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The Effect of Monosaccharides versus Disaccharides on the Rate of CO_2 Production

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Yeast undergoes anaerobic respiration which yields carbon dioxide (CO_2) and ethanol as byproducts. Many things can affect the rate of CO_2 production, and we tested how monosaccharides and disaccharides could affect this rate. We proposed that using both monosaccharides and disaccharides would supply different rates of CO_2 production. We placed different sugar solutions in the respiration chamber with yeast to test the rate of CO_2 production for each solution. We expect that this approach would be of interest to those wanting to learn more about the factors that affect fermentation in yeast.

Introduction

Monosaccharides are the monomer of carbohydrates. In their simplest form, monosaccharides are easily digested and are available for energy quickly. The three monosaccharides consist of glucose, fructose, and galactose. Disaccharides consist of two monosaccharides bound together through dehydration synthesis. The three disaccharides consist of lactose, maltose, and sucrose. Due to the more complex structure of disaccharides, they are harder to break down and do not provide readily available energy like monosaccharides do (Barakat & Abd El-Wahab, 1951).

Yeast are eukaryotic single celled micro-organisms classified as members of the fungus kingdom. They conduct anaerobic respiration because they metabolize sugars in the absence of oxygen. Since the amount of carbohydrates available to the yeast is not constant, they have evolved to take up many different types of carbohydrates in an attempt to maintain homeostasis (Verstrepen, 2004). In this modified version of anaerobic respiration, CO_2 and alcohol ethanol are waste products. The Crabtree effect is the process in which yeast, *Saccharomyces cerevisiae*, exhibits alcoholic fermentation until all sugar is gone from the solution (Hagman, Säll, & Piškur, 2014). We investigated if the rate of CO_2 production is affected more by monosaccharides or disaccharides. Based on this question, we hypothesized that the monosaccharide solution will yield a higher rate of CO_2 production than the disaccharide solution because monosaccharides require less energy to break down.

Fermentation is the process in which yeast-establishes metabolism and creates CO_2 as a byproduct. We will know our hypothesis is supported if the monosaccharide solutions have a

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larger production of CO_2 than the disaccharide solutions. If CO_2 is not produced as a byproduct of fermentation, then we will know that the type of sugar used has no effect on the rate of CO_2 production.

Methods

We tested the effect of different types of sugars on the rate of CO_2 production. We chose these variables because we wanted to develop an understanding of how different types of sugars could affect rate of CO_2 production over time. We tested the rate of CO_2 production because CO_2 is a direct byproduct of fermentation, so if CO_2 is detected we will be able to understand the effects of the monosaccharides and disaccharides on the fermentation process. Our comparison group was the monosaccharide solutions which were glucose and honey, which is a 50/50 mix of glucose and fructose. Our experimental group was the disaccharide solutions which were lactose (glucose and galactose) and refined sucrose, which consists of glucose and fructose. We made the monosaccharide solutions our control group because we predicted that the monosaccharide solution would produce more CO_2 than the disaccharide solutions. For each solution, there were three trials, all of which lasted 5 minutes. The monosaccharide solutions of glucose and honey were 0.3 M, while the disaccharide solutions of lactose and refined sucrose were .15 M. We did not balance the solute concentration because a disaccharide is two monosaccharaides, so a .15 M solution of disaccharides is equivalent to a 0.3 M solution of monosaccharides.

For each solution, a respiration chamber was filled with 10mL of pure water, 0.6 grams of yeast and 10mL of the chosen solution. A respiration chamber was used to create a controlled environment in which outside factors were eliminated. This was necessary to accurately measure the CO_2 production in yeast. This mixture mixed on the stir station for 5 minutes in order to activate the yeast. During this time, the carbon dioxide sensor heated up for 5 minutes before testing the CO_2 production of the desired sugar type. After this time period, the CO_2 sensor recorded the levels of CO_2 production and relayed this data to the logger pro software. The amount of CO_2 production was measured in parts per million (ppm). After the data was collected, the data was graphed using a bar graph with four different bars representing the average rate of CO_2 production in the two monosaccharides and the two disaccharides. We chose a bar graph to easily compare how the rate of CO_2 production varied in the two different types of monosaccharides and disaccharides. We calculated the linear rate of change in CO_2 production using the rate of change equation. The One-Way ANOVA test was chosen because we had nominal and measurement data that consisted of more than three variables. Additionally, our data was normally distributed therefore the One-Way ANOVA test was chosen.

Results

The monosaccharides we used in our experiments (glucose and honey) produced a higher rate of CO_2 than the disaccharides (refined sucrose and lactose) did. The initial rate was similar throughout the sugars, but after minute one, the monosaccharides separate from the disaccharides and increase at a faster rate than the disaccharides.

