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Investigation on the Osmosis behavior in potatoes

Research Question: What is the effect of 0%, 2.5%, 5%, 10%, 15%, 20% sucrose concentration on the mass change of sweet and yukon gold potatoes?

Introduction

Both type 1 and type 2 diabetes have shown an increase among human beings in recent years. According to nature.com, Globally, the incidence of diabetes increased from 11.3 million (95% UI 10.6–12.1) in 1990 to 22.9 million (21.1–25.4) in 2017, with a 102.9% increase (Lin et al., 2020). Diabetes can have a severe influence on a person's health. Some long-term effects of diabetes are damage to large and small blood vessels, causing heart and kidney problems, accompanied by malfunction of other organs. Among two kinds of diabetes, according to medicinenet.com, type 2 diabetes is a lot more common than type one diabetes (Melissa Conrad Stöppler, 2020). That's why this experiment will present suggestions for specific patients with type 2 diabetes.

The purpose of this experiment is to find the best choice of potatoes for patients with type 2 diabetes by determining the sugar content in each type of the potato. Potatoes are common in people's diets but there is a difference between different kinds of potatoes and some of them might cause the symptoms of type 2 diabetes to exacerbate. According to webmd.com, "even though a potato is considered a complex "healthy" carb, your body digests these carbs faster than other kinds of complex carbs. These broken-down carbs (except for fiber that cannot be broken down into sugar) flood your blood with sugar. This makes your blood sugar spike quickly." When the sugar in blood gets high, the excessive sugar gets transported from the blood to urine. And then a filtering process takes place, drawing a huge amount of fluid out of your body. This might lead to severe dehydration and diabetic coma.

Potatoes contain different amounts of carbohydrates that will be transformed into glucose. But to make this simple, in the experiment, only the content of sugar will be measured. Two kinds of potatoes will be measured in their sugar concentration and determined which one is more beneficial for patients with type 2 diabetes.

The basic concept of the experiment is osmosis. According to Wikipedia, Osmosis is the spontaneous net movement or diffusion of solvent molecules through a selectively permeable membrane from a region of lower solute concentration to a region of higher solute concentration (unknown, 2021). Because the sugar particles are big, there won't be a diffusion effect, which is a phenomenon of particles spread out and finally equally distributed in a medium. Instead, Osmosis will take place. Osmosis, in simple words, is the movement of water, to achieve equilibrium.

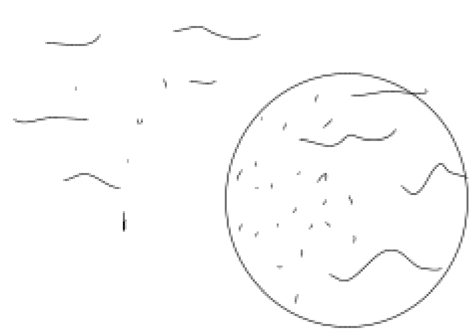

Figure 1: the graph demonstration of the potato and the surrounding concentration

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As the figure above shows, there are a lot of particles in the cell with water and there are a smaller amount of particles outside with water. Now, the concentration inside is hypertonic to the outside meaning that its concentration level is higher than the outside because it has more particles but less water. And the solution on the outside is hypotonic to the inside. The thing that will happen is the water on the outside will move into the cell through the cell membrane to increase concentration outside and lower the concentration inside. Then the equilibrium(isotonic) can be achieved.

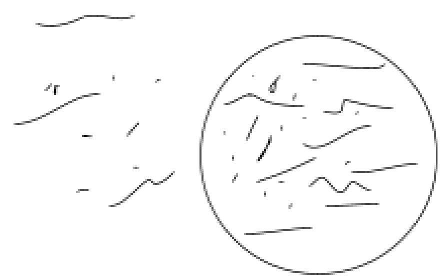

Figure 2: the graph demonstration of the potato and the surrounding concentration

In the experiment, two types of potato slices will be dip into sugar water for 24 hours. In water, osmosis can happen to the potatoes. If a potato has a high amount of sugar, then the concentration of sugar inside the potato will be high. After the osmosis takes place, if the water moves into the potato, then the potato is sweeter than the sugar water because water moves into the lower the concentration inside and to increase the concentration outside and vice versa. This "move-in move-out" process will be determined by measuring the mass change of potato slices before and after the experiment. If the mass of the potato slice increases, it suggests that there is a move-in of water, indicating that the potato is sweeter than the sugar water. If the mass change is zero, an isotonic state is reached, meaning that concentration outside and inside the potato is the same. Then, the concentration of sugar water can be used to represent the sugar level of the potato.

