The Effect Of Various Sugars On Cellular Respiration In Saccharomyces Cerevisiae

Abstract

In order to make products such as wine, beer and bread, yeast must be used to convert sugar to alcohol and metabolic byproducts through alcoholic fermentation. One yeast that is commonly used in the manufacturing of such products is Saccharomyces cerevisiae. Yeasts such as S. cerevisiae have the ability to metabolize different sugars— some sugars with more efficiency than others. One method of detecting cellular respiration in yeast is by measuring the released amount of CO2, a metabolic byproduct, through the use of a Durham tube. In this experiment, S. cerevisiae was placed in solutions of glucose, fructose and sucrose, and the release of CO2 (mL) was measured using a Durham tube apparatus. It was found that in a 20-minute time frame, each sugar and yeast mixture released approximately the same amount of CO2. The results of the experiment show that the yeast utilized each carbohydrate at approximately the same rate, despite differences in molecular structure and sucrose having to first undergo hydrolysis. What the experimental results suggest is that glucose, fructose and sucrose substrates have no significant effect on the rate of cellular respiration in S. cerevisiae when compared as separate sugar-yeast solutions.

Introduction

Saccharomyces cerevisiae has the ability to undergo both aerobic and anaerobic respiration. The process in which alcoholic beverages are produced is through yeast fermentation, an anaerobic metabolic process. Before fermentation can take place, glucose must be converted into pyruvate through glycolysis. While pyruvate can be used in the presence of oxygen to generate ATP, if no oxygen is present then said pyruvate molecules will go through either lactic acid or alcohol fermentation. The rate at which cellular respiration occurs can depend on various factors such as available substrates, substrate concentration, temperature, enzymes present in the cell or pH. One method of detecting cellular respiration in organisms such as yeast is to collect the amount of CO2 released by the cells through the use of a Durham tube (Querengesser & Froggatt, 2016). In comparison to a control group such as water and other substrates, an increase of CO2 present in the Durham tube indicates an increase in cellular respiration.

Yeasts that are considered to be glucophilic, such as S. cerevisiae, prefer glucose over other sugars for cellular respiration (Guillaume et al, 2007). It can be inferred that glucophillic yeasts will metabolize glucose at a faster rate compared to other substrates when more than one sugar is available. The monosaccharides chosen for this experiment are glucose and fructose which are both hexose sugars with the same molecular formula, differing in the functional groups within their structures. Sucrose was the last sugar chosen for comparison in this experiment as it is a disaccharide composed of one glucose and one fructose. Because sucrose is a disaccharide, the molecule needs to undergo hydrolysis in the yeast cells in order to be utilized for metabolic purposes. Hydrolysis of sucrose in S. cerevisiae is catalyzed by invertase–an enzyme that helps turn the disaccharide into an invert sugar mixture of glucose and fructose

(Bhalla et al, 2017).

In this experiment, glucose, fructose and sucrose solutions were used in combination with S. cerevisiae to investigate if the molecular structure of the sugars had a significant effect on the rate of metabolic processes in the yeast. The amount of CO_2 released by the sugar-yeast solutions, as measured with a Durham tube apparatus, reflected the rate of cellular respiration in the twenty-minute time frame allowed for the experiment. The results of the sugar-yeast solutions were compared to a control, and thus the measured CO_2 indicated the occurrence of cellular respiration. It was hypothesized that the glucose-yeast solution would result in the greatest amount of CO_2 released, indicating glucose as the best substrate for metabolism in S. cerevisiae.

Materials And Methods

Test tubes containing 4.5 mL of water, 0.5 M glucose, 0.5 M fructose and 0.5 M sucrose respectively, were first placed in a water bath at 40°C for 10 minutes. 1.5 mL of yeast was then added to each solution and thoroughly mixed. Durham tubes were filled with each sugar solution and then inverted back into their respective test tubes. Once all tubes had been inverted, they were placed back in the 40°C water bath for exactly 20 minutes. After 20 minutes, the test tubes were removed from the water bath and the release of CO_2 was measured in mL from the Durham tube. In order to ensure precise results, the time of entering and removing the Durham/test tube apparatuses from the water bath was recorded. The sample size for this experiment was three, and the average values and standard deviations for each trial was calculated using Microsoft Excel.

