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Breathe In, Breathe Out: The Negative Effect of Synthetic Sugar on Cellular Respiration

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As food producers seek "healthier" alternatives to sugar, synthetic sugars such as saccharine have become popular in western culture. However, one must be mindful of the effect of this synthetic sugar on the body, and how (or if) the body processes it. We measured the respiration rates of synthetic versus natural sugar mixed with yeast to determine which type of sugar produces more carbon dioxide and therefore respires more readily. Using a carbon dioxide probe, we measured the amount of carbon dioxide produced by the yeast solution when placed separately in glucose, saccharine, or deoxidized water. Yeast solution in saccharine produced significantly less carbon dioxide, limiting energy production in organisms. These results may be utilized when evaluating the value of synthetic sugar in maintaining a healthy diet and achieving longevity in life.

Introduction

Cellular respiration is required by many organisms to survive; it is a process by which a cell can convert carbohydrates to adenosine triphosphate (ATP), an easily usable source of potential energy (Hoefnagels, 2014). Respiration begins when glucose enters glycolysis and is broken down to simpler compounds. Compounds other than glucose must either be broken down before they enter glycolysis (such as complex carbohydrates) or enter respiration at another step (such as fats).

However, it is questionable if certain compounds, including synthetic sugars, can enter the process of cellular respiration at all. We compared the chemical formula of saccharine, $C_7H_5NO_3S$, as well as its chemical structure (Figure 1.1), to those of glucose ($C_6H_{12}O_6$ and Figure 1.2). Glucose is a monomer for many other more complex carbohydrates, but not for saccharine, as saccharine is not a polymer. Saccharine cannot break down into glucose molecules in order to enter glycolysis; therefore, it is unlikely that it can participate in cellular respiration at all.

According to "Glucose and sucrose: hazardous fast-food for industrial yeast?", when given the choice between a variety of carbohydrates, yeast will consume glucose and sucrose first (Verstrepen et al, 2004). Cellular respiration more easily uses monomers because they do not have to be broken down before entering glycolysis, allowing cells to expend less energy

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prior to respiration. In a different study, researchers gave oral doses of 40 mg of saccharine to rats and monkeys of both sexes and analyzed the urine of each species. Researchers found that neither animal had been able to metabolize the saccharine (Byard and Golberg, 1973). However, in another study using humans instead of rats and monkeys, six subjects ingested a 1-gram dose of saccharine, and scientists did not find any traces of saccharine in the urine of the subjects (McChesney and Golberg, 1973). The saccharine must have broken down in the human body; however, it does not specify at what point saccharine broke down, including if it broke down during cellular respiration.

The question develops, then: does the type of sugar affect the rate of cellular respiration in yeast? Based on the information gathered regarding the ability of glucose and saccharine to metabolize, we hypothesized that yeast solution respires faster in the presence of natural sugar than in the presence of synthetic sugar because natural sugar can directly enter glycolysis. If the experiment supports the hypothesis, then yeast solution mixed with glucose will produce more carbon dioxide in the given time interval than the yeast solution mixed with saccharine. However, one alternative hypothesis for this predicted outcome is that the yeast solution respires faster in the presence of natural sugar than in the presence of synthetic sugar because natural sugar contains calories while the synthetic sugar does not. As calories are a measure of energy, they may predict and/or determine the amount of carbon dioxide produced as a result of cellular respiration as energy changes forms within a cell (Bauer et al, 2016).

Methods

To test the effect of sugar type (natural versus synthetic) on yeast respiration rate, we recorded the amount of carbon dioxide production by a yeast solution over a set period of time. Carbon dioxide production was measured when yeast was in the presence of glucose, saccharine, and deionized water. The condition of deionized water served as a negative control and as a baseline for comparison. In order to gather an adequate amount of data, our group performed four trials for all three of our conditions. To maintain the validity of our experiment, we kept total volume constant

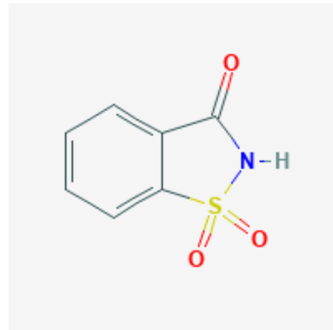

Figure 1.1. Structure of saccharine

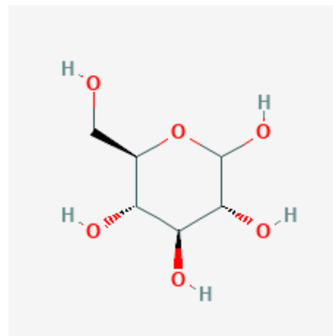

Figure 1.2. Structure of glucose

throughout all of our trials. A carbon dioxide probe informed us of the amount of carbon dioxide produced during the yeast's respiration, and therefore allowed us to measure the rate of respiration. An ethanol probe was not used because ethanol is only produced in fermentation, while carbon dioxide is produced in both fermentation and cellular respiration.

