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EFFECTS OF WHITE SUGAR AND SUGAR SUBSTITUTES ON THE GROWTH OF ACTIVE DRY YEAST

AUTHORS
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Abstract - Gill, P.;

Sugar, a vital component for yeast growth and an essential ingredient in processes like baking and brewing, is responsible for some of our most important foods and beverages, there is little research on the environmental impact.This experiment aimed to determine how sugar substitutes affect yeast growth, while also considering the environmental risks they may pose. We hypothesized that yeast will grow most with white sugar compared to other sugar substitutes (i.e. Splenda and Stevia). An experiment was conducted and yeast growth was measured under four conditions: no sugar (control), white sugar, Splenda, and Stevia. Warmed water was used alongside various sugars, added with the yeast. For each treatment, the experiment was replicated five times to ensure consistent results. The average yeast growth after 40 minutes for white sugar, Splenda, Stevia and the control was recorded to be 12.7 cm, 10.6 cm, 8.3 cm and 0.0068 cm, respectively. For data analysis, we performed a one-way ANOVA test and a Tukey test, and concluded that white sugar yielded the highest yeast growth. Thus, signifying that sugar substitutes cannot replace sugar in important processes and are not worth the damage they cause to the environment.

INTRODUCTION - Gill, P. & Siu, J.

Whether we are making cinnamon buns, beer, wine, or even insulin, yeast is an essential ingredient. Yeast is a single-celled organism that derives its energy from sugar, converting it into alcohol and carbon dioxide via a process called fermentation. In other studies, it was observed that sugars with higher caloric content induce higher yeast growth than sugars with lower caloric content.[1] The increase in calories allows the yeast to metabolize at a faster rate and release more CO2 into the surroundings.[1]

The objective of our study is to examine the effects of different sugars on the growth of active dry yeast and whether these sugar substitutes can effectively replace white sugar. A sugar substitute is a food additive that duplicates the taste of sugar and usually contains zero calories.[4] Over the years, the trend of using sugar substitutes has emerged and the use of artificial sweeteners is posing a threat to the environment. Once these sugar substitutes are ingested, sufficient amounts of these artificial sweeteners escape unchanged from the human body and are added to the environment.[2] Artificial sweeteners are resistant to wastewater treatment processes and are continuously introduced into water environments.[2] Once introduced to the aquatic environment, Ultraviolet A (UVA) further worsens the pollution of the substitutes.[5] The organisms to first experience the negative effects of the sweeteners include algae and water fleas. The damage caused to the smaller organisms can affect larger sea animals in the food web, which include species like sockeye salmon.[6] However, the environmental ecotoxicological contributions of artificial sweeteners in our water resources still remain largely unknown.[2] In addition to the harm that sugar substitutes present to the environment, animal studies have proven that artificial sweeteners can cause weight gain, brain tumors, bladder cancer, and many other health hazards in humans.[3] One of the more serious side effects of sugar substitutes is the negative impact on the health of the gut, which can lead to an increased risk of diabetes. Additionally, sugar-rich habitats have the potential to create stressful or stable environments for the microbiology of the area.[7] This can cause changes to the water that the salmon are swimming in, making it more or less likely to be inhabited by salmon populations. This does however leave out the effects of sugar substitutes on ecosystems, which is reasonable to consider based on the findings that a high sugar concentration environment can have significant effects on the microbiology[7]. As previously mentioned, sugar substitutes can have negative impacts on the environment, but how severe is the damage? Will sugar substitutes work the same way as conventional white sugar, or will we see some differences in yeast growth?

METHODS - Jang, C. & Siu, J.

Materials

Due to the simple nature of the experiment, the materials used for the experiment were mostly common household products.

- Baking tray
- Scale
- Thermometer
- Dry active yeast (160 g)
- Treatments white sugar, Splenda, Stevia (16 grams each)
- 4x identical glass cups
- Baking tray that fits all the cups
- 4x spoons to mix
- Measuring spoons
- Measuring cup (100ml)
- Kettle

Design and Procedure

First, 8g of active dry yeast was measured using a digital scale and placed into four identical glass cups (32g total). We then measured 4g of each sugar treatment (white sugar, Splenda, Stevia) placing a different type into each cup with the previously measured yeast. The fourth cup would act as our control and did not have any sugar treatment, only containing yeast. Then, 400mL of water was heated to 38°C (the optimal temperature for yeast growth), and 100mL of water was poured into each glass cup. All mixtures were stirred with a separate teaspoon until each sugar treatment was dissolved. Next, the initial heights of the yeast mixtures were marked on the glass cups. The four glass cups were placed on a baking tray that was filled with water measured at 38°C. Periodically, warm water was added to the baking tray to maintain the water temperature from 35-38°C. Each treatment was left to rest for 40 minutes. Lastly, the final height of the yeast mixture was marked and the difference in the volume of yeast replicated was calculated.

