Deceptively Sweet: Uncovering Hidden Sugars

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Abstract:

As middle schoolers, we were worried to see a trend of obesity and juvenile diabetes on raise at our school. We were puzzled with this epidemic and started doing research to understand the trend.
We spoke to several of our schoolmates to find out about their diet and life style. They all had a seemingly healthy diet and active lifestyle. We quickly realized that hidden sugars were the real culprit.

Sugar is a carbohydrate found naturally in a host of different foods, from lactose in milk to fructose in fruit and honey. A single food item can contain multiple kinds of sugar in it, and our bodies process these distinct types of sugars differently.

An average adult living in the U.S, consumes about **22 teaspoons** of added sugars every single day, including hidden sugars from food types is believed to be healthy. Consuming lots of added or hidden sugar has been found to be directly linked to well-known medical conditions, such as diabetes, heart disease, obesity, high blood pressure, and cognitive disorders etc.

There are two types of sugars: **naturally occurring sugar** (such as the lactose in milk) and **hidden sugars** that include refined table sugar (sucrose) and concentrated sources like fruit juice, honey, and syrups.

The purpose of our experiment was to determine the amount of hidden sugars in commonly conceived healthy foods. We investigated how sucrose is converted into glucose with an enzyme, Invertase, and measured the amount of sucrose converted into glucose in each of the foods with glucose test strips.

We found fruit juice had the highest sucrose concentration at around 75%. Fruit juice, granola bar, dried fruits and ketchup also had high sucrose concentrations. Almond milk, almond butter and flavored soy milk had the lowest sucrose concentrations.

1. Background

1.1 Research Question

Is the recent buzz about healthy foods worth the hype? Are they really a healthy alternative to cater to the needs of children and people with certain conditions like Diabetes and Hypoglycemia?

1.2 Hypothesis

Foods that are commonly perceived by the American public as "healthy" contain many added/hidden sugars that are detrimental to health. Foods such as flavored yogurt, dried fruits, and agave will have the most sugar because they more contain artificial disaccharides than naturally occurring simple sugars.

1.3 Purpose

The purpose of our experiment was to determine the amount of hidden sugars in commonly promoted "healthy" foods by measuring the concentration of two sugars- glucose and sucrose. We had to investigate how sucrose is converted into glucose with the help of an enzyme called invertase. We used this knowledge to measure the amount of sucrose converted into glucose in each of the food specimen using the glucose test strips.

1.4 Materials List

We used the following materials: 100 ml graduated cylinder, 1 gram of invertase powder, 6 grams of table sugar, 100 urinalysis test strips to measure glucose, 4- 3 ml graduated transfer pipettes, 25 disposable cups, red food coloring, distilled water, kitchen measuring spoons: half-teaspoon and tablespoon, timer, and digital scale

1.5 Foods Tested

We tested the following foods: agave, almond butter, almond milk, apple sauce, canned soup, flavored oatmeal, flavored water, flavored yogurt, fruit juice, ketchup, pasta sauce, protein powder, Italian salad dressing, and soy milk

2. Experiment Procedures

2.1 Testing Glucose Strips

We followed the following procedure for the positive controls (sample with different concentrations of glucose). First, make a dilution series to create the following concentrations: 2%, 1%, 0.5%, 0.25%, 0.125%, and 0.0625%. Then, label six cups with above concentration percentages, Next, add 4 grams of glucose to 200 mL of water in the cup labeled 2% and stir until the glucose dissolves. Then, add 2–5 drops of red food coloring to the 2% glucose solution. Note that the food coloring just keeps track of the dilution levels as the color of each dilution will get less intense. It does not interfere with the glucose measurements. Next, add 100 mL of water to the other five cups. Then, measure 100 mL of the 2% solution and add it to the cup labeled 1% to make a 1% solution. Stir. Next, measure 100 mL of the 1% solution and add it to the cup labeled 0.5% to make a 0.5% solution. Stir. Finally, repeat this process for the remaining dilutions. Note that at the end each cup should have 100 mL of liquid, except for the 0.0625% solution, which should have 200 ml.

