rate of fermentation, which in turn would result in a greater amount of the products of fermentation being produced. In a study conducted by Brown and Johnson, they observed that glucose, a monosaccharide, yielded a higher production of carbon dioxide and ethanol compared to galactose, a disaccharide (Brown and Johnson, 1970). The results from this study are parallel with our hypothesis. We hypothesize that monosaccharide sugars will produce carbon dioxide at a faster rate through fermentation than disaccharide sugars because of the lesser number of bonds needing to be broken. This will be proven if the initial rate of carbon dioxide production is greater in the monosaccharide and then slows down to the point of which the disaccharide carbon dioxide production succeeds it. If this hypothesis is not supported, disaccharide sugars will produce carbon dioxide at a faster rate, because the lesser number of bonds needing to be broken will not affect the rate of which the bonds are broken, and because of the greater amount of bonds in disaccharides. If monosaccharides and disaccharides produce carbon dioxide at the same rate, then no correlation between sugar type and rate of fermentation will be found.

Methods

In this experiment, we will test whether monosaccharides or disaccharides produce carbon dioxide at a faster rate. We will create a yeast solution containing .6 g of *Saccharomyces cerevisiae* yeast and 10 mL of water using the procedure from Shaw and French (Shaw and French, 2018). There will be a control group of a monosaccharide sugar, glucose, consisting of 10 mL of .3 M., and an experimental group of a disaccharide sugar, sucrose, consisting of 10 mL of .15 M. Each group will be placed in the yeast solution for 7 minutes, and the rate of carbon dioxide production will be measured using the carbon dioxide probe and LoggerPro (LoggerPro3, 2016). Carbon dioxide is a product of the process of fermentation, meaning the greater rate of carbon dioxide produced, the greater amount of fermentation taking place. Each trial will be performed 3 times. Using the data collected from the trials, a box and whiskers plot will be created to display the categorical data and convey the variability between the two types of sugars used in the experiment. This graph will show any outliers found, as well as the average carbon dioxide production rate of the each sugar.

The data measured was both nominal and quantitative, as well as unpaired. After determining that the data was normally distributed, an unpaired t-Test was conducted to compare the effect of the sugar type, monosaccharide or disaccharide, on the rate of carbon dioxide production in *S. cerevisiae* (Hammer and Harper, 2013).

Results

In every trial, sucrose produced carbon dioxide at a greater rate than glucose. As each of the three trials began, the carbon dioxide rate of both sucrose and glucose steadily increased, but by the end of each trial the sucrose had resulted in a greater production of carbon dioxide (refer to Figure 1). As a numerical value, the average slope of the sucrose carbon dioxide production rate was 1,198.88 ppm, while the average slope for the glucose carbon dioxide production rate was 881.83 ppm. The sucrose carbon dioxide production rate values ranged from 969.04ppm to 1,406.8ppm, while the glucose

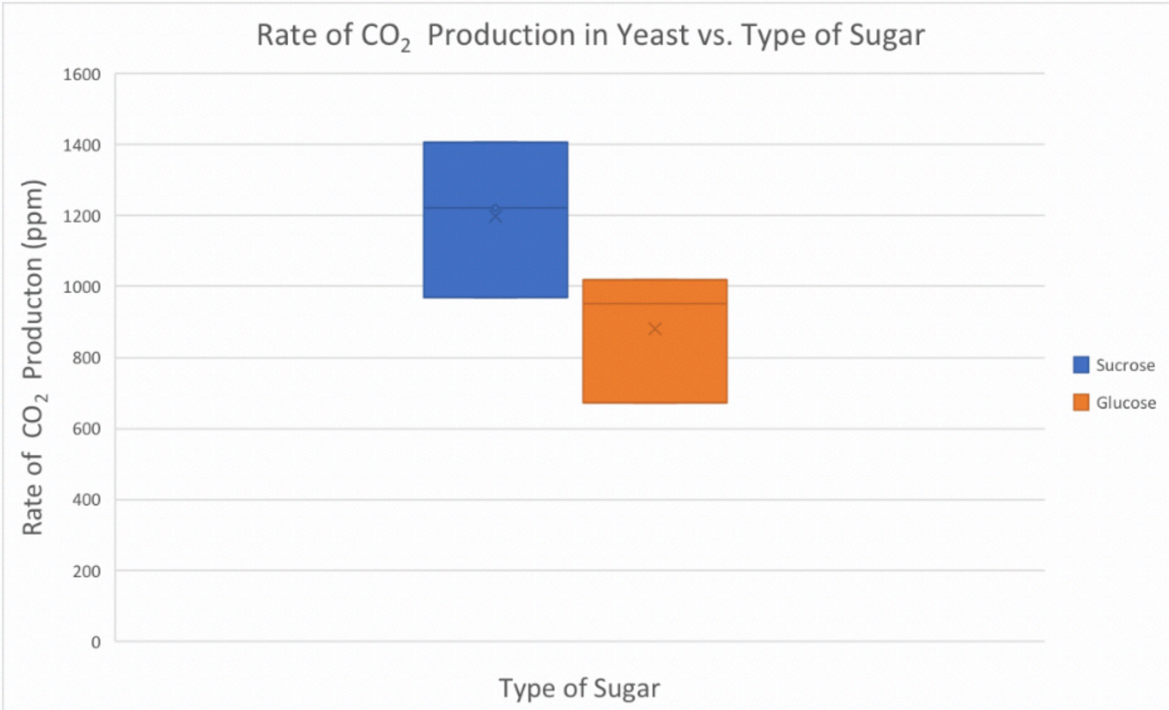

Figure 1. Rate of CO2 production increased in presence of Sucrose; t(df)= 1.916(5), p=0.12786.

carbon dioxide production rate values ranged from 672.85ppm to 1,019.8ppm. The t-Test conducted showed that there was not a significant difference between the rate of carbon dioxide production in the two sugars; t (df)= 1.916(5), p=0.12786.

Discussion

The results of the experiment disproved our original hypothesis of monosaccharide sugars producing a greater rate of carbon dioxide than disaccharide sugars. However, the results supported our null hypothesis by showing that sucrose, a disaccharide, resulted in a greater rate of production of carbon dioxide than glucose, a monosaccharide. The results of the unpaired t-Test helped to accept our null hypothesis. Sucrose most likely produced a greater rate of carbon dioxide compared to glucose because disaccharide sugars have twice the amount of covalent bonds compared to monosaccharide sugars. Therefore, when the bonds are broken during fermentation, more products will be present, one of which is carbon dioxide. Originally, we believed that the lesser number of bonds needing to be broken in monosaccharides would affect the rate of which the bonds were broken, however; the results disprove this. This information may be useful to winemakers, as they can use disaccharide sugars to produce a more bubbly wine compared to wine created with monosaccharide sugars.

The study conducted by Brown and Johnson emphasized a low concentration of glucose (Brown & Johnson). This may be the reason why the glucose in our experiment failed to produce a greater rate of carbon dioxide than the sucrose due to the .3M concentration used in our experiment. Future experiments should focus on varying monosaccharide and disaccharide sugars. Testing more sugars may result in a greater variability of the results. Future research would be useful into how the structure of the bonds, not the number of bonds, would affect the rate of carbon dioxide production.

The outcomes of our experiment could be the result of errors. It is possible that the mass of the yeast used in the experiment varied from trial to trial. Also, experimental trials may have been started too soon as the yeast takes about three minutes to activate, and the data collected by the carbon dioxide probe may have possibly collected data from the air surrounding it. Any of these inconsistencies may have resulted in an inaccurate measurement of the rate of carbon dioxide production.

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