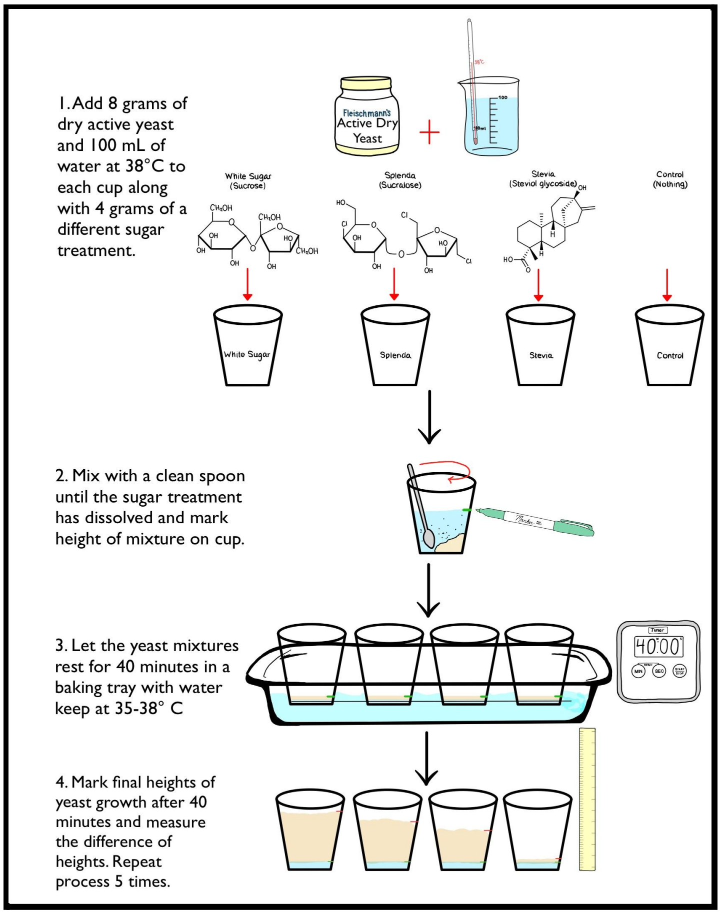

Figure 1. Method for testing yeast growth with different treatments - Jang, C. This process was repeated a total of 20 times total (5 trials per treatment).

Qualitative data such as appearances of sugars and yeast mixtures before and after resting were noted down during the experiment. Quantitative data such as initial and final height of yeast mixtures were collected in data tables, and the difference in volumes of yeast replicated were calculated. It is important to look out for any physical and chemical changes/reactions during the resting phase (colour change, bubbles, etc) and to note them down. These data were analyzed using a one-way ANOVA test, with a level of significance being $p=0.05$. If our results are deemed statistically significant, we will then use a Tukey Test to determine which groups are statistically significant compared to each other.