We followed the following procedure for the negative control (sample without glucose). Fill an extra cup with 100 mL water. Do not add any of the glucose solutions to it. Label it 0.

We followed the following procedure for the testing. First, dip a test strip into each of the seven cups, one at a time. Next, dip the strip for 5 secs and watch the test strip for 30 seconds. Finally, match the color of the glucose marker on the test strip to the color on the bottle.

2.2 Determine Linear Time Point (Enzyme Kinetics)

The purpose of determining the linear time point is to test the activity of the invertase enzyme by investigating how long it takes it to turn a known amount of sucrose (in solution) into glucose.

We followed the following procedure. First, fill a cup with 60 ml water. Then add 6 grams of sucrose (normal table sugar) to the water. Next, put 15 ml of this solution into a new cup. Then, add 15 drops (0.75ml) of invertase to the sucrose solution. Next, take glucose readings to see how much sugar has been converted every 5 minutes for the first 30 minutes, and then every 10 minutes until 90 minutes in total. Finally, when the glucose reading remained the same for at least 30 minutes (3 readings spaced 10 minutes apart), we stopped taking readings as the glucose concentration had hit a plateau. This is defined as Product Inhibition, when the rate of conversation of sucrose to glucose is extremely reduced.

2.3 Testing Glucose Concentration in Foods (Before and After Invertase Addition)

The purpose of testing the glucose concentration in selected food items is to observe their reaction with invertase and determine how it changes their glucose concentrations. For each food sample, two glucose readings were taken: one before adding the Invertase and one after, at the linear time point, that was determined in the "Testing Invertase Activity". All samples were ensured were at room temperature before testing (The activity of Invertase is affected by temperature. It is important that all test foods are at the same temperature, so that any differences in data due to differing temperatures can be eliminated)

We followed the following procedure. First, label the cups with the food samples. Then, for foods with considerable amounts of sugar, such as Agave, Soup, Almond Butter, flavored Yogurt, Flavored Oatmeal are diluted the samples 1:10 in water before testing them. To make the 1:10 dilution we used 1/2 tsp. of food sample. Next, to each cup, add 1 Tbsp. (15 mL) of the food to test. Then, use a glucose test strip to determine the concentration of glucose in each food sample before adding invertase. Next, if the color changes to the maximum range (2%) before 30 seconds, list it as greater than 2% (">2%") and perform a 1:10 dilution using 1/2 tsp. of your sample. Use the diluted sample for all tests. Then, set a timer for the linear time point you determined. Next,

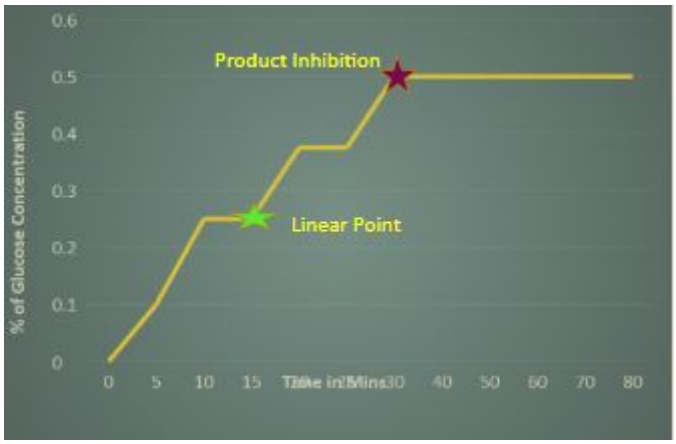
once the linear time point is reached, use a glucose test strip to determine the concentration of glucose in each sample. Note the glucose strip color and write down the glucose concentration. Then, repeat this for 4 trials for each sample of food. Next, graph the results. Finally, create a bar graph and put the food names of the samples on the x-axis and the glucose concentration on the y-axis. Include both glucose readings for each sample (before adding invertase and at the linear time point).

