OSMOSIS

The effect of increasing sucrose concentration on the mass of potato chips

Research Question:

The potato chips are submerged in a range of sucrose solution concentrations. Does their mass decrease beyond a certain concentration of sucrose solution?

Hypothesis:

A more concentrated sucrose solution will cause the mass of potato chips to decrease as water is likely to move out of the cells. The higher the concentration of sucrose solution, the less the mass of potato chips. Conversely, in distilled water or very low concentrations of sucrose solution, the mass of the potato chips will increase because the water will move into the cells.

The reason for this is that water moves from a hyperosmotic (concentrated) solution to a hypo-osmotic (dilute) solution across a partially permeable membrane[1]. This is demonstrated in the illustration below. If iso-osmostic (same concentration) solutions occur on either side of a partially permeable membrane, no net movement of water occurs. Osmosis will continue until equilibrium is reached, that is when equal concentration of solutes exists on both sides. Osmosis is a form of passive transport in which no ATP is used.

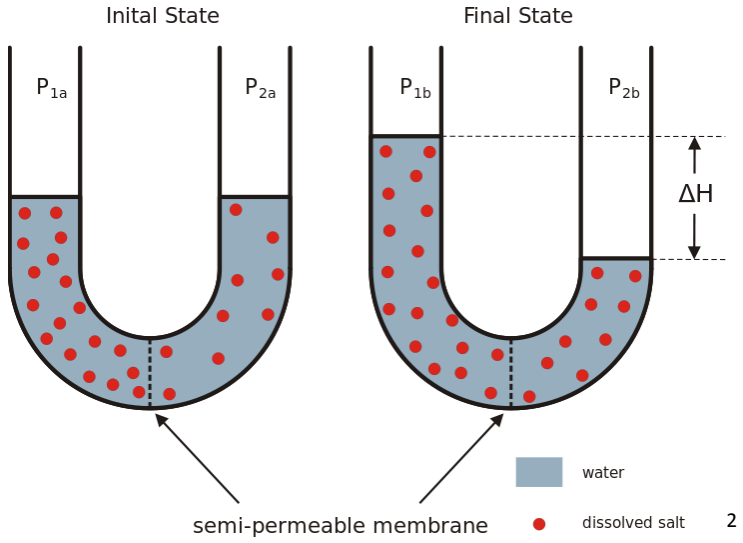


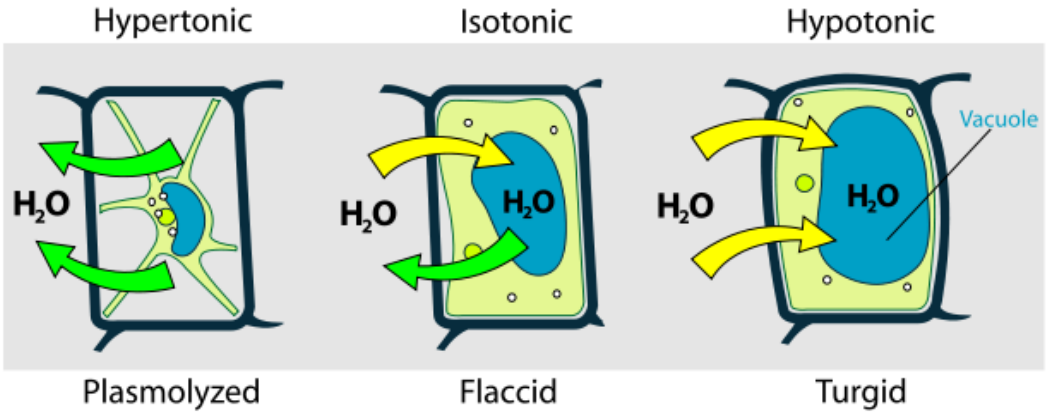
Figure 1: Osmosis- the movement of water molecules from a region of their higher concentration to a region of lower concentration until equilibrium is reached.

[1] Ward, W. and Damon, A. 2007. *Pearson baccalaureate*. Harlow, [England]: Pearson Education.
[2] Hillewaert, H. 2011. *An example of osmosis: dissolved salt forcing water to pass through a semi-permeable membrane*. [image online] Available at: http://en.wikipedia.org/wiki/File:Osmose_en.svg [Accessed: 8 Jan 2014]

Background information:

Osmosis is a fundamental concept in the study of biology. All cells use the principles of osmosis to transport water in and out of themselves. It is also very important in osmoregulation; a process which regulates the osmotic pressure of an organism's fluids in order to maintain a homeostatic environment.