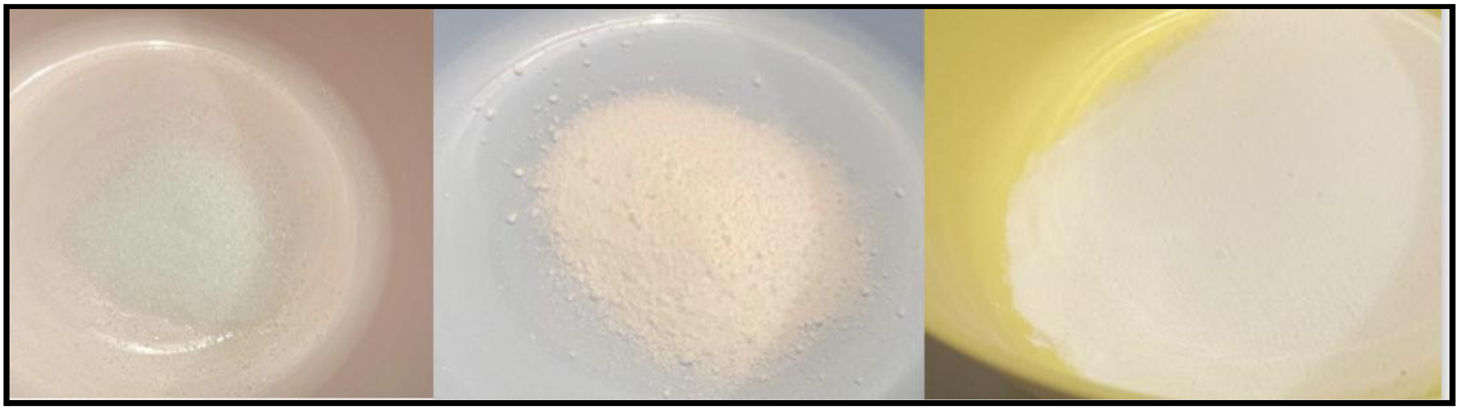

Figure 2 - Jang, C. Images from left to right (pink) white sugar, (blue) Splenda, (yellow) Stevia

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Figure 3. Total growth of yeast in 40 minutes - Siu, J. All yeast growth appeared foamy and beige in colour. Yeast growth in white sugar had the most volume and had some small air bubbles. Yeast growth in control was very minimal and had the smallest/almost no air bubbles. Yeast growth in Splenda is very similar to white sugar, but with less growth overall. Growth of yeast in stevia moderate growth with large air bubbles.

RESULTS - Jang, C

A total of 20 trials were performed with each different treatment (white sugar, stevia, Splenda, control) 5 replicates per treatment. After analyzing the results, we find that white sugar had the most growth per litre with a mean of 0.799, followed by Splenda with a mean of 0.6080, then Stevia with a mean 0.4596, and the control with a mean of 0.0068. The standard deviation found between groups varied; with the largest also having the most yeast growth. The standard deviation for white sugar was 0.0425, Splenda had a standard deviation of 0.0191, Stevia had a standard deviation of 0.012, and the control group had a standard deviation of 0.0025. After performing a one-sided Anova test with an alpha value of 0.05, our F value was calculated to be 977.11445. This meant our p-value was less than 0.00001 which is less than 0.05, meaning our null hypothesis that no difference exists between sugar type treatments and yeast growth would be rejected, suggesting there is statistical significance. To see where the differences exist between the treatments, a Tukey test was completed and the p-value was equal to 0, meaning the null hypothesis would continue to be rejected. The honest significance difference was found between each treatment; between the white sugar and Stevia was 0.34, white sugar and Splenda 0.20, white sugar and control 0.79, Stevia and Splenda 0.14, Stevia and Control 0.45, and Splenda and Control 0.60.