3. Relevant Figures

3.1 Observations of Invertase Activity on 10% Sucrose Solution

Time (mins)	% of Glucose Concentration (Amount of sucrose converted into glucose)	Qualitative Results (Glucose test strip color)
0	0	Pastel Blue
5	0.1	Pastel Green
10	0.25	Green
15	0.25	Green
20	0.375	Green to Golden Brown
25	0.375	Green to Golden Brown
30	0.5	Medium Brown
40	0.5	Medium Brown
50	0.5	Medium Brown
60	0.5	Medium Brown
70	0.5	Medium Brown
80	0.5	Medium Brown
90	0.5	Medium Brown

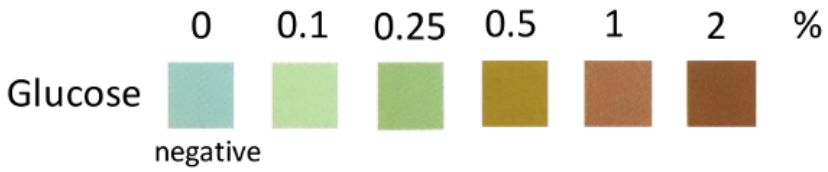
Above: Figure 1. Raw Data from Test Strips and Measurements



Above: Figure 2. Linear Time Point and Product Inhibition Interpretation

The linear time point is the time at which the glucose concentration is half before Product Inhibition sets-in. The following shows the corresponding calculation to determine linear time point. Glucose Concentration as product inhibition starts is 0.5%. Hence the linear time point is half of the glucose concentration, 0.25 % When converted into minutes, 0.25% would be a multiplied by 60 minutes of an hour, so the final linear time point is 15 minutes.

3.2 Glucose Strip Observations



Above: Figure 3. Glucose Strip Reading Guide

Note that after a glucose test strip is dipped in a glucose solution, its color should match a color on its bottle (or be between two colors). The color on the bottle indicates the percentage of glucose in the food tested. The following is what the measurements mean. Pastel Blue (negative) means 0 % glucose in the food. Pastel Green means 0.1% glucose in the food. Green means 0.25% glucose in the food. Golden Brown means 0.5% glucose in the food. Medium Brown means 1% glucose in the food. Dark Brown means 2% or more glucose in the food.

3.3 Analysis of Original Sucrose Concentration

Equation 1:

$$Percentage\ of\ sucrose\ converted = \frac{Glucose\ concentration\ at\ linear\ time\ point}{Original\ sucrose\ concentration} \times 100$$

Equation 2:

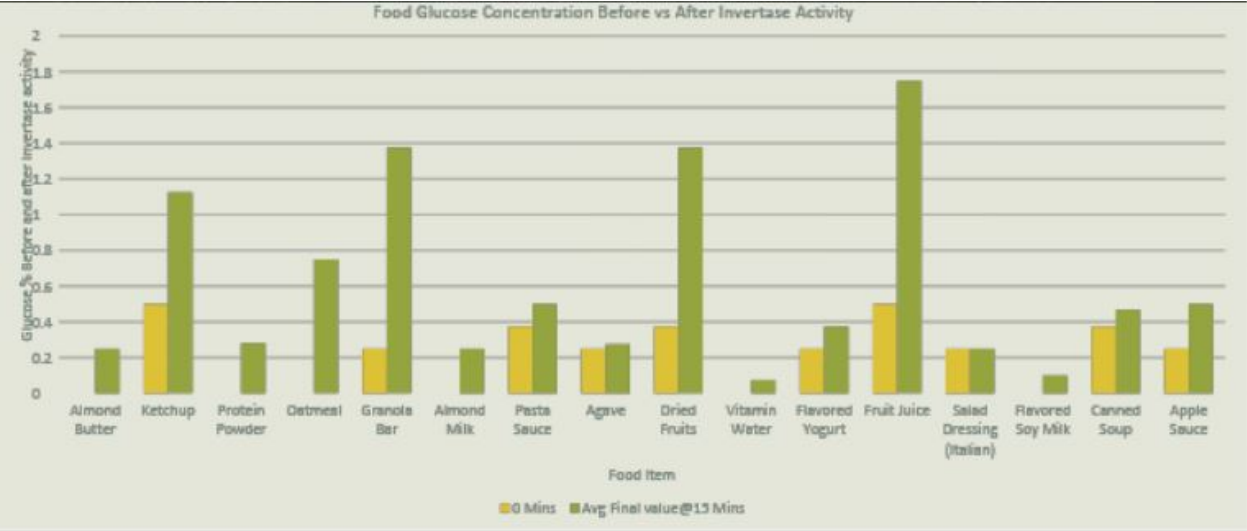
$$Original\ sucrose\ concentration = \frac{Glucose\ concentration\ at\ linear\ time\ point}{Percentage\ of\ sucrose\ converted} \times 100$$

