

# Metabolization of Different Sugars by Yeast (Saccharomycetales: Saccharomycetaceae) (1865 Luis Pasteur) using Fermentation and Cellular Respiration

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**Abstract:** Energy generation within plants is performed mainly by cellular respiration and fermentation. While cellular respiration is more efficient due to its electron transport chain use, its dependence on oxygen limits the environmental conditions this system can withstand. Conversely, fermentation can be utilized without oxygen, making it almost universally available within plants. *Saccharomyces cerevisiae* (1865 Luis Pasteur) can be tested within various environmental conditions, making it a good test subject within environmental conditions. *S. cerevisiae* was tested inside two environments, one that allowed the electron transport chain to be used and one inhibiting it, forcing the yeast to use fermentation. This tested the effectiveness of fermentation and cellular respiration and visualized how vast the differences between the efficiency of the processes were. Three different sugars were also tested, and it was found that the most effective energy generation occurred with glucose during cellular respiration.

*Keywords: Fermentation, Cellular Respiration, Saccharomyces cerevisiae, Sodium Azide*

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In many plant cells, an energy source called adenosine triphosphate (ATP) is the primary fuel that is used to provide energy for metabolic functions (BDEditors 2017). As a result, the production of ATP is vital, and there are two main ways for ATP to be generated: Cellular Respiration and Fermentation. While these two processes produce ATP, Fermentation does not require oxygen during its creation process, with the drawback that it is not as efficient as Cellular Respiration (Blaettler 2018). One of the main reasons that Cellular Respiration is more efficient is through its use of the Krebs Cycle, which uses a long chain of enzymes called the electron transport chain to generate large amounts of ATP. To begin both processes, the cell must first process sugars into glucose since it is the most accessible component to

break down and process. The most used sugars can be categorized into two main groups: Monosaccharides and Disaccharides. Monosaccharides are comprised of single-carbon rings and are represented by sugars such as Glucose and Fructose (Jakubowski 2021). Disaccharides, on the other hand, are much more complex and take more energy to process since they are made of two monosaccharides combined through a single glycosidic bond, which must be broken before the two rings can be converted into Glucose (Jakubowski 2021). Since both cycles utilized glucose during their energy generation process, the closer the chemical structure of sugar is to glucose, the more efficient the energy creation process is. While Sodium Azide is toxic, it mainly inhibits the electron transport chain, disabling the final

crucial enzyme, cytochrome oxidase, which uses oxygen to break down glucose during the Krebs cycle. With the enzyme disabled, any cells trying to process sugars are forced to use fermentation since they can no longer use any oxygen in the electron transport chain and will act as if they are inside an environment without any oxygen. To determine the difference in ATP generation between cellular respiration and fermentation, a common species of yeast called *Saccharomyces cerevisiae* (1865 Luis Pasteur) was tested using three different types of sugars. Additionally, the yeast was placed into two separate solutions to observe how *S. cerevisiae* would react in environments without oxygen using sodium azide.

## Materials and Methods

### Preparing Test Solutions without Sodium Azide

6.84 grams of Sucrose (Carolina Biological Supply Company, NC) was fully dissolved using a stir rod (Southern Labware, GA) into approximately 75 mL of water at 37°C. Once the Sucrose fully dissolved, 25mL of water at the same temperature was added to the solution. 2.5 grams of yeast (Carolina Biological Supply Company, NC) was added to the solution and stirred for 30 seconds using the same stir rod. The same procedure was done separately with Fructose (CP Lab Safety, CA) and Glucose (Carolina Biological Supply Company, NC), with the initial solutions being mixed with 3.6 grams each. 25mL of the resulting solutions were then transferred into a closed burette (Southern Labware, GA) and positioned with the burette stopcock facing upwards.

### Preparing Solutions with Sodium Azide

25 ml of the three tested solutions were added in separate burettes, but 250 µL 1M Sodium Azide (Cole-Parmer, IL) was added individually once it was time to test the solution.

### Measuring the displacement from Carbon Dioxide

The yeast solutions were then measured every 5 minutes, and the level of displacement from generated bubbles was recorded for approximately 30 minutes.

## Results

When compared using an ANOVA single-factor test, it was found that there were significant differences between the means of the six tests ( $p < 0.000736$ ). Glucose was metabolized by most of the three sugars, as it produced the most CO<sub>2</sub> in the ideal conditions during test 6 (Figure 1). Additionally, the sugar that metabolized the least was Sucrose with and without Azide added to the solution (Table 1). During the

Tests had 5 degrees of freedom, with an F statistic of 5.4970. When compared to each other using Tukey's test, it found that only Glucose without Azide produced significant differences in carbon dioxide production ( $p < 0.05$ ), as the rest of the carbon dioxide had insignificant differences ( $p < 0.9$ ).

## Discussion

The three tested sugars can be divided into two groups. Glucose and fructose are monosaccharides, and Sucrose is a disaccharide. Since monosaccharides are more straightforward in structure than disaccharides, less energy is needed to process glucose and fructose into usable energy, or ATP, than Sucrose (Eggebrecht and Zedalis 2018). Additionally, the structure of Sucrose is composed of two

monosaccharides,  $\alpha$ -glucose, and fructose, combined through a glycosidic bond (Eggebrecht and Zedalis 2018). Finally,

glucose into pyruvates. After this, there are two ways for cells to transform these pyruvates, such as those tested, into usable energy, cellular respiration and

Time Elapsed(Min)	Sucrose with Azide CO2 Production	Sucrose Without Azide	Fructose with Azide CO2 Production	Fructose Without Azide	Glucose with Azide CO2 Production	Glucose Without Azide
0	0	0	0	0	0	0
5	0.1	0	0.89	0.01	0.2	0.3
10	0.6	0.1	1.07	0.4	0.5	3.3
15	1	0.2	1.17	0.9	1	7
20	1.2	0.8	1.37	2.01	1.5	8
25	1.5	1.7	1.77	3.5	1.9	8.7
30	1.7	2.6	2.37	4.99	2.3	9.8
Average CO2 Production	0.87	0.77	1.23	1.69	1.06	5.30

Table 1. This shows the total amount of CO2 produced during the experiment, as well as the average CO2 generated every 5 minutes.