According to wikipedia, the sugar content in Yukon gold potatoes is 1.6g/100g, with a concentration level of 1.6%. Sweet potatoes are 5.5g/100g(Migala et al., n.d.), with a concentration level of 5.5%(Migala et al., n.d.). In order to make the measurement accurate, the sucrose concentration will be from zero level of concentration to 20% to cover the possible range of sugar concentration in the potatoes. For example, if the sugar content of the sweet potato measured is close to 5.5%, then it indicates that the result is accurate. If the concentration level used in the test is smaller than 5.5%, there won't be a time where there is no mass change, so no conclusion can be drawn.

The percentage change can be calculated by using m/Mpotato*100%. m is the actual mass change and Mpotato is the original mass. The reason why the percentage of mass change is chosen as the dependent variable and not actual mass change is that it's easier and more accurate to compare. For example, a 5g chip experiences a mass change of 1g and a 10g chip experiences a mass change of 3g. It's hard to compare which potato chip has experienced a greater change because their original mass is different. Using the percentage, the first has a 20% mass change and the second has a 30% mass change, so the conclusion can be drawn easily that the 10g potato chip experiences a greater change.

Hypothesis:

If putting the 6mm-long Yukon gold potato and sweet potato pieces to a sucrose solution with (0%, 2.5%, 5%, 10%, 15%, 20%) concentration for 24 hours, then if the pieces are put into sucrose solution of 5%

concentration, the Yukon gold potato lose weight and the sweet potato will gain weight because, for example, the sugar content of Yukon gold potato is 1.6% (Migala et al., n.d.), hypotonic to outside solution 5%, thus, water would come out to lower the concentration outside and increase it inside to achieve balance through osmosis since it occurs until the hydrostatic pressure of the water balances the osmotic pressure(Libretexts, 2020) and in this case, equilibrium of concentration. For sweet potatoes, whose sugar content is 5.5% (Migala et al., n.d.), hypertonic to outside sucrose solution of 5%, thus, water would come in to lower the concentration inside and increase it outside to achieve balance. As sucrose concentration increases, the mass change decreases because there is fewer and fewer needed to lower the concentration inside and when the concentration level exceeds the sucrose content in the potato, the water comes out, resulting in an increasing negative mass change.

Variables

Independent Variable	Range	How it will be changed
Concentration of the solution	0%, 2.5%, 5%, 10%, 15% 20%	By adding sugar to the container and solution In a proportionate way. For example, to achieve 5% concentration, we should add 5g of sugar into 100mL of water.

Dependent Variable	Units	How it will be measured
Mass change(delta M) of the potato	%	By subtracting the mass before the experiment from the mass after the experiment and dividing the original mass.

Controlled Variable	How it will be controlled	Why it needs to be controlled
Types of solution	By adding only one kind of material or sugar	Because if not, potatoes might react differently to different types of solutions, which makes the experiment results not accurate.
2 types of potatoes	By experimenting with only two kinds of potatoes and they have to the same	Because each kind of potato, based on their different structures containing elements, might react differently to the same solution, which leads to the inaccuracy of the experiment results. For example, if one slice was put into the solution for 10 seconds, osmosis might not even take place, then there won't be any change to its mass.
Duration of time when they are merged in solution	By putting two pieces in the container for 24hours each	If not, one potato might have a bigger change than the other potato because of having more time submerged. This causes diffusion of the cause and efficiency of the mass change.
same location to avoid any loss of mass caused by evaporation	It will be put next to each other, at the same location. A place by the wall is a good place	Containers that are put under the sun might experience evaporation, making the concentration of the solution go high. If one gets more evaporation, its concentration is higher than the other, which makes the result not accurate.