The following is a sample calculation with the above equations for the Ketchup data point. The average glucose concentration at linear time point is 1.125%. The percentage of sucrose converted is 2.5%. After plugging the values in the above equation, the original sucrose concentration of Ketchup is 45%

3.4 Observations of Food Glucose Concentration Before and After Adding Invertase

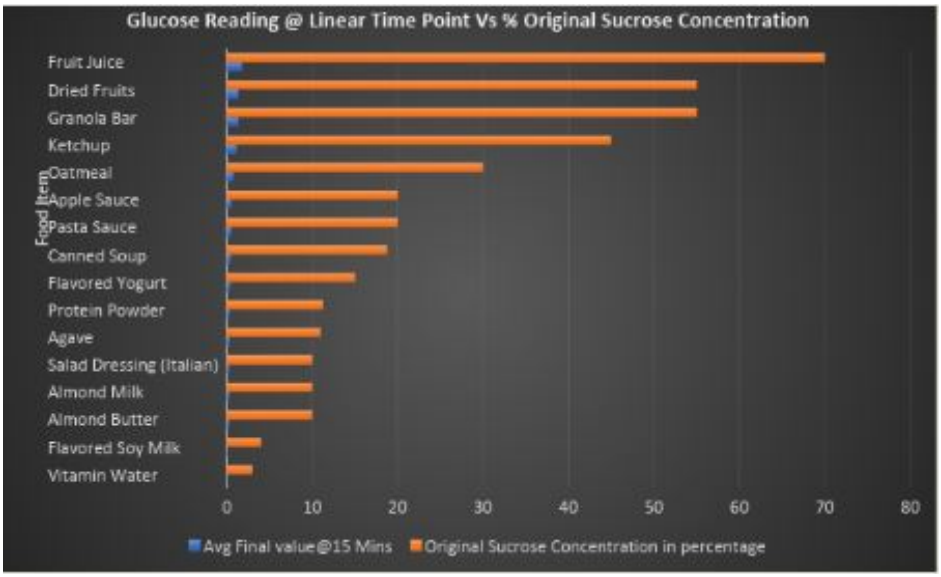
Food Item	Glucose Reading in % (Before adding Invertase@ 0 Mins)	Glucose Reading in % after 15 minutes (After Invertase Addition)				Avg Glucose Reading after 15 Mins (%)	% Original Sucrose Concentration
		Trial 1	Trial 2	Trial 3	Trial 4		
Almond Butter	0	0.25	0.25	0.25	0.25	0.25	10
Ketchup	0.5	1	1.5	1	1	1.125	45
Protein Powder	0	0.25	0.375	0.25	0.25	0.281	11.24
Flavored Oatmeal	0	0.75	0.75	0.5	1	0.75	30
Granola Bar	0.25	1.5	1.5	1.5	1	1.375	55
Almond Milk	0	0.25	0.25	0.25	0.25	0.25	10
Pasta Sauce	0.375	0.5	0.5	0.5	0.5	0.5	20
Agave	0.25	0.25	0.35	0.25	0.25	0.275	11
Dried Fruits	0.375	1	1.5	2	1	1.375	55
Vitamin Water	0	0.1	0.1	0	0.1	0.075	3
Flavored Yogurt	0.25	0.375	0.375	0.5	0.25	0.375	15
Fruit Juice	0.5	2	1.5	2	2	1.875	75
Salad Dressing (Italian)	0.25	0.25	0.25	0.25	0.25	0.25	10
Flavored Soy Milk	0	0.1	0.1	0.1	0.1	0.1	4
Canned Soup	0.375	0.5	0.375	0.5	0.5	0.469	18.76
Apple Sauce	0.25	0.5	0.5	0.5	0.5	0.5	20

Above: Figure 4. Raw Data from Invertase Trials



Above: Figure 5. Bar Graph of Glucose Concentration Before vs. After Invertase Activity

3.5 Glucose Reading Correlation to Linear Time Point



Above: Figure 6 Glucose Reading at Linear Time Point vs. Original Sucrose Concentration

Consumption of foods with high sucrose concentration result in higher and rapid increase in blood glucose concentration. Enzymes break sucrose at a faster rate releasing more glucose into the blood stream. Rapid increase in blood glucose level results in hyperglycemia. Sucrose concentration in foods is directly proportional to body's blood glucose level.