The test for normality gave us the p-values for each type of sugar. Glucose was 0.8288, honey was 0.7639, refined sucrose was 0.5015, and lactose was 0.9649. These are all greater than 0.05, therefore, the data is normal. A One-Way ANOVA test was conducted to compare the effect of sugar types on the rate of CO_2 production in glucose, honey, refined sucrose, and lactose conditions. There was not a significant effect of sugar type on the rate of CO_2 production between the glucose, honey, refined sucrose, and lactose conditions. [$F(3,20) = 0.9094$; $p = 0.4541$].

Discussion

We investigated the question of whether or not monosaccharides or disaccharides had an effect on the rate of CO_2 production. Additionally, we hypothesized that monosaccharaides have a faster rate of respiration than disaccharides because they are less complex and therefore take less time to break down, thus providing more readily available energy than disaccharides. The data caps at 10,000 ppm because the CO_2 detector is set to a low of 10,000 parts per million. Our hypothesis was supported by our data because the monosaccharaides hit the cap at 10,000 ppm while

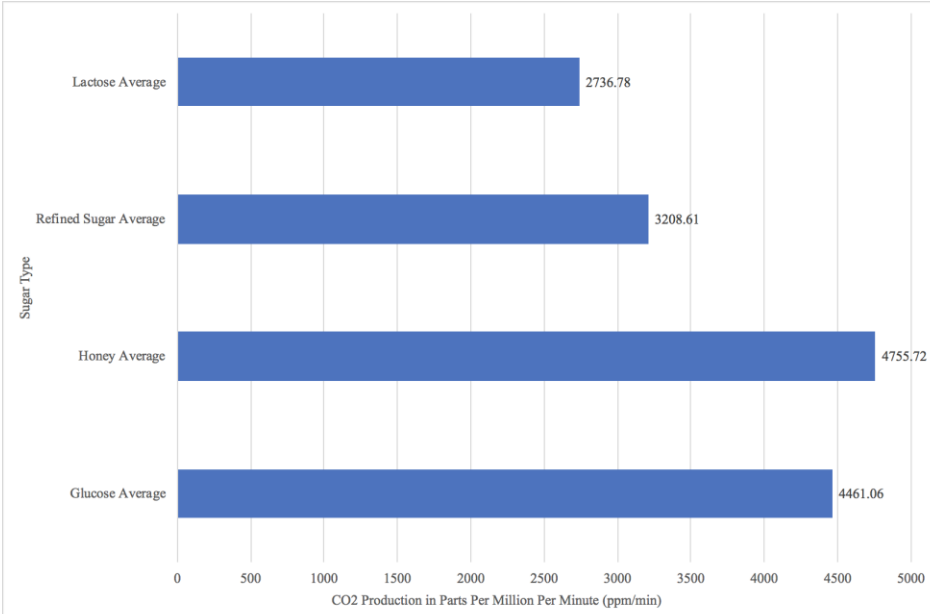

Figure 1.1: CO_2 production is affected by sugar type. The monosaccharides had a much higher rate of CO_2 production as compared to the disaccharides. The bar graph shows the average rate of CO_2 production ppm/minute for each sugar type.

the disaccharides never reached the cap within the 5 minute trial time. Also, the monosaccharides (glucose and honey) overall had a much higher rate of CO_2 production than the disaccharides (refined sucrose and lactose) thus supporting our hypothesis (see Figure 1.1). According to the data collected in our experiments, we have concluded that yeast uses fermentation to maintain their metabolism, given that they have an initial energy source for these reactions. In the case of our experiment, the monosaccharides provided that energy source better than the disaccharides did because less initial energy was needed to break down the simpler carbohydrates. We could have tested a group that had no carbohydrates and just distilled water to see if the yeast needed an energy source to undergo fermentation at all. If yeast didn't have any energy coming from the sugar, there would have been no CO_2 production at all (Bauer, Burton, Christopher, Bauer, & Ritichie, 2016).

We did not account for the CO_2 already in the room prior to placing the carbon dioxide probe into the respiration chamber. This could explain why the CO_2 probe was never at 0 ppm but rather at varying starting amounts. Alternative interpretations to our data would be heat from the friction of the stir bar against the respiration chamber could have contributed to the higher amounts of expelled CO_2 from the yeast rather than the different types of sugars used. Fermentation is greatly affected by temperature and the optimal temperature occurs at 35 degrees Celsius (Janssens, Kim, Lee, & Salehzaden). For future research the rate of ethanol production could also be measured in combination with CO_2 production. Ethanol production from yeast fermentation is used in a variety of baking instances such as allowing dough to rise (Carrau, et al. 2008).

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