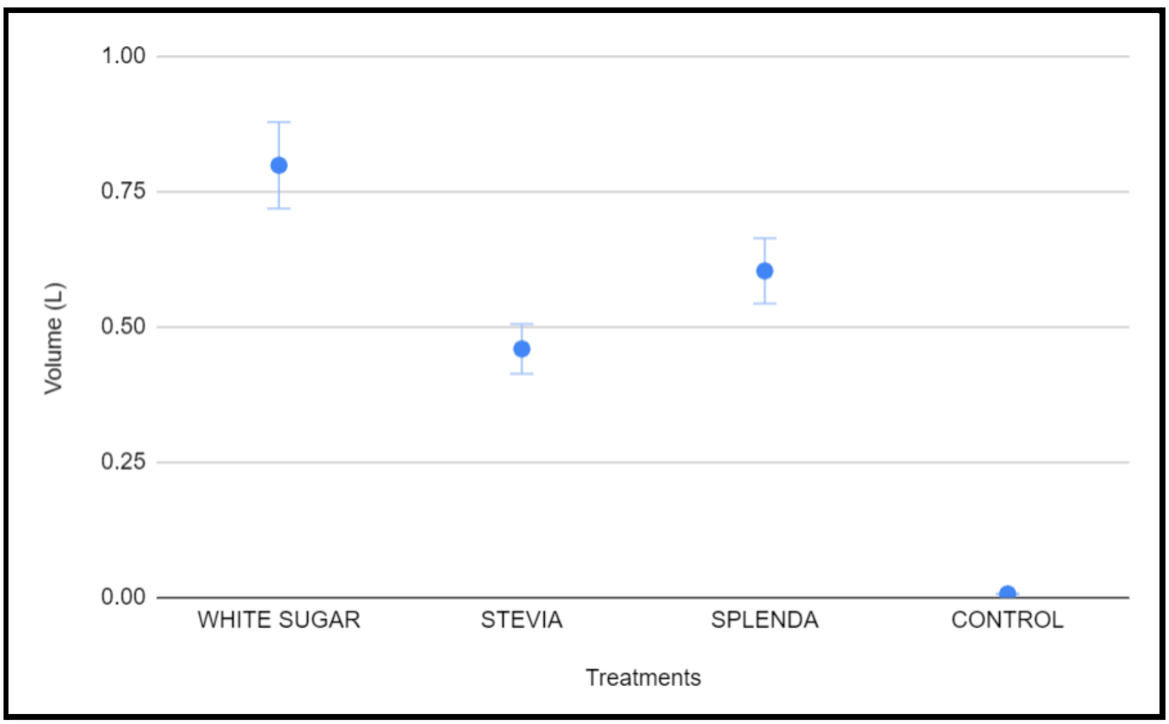

Figure 4 - Siu, J. A scatter plot of yeast growth in g/ml in 40 minutes. The circles represent the mean, and the error bars are the standard deviation within the group.

DISCUSSION - MESBAHNEJAD, M & SIU, J.

In our statistical analysis, a one-sided ANOVA test was conducted and the F value we calculated indicates that our p-value is less than our alpha value of 0.05. This signifies that the null hypothesis stating that there are no differences between sugar treatments and yeast growth, is rejected. Therefore, each type of sugar treatment, based on its respective caloric content and affinity optimality, affects yeast growth individually. Our prediction which states that yeast growth will be most abundant with the addition of white sugar compared to the other sugar substitutes was observed to be correct. This was supported by our statistical analysis using ANOVA and Tukey's test, which showed the treatments that produced the most effect on the yeast were white sugar, followed by Splenda, Stevia, and the control group respectively.

Looking back, the null hypothesis being rejected is reasonable, since the caloric content is not high when compared to sugar, despite the fact that the sugar substitutes provide a similar level of sweetening to that of sugar. Due to the fact that the level of glucose is much lower in the sugar substitutes than it is in sugar, the yeast had less glucose in its environment to make energy. Yeast can survive and generate energy either by means of anaerobic or aerobic respiration. Anaerobic respiration is a process that does not require oxygen as a necessity and can still produce usable energy. Instead, the yeast respires by using the glucose found in the sugar treatments, and the carbon dioxide waste is released as bubbles, allowing the yeast to rise. On the other hand, aerobic respiration converts sugar sources into carbon dioxide and water. This releases a greater amount of energy from the breakdown of food. By using aerobic or anaerobic respiration, the growth of the yeast could be measured because of the release of $CO2$ gas, allowing us to determine which treatment was the most effective.

One source of uncertainty that could have impacted the results is the uncertainty of measurements. Regardless of how precise and accurate a measurement may be, there will still be some degree of uncertainty caused by systematic error and random error. Systematic errors are defined as the limited accuracy of the measuring instrument - which is a thermometer in this experiment. All measuring instruments have some degree of naturally occurring systematic errors that may affect the accuracy of any measurements. For instance, the thermometer could read 38°C when in reality, the estimated uncertainty might have had a large enough range that the actual temp was closer to 37°C instead. However, systematic errors could be improved if the magnitude and the direction of the error is known, which can then be fixed by additive or proportional corrections. These corrections however, are not within the scope of this course and not given with the thermometer; therefore, it was not taken into concern in this experiment. On the other hand, random errors could have also influenced the results in an unpredictable manner. An example of this is the imprecise measuring scale that was used to weigh all compounds in this experiment. The scale is only accurate to the nearest whole number; therefore, each measurement (ie. 8.2g of yeast) was either rounded up or down (to 8g in this case). However, this random error was kept in mind from the very beginning, and was mitigated by taking repeated measurements and taking the mean of all the measurements to end up with results closer to the true value.

CONCLUSION - Gill, P.

The purpose of this research study was to determine whether sugar substitutes had similar growth patterns when compared to conventional white sugar in regards to yeast growth. We hypothesized that white sugar would allow for the most yeast growth, which we observed to be the case in our research. We concluded that the threats sugar substitutes pose to the environment are not worth the damage, since they cannot effectively replace white sugar and are associated with a wide range of health complications.

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