Same sizes of pieces	It will be cut into pieces of 6mm long with the same base area after being measured with the ruler and cut with the potato cylinder pushed out by the cork borer.	Bigger slices can have a bigger contact with the solution, which might lead to a more significant exchange of materials and change of mass, causing inaccuracy in the experiment.

Materials

- 1 _yukon gold_______ potato
- 1 sweet potato
- 6 petri dishes with lids
- cork borer
- knife
- ruler
- 100 ml graduated cylinder
- 30ml distilled water
- 30ml 2.5% sugar solution
- 30 ml 5% sugar solution
- 30ml 10% sugar solution
- 30ml 15% sugar solution
- 30ml 20% sugar solution
- electronic balance
- masking tape
- marker/pen
- sweet potato chips cutting into 6mm long cylindrical pieces with fixed base area, so the same volume
- Yukon gold potato chips cutting into 6mm long cylindrical pieces with fixed base area, so the same volume

Procedure: *This procedure is not well controlled as is. You will have to add/modify some details for YOUR report*

1. Put on safety goggles and gloves
2. Using a cork borer, remove several potato cylinders from each of your allocated potatoes (see diagram). Insert the cork borer into the potato and uses another cylinder to push the potato cylinder out
3. Using a knife cut 5 thin potato discs for 6mm for each potato. To do this, we make sure the bottom of the cylindrical potato lines up with the “0” on the ruler and cut the potato right on the “6”mm.
4. Draw a star pattern on the bottom of the petri dish and label each section with the numbers 1-5 in sequence
5. Take out the balance and make sure the number is zero before measuring.
6. Measure the initial mass of each piece of potato using an electronic balance and record in a data table.
7. Place each piece of potato in its appropriate location in the petri dish, in its assigned section that is numbered. Each section should have 1 piece of each potato.
8. Measure 30ml of the sugar solution (distill water, 2.5%, 5%, 10%, 15%, 20%) using a graduated cylinder and pour CAREFULLY into the petri dish, avoid letting the potato chips move.

9. Walking slowly to the final location(by the wall) and avoiding water leaking and placing the petri dish flat.
10. Place the lid on each petri dish slowly and leave for 1 day(24 hours) and make sure the water doesn't leak out
11. Clean the cork borer and knife, throw away unnecessary potato slices into the organic rubbish bin. Put the goggles and gloves back, clean
the balance and graduated cylinder.
12. After 1 day (24hours) re-measure the mass of each disc of potato. Use a paper towel to absorb any excess liquid.
13. place each piece onto the electronic balance again, make sure to make the balance zero before start.
14. Record the final masses in the data table.
15. Clean the equipment and throw away the potatoes into organic recycle bins.

Results

Raw data table

Table 1: Mass of yukon gold potato discs before and after putting into the sucrose concentration for 1 day.

	sucrose concentration (%)											
	0.0%		2.5%		5.0%		10.0%		15.0%		20.0%	
	mass of potato discs (g)											
	Initial Mass (g)	Final Mass	Initial Mass	Final Mass	Initial Mass	Final Mass	Initial Mass	Final Mass	Initial Mass	Final Mass	Initial Mass	Final Mass
Trial 1	0.53	0.63	0.68	0.77	0.44	0.50	0.38	0.29	0.45	0.36	0.48	0.36
Trial 2	0.45	0.54	0.63	0.70	0.54	0.59	0.48	0.27	0.35	0.29	0.48	0.33
Trial 3	0.40	0.45	0.57	0.64	0.59	0.67	0.32	0.33	0.41	0.35	0.38	0.30
Trial 4	0.67	0.79	0.58	0.64	0.58	0.68	0.44	0.39	0.42	0.36	0.34	0.28
Trial 5	0.41	0.50	0.59	0.66	0.40	0.48	0.57	0.51	0.44	0.34	0.42	0.34