4. Results and Conclusion

4.1 Results

Fruit Juice had the highest sucrose concentration around 75%. Fruit Juice, Granola Bar, Dried fruits and Ketchup were the top 4 food items that had the highest Sucrose concentrations. Almond Milk, Almond Butter and Flavored Soy Milk had the lowest Sucrose concentrations. Ketchup and Fruit Juice had the highest Glucose concentration before Invertase enzyme was added. Agave had the same Glucose levels, before and after invertase activity as its primary sweetening agent is Fructose.

4.2 Conclusion

Our Hypothesis was partially right. Flavored Yogurt, Dried Fruits had high concentration of Sucrose. Agave on the other hand did not have high concentration of sucrose. A diabetic must avoid fruit juices as it might spike their blood glucose levels immediately. They can substitute with options that are lower in Sucrose like Soy Milk, Almond Milk. Fruit Juices may be excellent source of sugar for someone with low blood sugar levels. It will quickly provide the 4 grams of Sucrose needed to balance the blood sugar levels. Homemade soups, sauces without added sugars will help us lead healthier lifestyles. Eating fresh fruits are recommended over dried ones as taking out the water in dried fruits result in high concentration of both nutrients and sugars.

4.3 Literature Review

We were also inspired by the following paper by researchers from the University of California, Berkeley School of Public Health titled “Added sugar intake and metabolic syndrome in US adolescents: cross-sectional analysis of the National Health and Nutrition Examination Survey 2005-2012”. This paper addresses a connection between added sugar and metabolic syndrome in youth ages 12-19. The research established a positive connection, meaning that higher added sugar intake does contribute to metabolic syndrome.

Biographies

Akshara Karthik is an 8th grader at Orchard Lake Middle School and will begin high school in the fall of 2018. She is an enthusiastic science student and with her classmate, Priya Shah, has consistently won Grand or First awards in the Science and Engineering Fair of Metro Detroit for the past three years. She loves to participate in quiz programs, Math Pentathlon, and speech contests. Akshara wrote a piece on MLK titled “His Dream Raises Us Up” and won the Optimist essay club award. She presented at the MLK day celebrations in West Bloomfield High School, presided by Congresswoman Brenda Lawrence. She was her school spelling bee champion and participated in the Oakland County level competition. She was also the first elected president of her school’s National Junior Honor Society.

Akshara has great passion for music. She is a vocalist and violinist playing both western classical and Indian Carnatic music since age 5. Music has helped improve her coordination and concentration. She loves to sing and play in the orchestra as it teaches her to be part of a cohesive and collaborative team. She stays in touch with her family's tradition, culture, and language through Indian classical music.

Priya Shah is an incoming 9th grade student at the International Academy in Bloomfield Hills, Michigan. She has successfully placed in the Science and Engineering Fair of Metro Detroit for the past several years with her teammate, Akshara Karthik. The focus of their research projects is food science at the molecular level. They have done experiments to determine which household items can extract the most DNA from strawberries, how a fruit or vegetable's color affects its Vitamin C content, and uncovering hidden sugars from seemingly healthy foods. Priya plans to continue her passion for scientific research in high school through the science fair and other STEM education opportunities.

Apart from her research, Priya enjoys playing piano, learning classical Indian dance, and travelling around the United States. She has been playing piano for the past five years and actively participates in local recitals. She has also been learning classical Kathak dance for the past five years and is on track to earn her certification. Additionally, Priya loves public speaking and has participated in competitions around the community through the Optimist Club Oratorical Contest and local Martin Luther King Jr. memorial event to name a few.