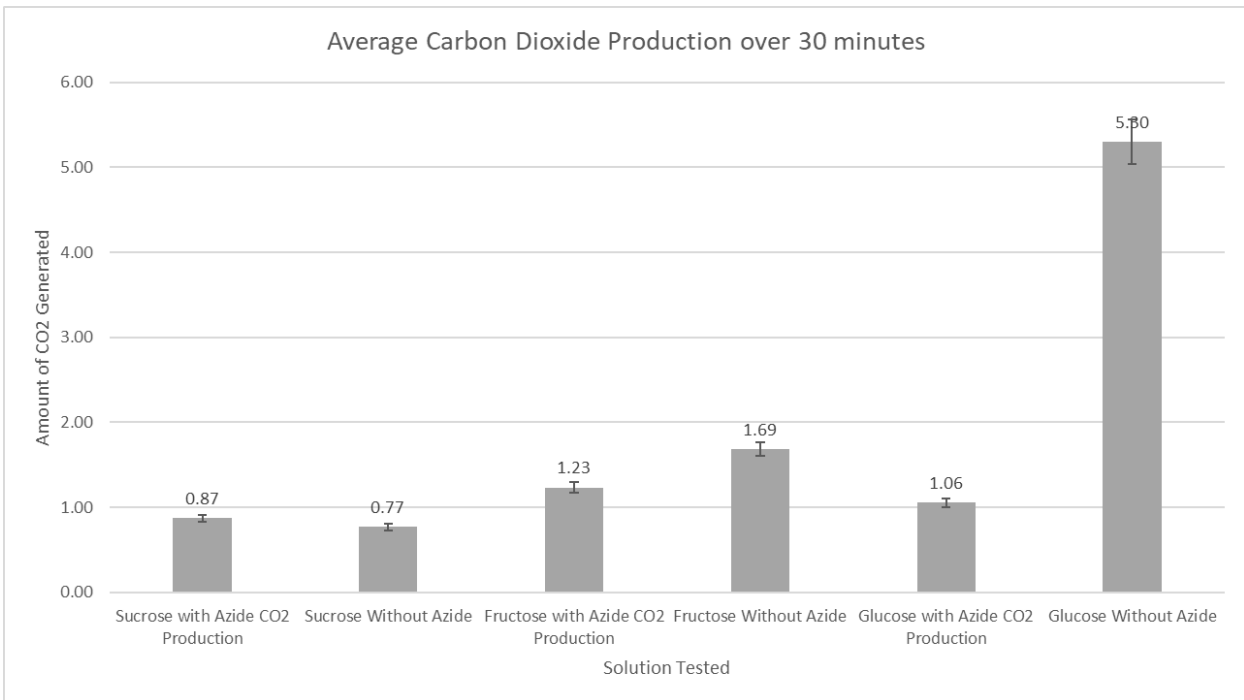


Figure 1. This shows the total amount of CO2 generated during the observed trails, as well as the possible range of error.

fructose is converted into glucose before being processed into energy (Thomas 2019). The most common way for cells to create energy starts with converting sugars into glucose, with another process called glycolysis being used with ATP to convert

fermentation. The critical difference between these two processes is the presence of oxygen since another process called the Krebs Cycle heavily depends on oxygen (Buckley 2021). Only fermentation can occur if no oxygen is

present since the Krebs Cycle is the main component of cellular respiration (Buckley 2021). To compare the rate of energy creation from *S. cerevisiae* through cellular respiration and fermentation, a method of allowing the yeast to process the sugars without using oxygen was needed. Sodium Azide was selected to disrupt the electron transport chain by inhibiting cytochrome oxidase, the crucial last enzyme on this chain, forcing the cells to generate energy as if they had no oxygen in their environment (Harvey et al. 1999). A byproduct of both tested energy cycles is CO<sub>2</sub>, so as energy was being created, *S. cerevisiae* released CO<sub>2</sub> into the burette, giving a rough indication of how much energy was generated. Figure 1 shows that when Sodium Azide was present, levels of energy creation were reduced within the monosaccharide's glucose and fructose. It is also worth noting that the most complicated sugar present, Sucrose, created the least energy overall due to *S. cerevisiae* needing to perform more steps and use more energy in its consumption. Finally, between glucose

and fructose, in the trial with oxygen present, allowing cellular respiration to be performed, *S. cerevisiae*, using glucose, made significantly higher levels of CO<sub>2</sub> since it did not need to be broken down initially to start the process of ATP generation. The results show that cellular respiration produces much more energy than fermentation and is the preferred process of ATP generation within *S. cerevisiae*. Additionally, more superficial sugar structures are more accessible to process energy, allowing cells to generate more energy efficiently. While this study focused on yeast inside laboratory conditions, it shows how vital oxygen levels are for plants. Similar processes targeting the electron transport chain could be an effective treatment against water-borne algae during events like Red Tide, as disrupting cytochrome oxidase dramatically reduces the amount of energy the algae could generate.

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