Table 2: Mass of sweet potato discs before and after putting into the sucrose concentration for 1 day

	sucrose concentration (%)											
	0%		2.5%		5.0%		10.0%		15.0%		20.0%	
	mass of potato discs (g)											
	Initial Mass (g)	Final Mass	Initial Mass	Final Mass	Initial Mass	Final Mass	Initial Mass	Final Mass	Initial Mass	Final Mass	Initial Mass	Final Mass
Trial 1	0.42	0.51	0.59	0.74	0.65	0.77	0.47	0.53	0.63	0.60	0.53	0.38
Trial 2	0.37	0.42	0.66	0.64	0.57	0.68	0.52	0.42	0.51	0.46	0.64	0.49
Trial 3	0.35	0.4	0.54	0.76	0.48	0.60	0.50	0.48	0.52	0.51	0.51	0.34
Trial 4	0.49	0.58	0.54	0.58	0.52	0.59	0.43	0.50	0.48	0.44	0.53	0.38
Trial 5	0.29	0.32	0.55	0.61	0.47	0.57	0.54	0.65	0.52	0.48	0.50	0.40

Processed data table?

table 3: The mass change of Yukon gold potatoes in sucrose concentration of 0%, 2.5%, 5%, 10%, 15% and 20%

	sucrose concentration level (%)					
	0%	2.50%	5.00%	10%	15%	20%
	mass change (%)					
Trial 1	18.87	13.24	13.64	-23.68	-20.00	-25.00
Trial 2	20.00	11.11	9.26	-43.75	-17.14	-31.25
Trial 3	12.50	12.28	13.56	3.13	-14.63	-21.05
Trial 4	17.91	10.34	17.24	-11.36	-14.29	-17.65
Trial 5	21.95	11.86	20.00	-10.53	-22.73	-19.05
average	18.25	11.77	14.74	-17.24	-17.76	-22.80
upper range	3.71	1.47	5.26	20.36	3.47	5.15
lower range	5.75	1.42	5.48	26.51	4.97	8.45

Table 4: The mass change of sweet potato in sucrose concentration of 0%, 2.5%, 5%, 10%, 15% and 20%

	sucrose concentration level (%)					
	0%	2.50%	5%	10%	15%	20%
	mass change (%)					
Trial 1	21.43	25.42	18.46	12.77	-4.76	-28.30
Trial 2	13.51	-3.03	19.30	-19.23	-9.80	-23.44
Trial 3	14.29	40.74	25.00	-4.00	-1.92	-33.33
Trial 4	18.37	7.41	13.46	16.28	-8.33	-28.30
Trial 5	10.34	10.91	21.28	20.37	-7.69	-20.00
average	15.59	16.29	19.50	5.24	-6.50	-26.67
upper range	5.84	24.45	5.50	15.13	4.58	6.67
lower range	5.24	19.32	6.04	24.47	3.30	6.66