To begin the experiment, a carbon dioxide probe heated for five minutes (it only heated once per laboratory session). Next, our group measured 0.6 grams of yeast in a weigh boat and placed it in a respiration chamber with 10 mL of deionized water. A magnetic stir bar mixed the solution for five minutes to activate the yeast molecules and ensure uniformity. Afterward, we added 10 mL of either deionized water, glucose (a natural sugar), or saccharine (a synthetic sugar) to the yeast solution. Then, the carbon dioxide probe was placed above the respiration chamber to measure the amount of carbon dioxide that was emitted from the solution over the course of seven minutes. We repeated the creation of the yeast solution, the addition of the sugar (or water), and the measurement of carbon dioxide production in each condition each trial.

We used LoggerPro to record and organize our data. We employed a bar graph to most efficiently illustrate the data and a One-way ANOVA to determine if the type of sugar (synthetic vs natural) and presence of sugar makes a difference in cellular respiration rate. We followed the One-Way ANOVA test_with a Tukey's Pairwise test as a post hoc to determine which groups differed from one another.

Results

As is demonstrated by Figure 2.0, the yeast solution in the presence of glucose produced considerably more carbon dioxide than the other two conditions. The saccharine condition emitted less carbon dioxide than both the glucose and control (deoxidized water) conditions. A One-Way ANOVA was conducted to compare the effect of type of sugar on cellular respiration rate in glucose, saccharine, and control conditions. There was a significant effect of type of sugar on cellular respiration rate between the three conditions. $[F\ (2, 9) = 21.9; p = 0.000350]$. A Tukey's Pairwise Test revealed cellular respiration rate was statistically lower in the saccharine condition than the glucose condition.

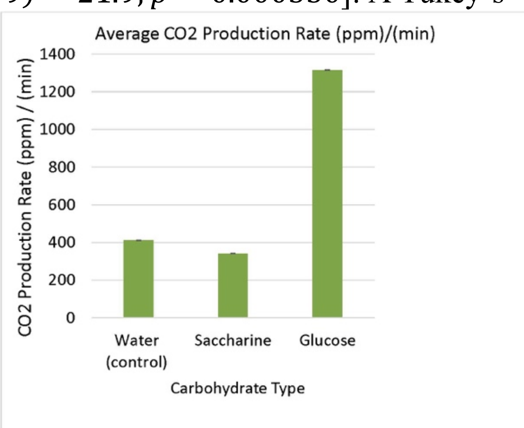

Figure 2.0
The control group was 10mL of water; the solution produced an average of 411.125 ppm of carbon dioxide per minute. The highest average rate of carbon dioxide per minute, 1467 ppm/min, was produced by 10 mL of glucose. The lowest average rate of carbon dioxide per minute, 341.525 ppm/min, was produced by 10 mL of saccharine.

Discussion

The data supported our hypothesis that yeast solution respires faster in the presence of natural sugar than in the presence of synthetic sugar because natural sugar can directly enter glycolysis. We had predicted that yeast solution mixed with glucose will produce more carbon dioxide in the given time interval than the yeast solution mixed with saccharine. The data we collected from our experiment followed our prediction and demonstrated that the glucose condition emitted a greater amount of carbon dioxide, and therefore permitted cellular respiration at a faster rate.

These results suggest that yeast performs cellular respiration at a slower rate in the presence of saccharine; therefore, synthetic sugars must not be broken down as readily as natural sugars. The yeast cells respired at a faster rate in the presence of glucose than in the presence of saccharine, possibly because glucose can be consumed faster (as it is a direct reactant in glycolysis) or because saccharine cannot be consumed for cellular respiration at all. Further research is necessary to explore these options.

Prior to conducting our trials, we created the alternative hypothesis that the yeast solution respires faster in the presence of natural sugar than in the presence of synthetic sugar because natural sugar contains calories while the synthetic sugar does not. Although our experiment did not directly test this hypothesis, our results do support the statement (Bauer et al, 2016). Saccharine boasts an absence of calories, which are essentially a way of measuring the energy available for use in food (Conn). Because this synthetic sugar has no calories, it follows that the yeast would respire very little in its presence.

Despite its readiness to break down during respiration, glucose still may not necessarily be the healthiest option. A study showed that a reduced rate of glucose activity is important in life longevity and explained why calorie restriction can result in a longer life (Lin et al, 2002). Although glucose causes higher rates of respiration in yeast, it still has more calories than saccharine and therefore would not be as "healthy" as saccharine. However, organisms still need to have a certain respiration and metabolic rate in order to survive. Though saccharine has zero calories, ingesting saccharine would result in a very low energy output and may not provide an organism with enough energy to live. When forming the most beneficial diet, humans must be aware of the effects of saccharine on cellular respiration.

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