Results

The control group of distilled water released the least amount of CO_2 measured at 0.0 mL. 4.6 mL of CO_2 was measured for both glucose and fructose yeast solutions, and 4.8 mL was measured for the sucrose yeast solution. The water control and fructose solution both had the most consistent results, with standard deviations of 0.0. The results for both sucrose and glucose fluctuated slightly, with standard deviations of 0.1 and 0.2 respectively (Table 1). Overall, the recorded release of CO_2 for each solution was approximately the same (Figure 1).

Table 1. The effect of various sugars on the release of CO_2 (mL) in yeast (Saccharomyces cerevisae) cells, n=3.

Solution

- Average Release of CO_2 (mL)
- Standard Deviation
- water 0.0 / 0.0
- glucose (0.5 M) 4.6 / 0.2
- fructose (0.5 M) 4.6 / 0.0
- sucrose (0.5 M) 4.8 / 0.1

Discussion

This experiment ultimately indicates that the difference in molecular structures of the selected sugars did not significantly impact the rate of metabolism in S. cerevisiae, thus disproving our original hypothesis. While the glucose-yeast solution was expected to release a significant amount of CO2, it was not expected that the fructose and sucrose solutions would produce the same amount, indicating no significant difference in metabolic efficiency between the 3 mixtures. Therefore, it can be inferred that when compared as separate solutions, the catabolism of fructose and hydrolysis sucrose do not significantly affect the rate of cellular respiration in S. cerevisiae. When compared to our experiment, an experiment performed by Guillame et al (2007) may provide an explanation for our trials having nearly identical results — our sugars were compared as separate solutions.

There is a vast amount of research done on the metabolic processes in yeasts, particularly revolving around alcoholic fermentation to produce wine or beer products. In wine musts, there is an equal amount of glucose and fructose present, and because of the glucophilic nature of S. cerevisiae, glucose is metabolised faster than fructose when the specific yeast is used for fermentation. While the exact reason for the disproportion of metabolic rates in this process remains unclear, a possible explanation centres around the differing abilities of hexokinases and glucokinase to efficiently catalyze phosphorylation for both monosaccharides in the yeast cells (Guillame et al, 2007). Unlike our experiment, their experiment was performed using a solution (synthesized grape must) containing both fructose and glucose, therefore they were able to gather data for the rate of sugar consumption by the yeast when more than one sugar substrate is present. While they did not include sucrose in their study, it is widely understood that sucrose must first undergo hydrolysis, catalyzed by invertase, to convert the disaccharide into an invert sugar of glucose and fructose (Bhalla et al, 2017). Because of this first step of hydrolysis, sucrose would typically be expected to be utilised at a slower rate compared to monosaccharides. While our experimental results disprove our initial hypothesis, I conclude that if we had the scientific knowledge and tools to compare glucose, fructose and sucrose in one sugar-yeast solution for our experiment, then there would be distinguishable variation in our results.

While our experiment showed minimal uncertainty of values in the results, it should be noted that possible sources of experimental error exists. One possible source of error could be that the lid on the water bath was not able to cover the Durham apparatuses, which could result in variation of temperatures for cellular respiration to take place. This is a reasonable explanation for the minimal error in our experiment as our three trials were performed separately, not all at once. It is also possible that larger sample size for our experiment would result in a slightly more distinguishable trend in the collected data.

Overall, the experiment showed no significant difference in the metabolism of glucose, fructose and sucrose substrates in Saccharomyces cerevisiae. In conclusion, had the experiment been performed differently, there would likely be a distinguishable difference in metabolic rates for the substrates used.

Literature Cited

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