Graph

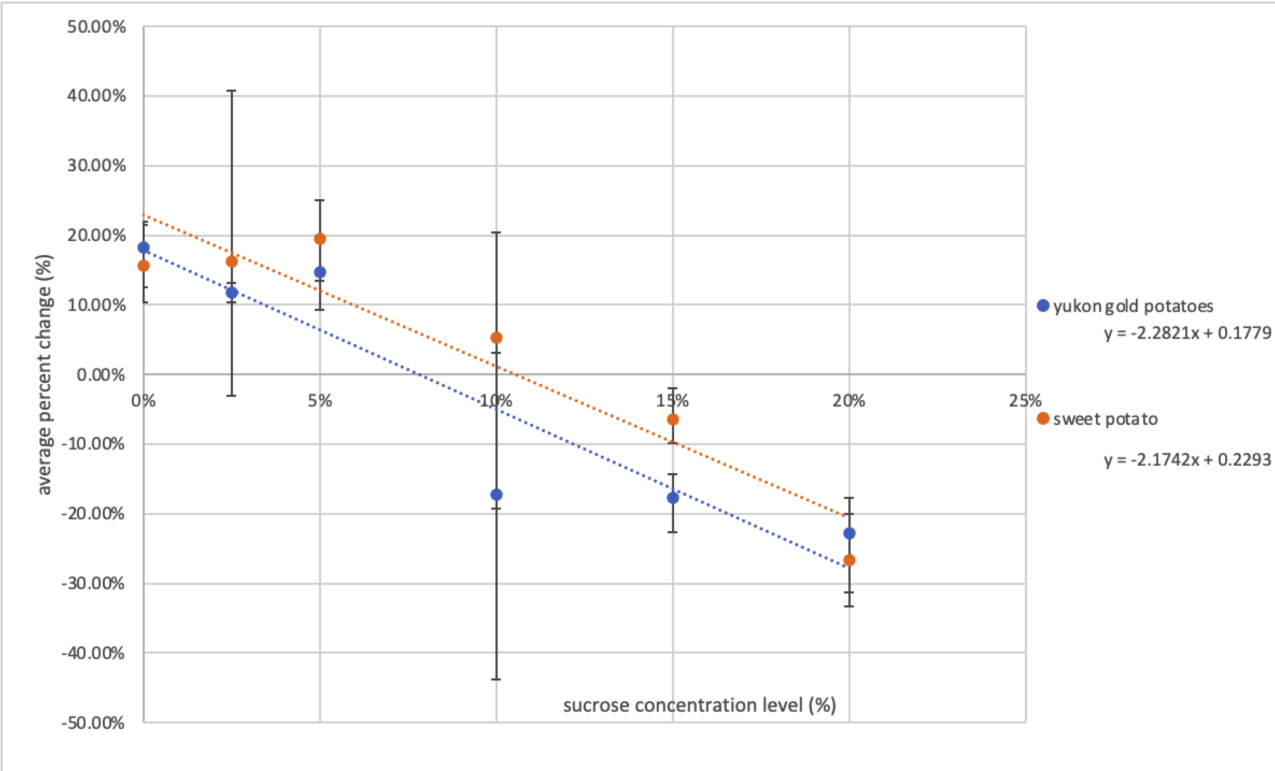

Figure 3: The mass change of 6mm long cylindrical yukon gold potato and sweet potato pieces in sucrose concentration of 0%, 2.5%, 5%, 19% 15% and 20% after 24 hours.

Conclusion

The purpose of the experiment is to investigate what is the effect of 0%, 2.5%, 5%, 10%, 15%, 20% sucrose concentration on the mass change of sweet and yukon gold potatoes. From the graph, it is discovered that as sucrose concentration level increases, the mass change in percentage of yukon gold potatoes and sweet potatoes decreases. Also, at sucrose concentration 5%, yukon gold potatoes have a mass change of 14.74% and sweet potatoes have a mass change of 19.50%.

Name of statistics	explanation
equation	The equations of Yukon gold potatoes and sweet potatoes---y=-2.2821x+0.1779 and y=-2.1742x+0.2293 indicate the relationship between sucrose concentration and mass change of potatoes. The negative sign before (x) indicates a negative relationship between sucrose concentration and mass change. As the sucrose concentration level increases, the mass change decreases. For example, in equation y=-2.2821x+0.1779, when x is 0%, the value is 0.1779, when x is 5%, the value is 0.0638. 0.1779<0.0638, so when x increases, the value of the equation, which is the mass change decreases. This happens because when the sucrose concentration is lower than the sugar content

	in potatoes, water moves in to achieve balance, resulting in a positive mass change. When the sucrose concentration exceeds the sugar content in potatoes, water from potatoes moves out to achieve balance, resulting in a negative mass change. The higher the sucrose concentration, the more water needs to move out. That's why when the sucrose concentration increases, the mass change decreases. It fits what is hypothesized about the results, which is mass change decreases as sucrose concentration increases, suggesting the validity of the trend.
x-intercept	It's discovered that the sucrose content in Yukon gold potatoes and sweet potatoes are 7.8% and 10.5% respectively. It is calculated that the x-intercept is (0.078,0) from the formula y=-2.2821x+0.1779 for Yukon gold potatoes and (0.105, 0) from the formula y=-2.1742x+0.2293. when y=0, (mass change=0%), the results of x are 7.8% and 10.5% respectively. When there is no mass change, there is no water moving in or moving out of the potato and an isotonic state is achieved. And the isotonic state is when the concentration outside is the same as the inside(Khan Academy, n.d.). Then the sugar content in the potato can be determined as the value of x-intercept 7.8% and 10.5% because it is when the isotonic state is achieved. However, according to the research, the sucrose content in Yukon gold and Sweet potatoes are 1.6% and 5.5% respectively (Migala et al., n.d.), suggesting the invalidity of the experiment result.
The difference between Yukon gold potatoes and sweet potatoes mass change at each point	It is discovered that at each point except for 0% and 2.5%, the mass change of sweet potatoes is always bigger than that of Yukon gold potatoes(not the magnitude of mass change), suggesting a higher sugar content in sweet potatoes. The function of sweet potatoes is also higher than yukon gold potatoes and mathematically, a higher function means bigger value. It's understandable that sweet potato has a greater mass change. suppose sugar content of Yukon gold potato is x, of sweet potato is y, and sucrose concentration is z. And it's given y>x. 1. when z<x<y, both gain water. Because x<y, sweet potatoes need more water to lower the concentration then Yukon gold potatoes. Then, sweet potato has a bigger mass change. 2. when x<z<y, Yukon gold potato loses water to increase its concentration ,sweet potato gains water to lower its concentration. Then Yukon gold potato experiences a negative mass change while sweet potato experiences a positive. So, sweet potato has a bigger mass change. 3. when x<y<z, both lose water. Because x<y, then Yukon gold potatoes need to give away more water to lower the concentration than sweet potatoes. And because the mass change is negative, then sweet potato has a bigger mass change (but smaller in magnitude). In all three circumstances, sweet potatoes have a bigger mass change when its sugar content is higher than that of Yukon gold potatoes. According to the research, the sugar content of sweet potatoes is 5.5% and in Yukon gold potatoes is 1.6% (Migala et al., n.d.). It shows that the finding in the graph fits the research, suggesting the validity of the data in their relationship.

Evaluating the procedure:

The hypothesis states that when keeping the Yukon gold potatoes and sweet potatoes in sucrose concentration 5% for 24 hours, Yukon gold potatoes lose weight and sweet potatoes gain weight. However, according to the graph, at sucrose concentration 5%, both potatoes gain weight, 14.74% and 19.50% on average, revealing that the data refutes the hypothesis because the mass change should be negative for Yukon gold potatoes if it loses weight. If the data is valid, then the hypothesis is incorrect.

Reliability of results:

The range bar indicates the range of data collected and shows the deviation of data collected. Range bars indicate how spread the data are around the mean value. Bigger range bars, bigger spread (unknown, n.d.). The bigger the spread, the bigger the deviation of results and the data is less reliable. At sucrose concentration 2.5% for Yukon gold potatoes, the range bar is from 11.11 to 13.24%, suggesting a small deviation of data, meaning that the results are reliable. However, at sucrose concentration 2.5% for sweet potatoes, the range bar is from -3% to 40.74%, suggesting a huge deviation of data, meaning that the results are unreliable. According to the graph, data at concentration levels 2.5% and 10% indicates a huge deviation of data, and the rest data has a relatively smaller deviation of data to some extent, suggesting the unreliability of the results.

The upper range and lower range on the table also suggest the unreliability of the results. The averages of upper range and lower range for Yukon gold potatoes are (3.71%+1.47%+5.26%+20.36%+3.47%+5.15%)/6=6.57% and (5.75%+1.42%+5.48%+26.51%+4.97%+8.45%)/6=8.76%. The averages of the upper range of lower range for sweet potatoes are (5.84%+24.45%+5.50%+15.13%+4.58%+6.67%)/6=10.37% and (5.24%+19.32%+6.04%+24.47%+3.30%+6.66%)/6=10.83%. These four averages of the upper and lower range are huge for a controlled experiment, suggesting inaccuracy and a low level of precision. Thus, the results collected are not reliable.

The dispersion of the data also suggests the unreliability of the results. For example, at sucrose concentration 10% for Yukon gold potatoes, there are data -23.68%, -43.75%, 3.13%, 11.36% and 10.53%. It's understandable if there are only one or two pieces of data that are different from the other three. But for this set, only two pieces of data stay close. At sucrose concentration 2.5% and 10% for sweet potatoes, similar problems occurred. At 2.5% and 10%, ten pieces of data acquired are (25.42%, -3.03%, 40.74%, 7.41% and 10.91%) and (12.77%, -19.23%, -4%, 16.28% and 20.37%). Hardly ever data stays together. So the conclusion can be drawn that the results are unreliable.

Strengths of the method and data:
The control of the size of each potato piece was done well. The uniform cork borer gives cylinders of the same base area, and each cylinder was cut into pieces of 6mm long small cylinders. The measurement was done very carefully and it's easy to make sure all the potatoes were literally the same size. Thus, the mass of each trial should be controlled to the same.

All of the pieces were kept in the same location under the same condition. This helps to prevent any kind of change of status of pieces. For example, evaporation caused by sunlight, a process that can cause a loss of mass other than osmosis, can be controlled the same so each potato piece would lose the same amount of mass because of that.

Weaknesses:

When measuring the mass of each potato piece before and after the experiment, the number on the balance was fluctuating because of the wind, which led to inaccurate results. It would affect the experimental results because, for example, if the mass before was actually 4g, but because of fluctuations, it was read as 4.5g. After the experiment, the mass was 5g, but it was 4.8g, then the real mass change would be a lot bigger than the mass change measured. It makes the data less accurate and reliable. This fluctuation, which was about 0.06 grams, would likely have a big influence on the data. The design and the method of the investigation were appropriate and they didn't cause the fluctuation. This error is systematic because it can be acknowledged as an error that can hardly be limited in ordinary laboratories.

When measuring the mass of potato pieces after the experiment, the results won't be accurate because the pieces were not dried completely. When the pieces brought water onto the balance, the result would be heavier than usual. This made the measured mass change bigger than usual. This causes inaccuracy of the results and makes the results less reliable. This error won't create a huge influence on the data because the extra mass caused by undried water might be relatively small. The design and the method of investigation can hardly prevent this from happening. This error is systematic because it's hard to determine how dry the piece should be after the experiment. Thus, it cannot be eliminated.

When transporting the Petri dishes filled with solution to the final location, the pieces were floating in the container. They might switch positions without notice. For example, a sweet potato piece which was determined to be trial 2, switched position with a sweet potato piece in trial 3. They were so easy to change the position that it was hard to prevent this from happening. This made the result inaccurate because people are not measuring the mass change of the same pieces. It's a random error which it's unpredictable that is caused by an operation mistake.

Although the petri dish of each sucrose concentration was at the same location, the Petri dishes of other groups were not in the same location. This made the experiment results inaccurate because different levels of evolution caused by sunlight and temperature can cause a different amount of mass change not caused by osmosis. The more water evaporates, the smaller the final mass becomes. This won't also create a huge influence on the results because the loss of mass caused by evaporation was relatively small. The design of the method of investigation also cannot eliminate the influence. This error is systematic since it's predictable and it's associated with environmental interference.

Improvements:

1. The best possible solution to eliminate the inaccuracy of weighing caused by wind fluctuations is to find a lab with no airflow. When doing the experiment, it's better to have no one moving because that will generate airflow that will impact the number on the balance.
2. There won't be a good solution to this one because it's unpredictable how much time the pieces after the experiment should be dried and how it would be dried to prevent loss of mass caused by over-evaporation. The only way is to use the tissue to dry the moisture on the surface of the potato but it might bring out more water inside the potato, causing an unpredictable loss of mass.
3. The solution to this problem is to choose the final location first and pour the solution into the petri dish after arriving at the location. This will prevent the pieces from switching places while floating when being transported to their final location.
4. It's better to put all the Petri dishes as close together as possible. This will make the deviation caused by evaporation as small as possible. Also, they are likely to stay at the same temperature so their evaporation level won't be very different.

In the experiment, only the sugar content in the potatoes is measured. However, in potatoes, starch and carbohydrates also raise blood sugar values. People can also investigate the content of starch and carbohydrate in the potatoes to give patients with diabetes better suggestions. They can also investigate the content in different potatoes like red potatoes and petite potatoes to provide more choices for patients. In experiments, People should focus on eliminating the deviations on controlled variables and implement wise designs to avoid fixable mistakes. People should also use the equipment properly and follow the instructions to prevent inaccuracy caused by improper operation.

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