Osmotic pressure is essential for support in plants. Entry of water in the cell raises the turgor pressure exerted against the cell wall, making it turgid and enabling it to stand upright. Plant cells are usually in hypotonic environments, where the fluid in the cell is more concentrated than that outside the cell, so water enters in. This is illustrated below.



[3]

Figure 2: Plant cells in hypertonic, isotonic and hypotonic environments.

Figure 2 also shows that if plant cells are in a hypertonic environment, then all the water will leave the cell, making it plasmolyzed[4]. This causes the cytoplasm to be pinched away from the cell wall, and the cell can no longer function. If plants are in isotonic environment, they are not turgid, but flaccid; they tend to wilt.

Osmosis is also responsible for the ability of plant roots to draw water from the soil. Roots are adapted for this because of the numerous root hair cells; they increase the surface area to volume ratio, making the absorption highly effective. Animal cells also use osmosis to transport water in and out, but the consequences in this case are different due to the absence of cell walls.

[3] Villarreal, M. 2007. *Turgor pressure on plant cells*. [image online] Available at: http://en.wikipedia.org/wiki/File:Turgor_pressure_on_plant_cells_diagram.svg [Accessed: 8 Jan 2014].
[4] Plasmolysis: shrinking of the cytoplasm away from the wall of a living cell due to outward osmotic flow of water

Variables:

Independent Variable
Concentration of sucrose solution Four trials of each of the following concentrations 1. 0.00 mol dm^{-3} (Distilled water) 2. 0.20 mol dm^{-3} 3. 0.40 mol dm^{-3} 4. 0.60 mol dm^{-3} 5. 0.80 mol dm^{-3} 6. 1.00 mol dm^{-3}
Dependent Variable
How much water is absorbed in the potato chips

Table 1.1 and 1.2: Independent, dependent and controlled variables.

Controlled Variables		
	Why was it controlled?	**Method for Control**
1. 200 cm^3 volume of solution in the beaker.	To ensure the concentration is the only variable changing, the volume of the solutions must be controlled.	A 100 cm^3 measuring cylinder was used to measure the volume. In addition, beakers were covered with a removable cling that did not let water vapor in.
2. Diameter of potato chips	Surface area to volume ratio affects the rate of osmosis.	0.6 cm diameter borer was used to cut out the chips
3. Length of potato chips	Surface area to volume ratio affects the rate of osmosis.	3 cm length was measured using a rule. The chip was then cut accordingly using a scalpel
4. Initial mass of potato chips	So it's a fair test for calculating final mass in the beaker	A balance was used to verify the mass
5. Temperature	Temperature affects the rate of diffusion	Air conditioning of the lab was kept on at the same temperature throughout.
6. Time	To ensure a fair test time has to be controlled because if some beakers are given more time than others, more transfer of water will occur.	All potato chips were immersed in the 6 beaters at the same time and the lab assistant helped to start the stopwatch.
7. Blotting	More or less blotting will affect the reading of the mass.	Balanced use of paper towels was

Materials and Apparatus:

- Six 250 cm^3 beakers (± 25 cm^3, but used as a container, not for measuring the volume)
- 100 cm^3 measuring cylinder (± 1 cm^3)
- 200 cm^3 of pre-prepared sucrose solutions of the following concentrations:
  - 0.20 mol dm^{-3}
  - 0.40 mol dm^{-3}
  - 0.60 mol dm^{-3}
  - 0.80 mol dm^{-3}
  - 1.00 mol dm^{-3}
- 200 ml Distilled water
- 10 potatoes
- A 0.6 diameter borer
- White tile
- 15 cm ruler (± 0.05 cm)
- Scalpel
- Spatula
- Paper towels
- Balance (± 0.1 g)
- Stopwatch (± 0.01 s)

Risk Assessment:

All materials are safe to use except scalpels. They are very sharp and should be used with caution. Lab coats or safety goggles not necessary.

Uncertainties: Table 2: Percentage uncertainty calculations

Apparatus		Percentage uncertainty
Measuring cylinder x 2		$\frac{2}{200} \times 100 = 1\%$
Balance	Initial mass	$\frac{0.1}{1.7} \times 100 = 5.88\%\ (3\ s.f)$
	Final mass	$\frac{0.1}{x} \times 100 = \frac{10}{x}\%$
Ruler		$\frac{0.05}{3} \times 100 = 1.67\%\ (3\ s.f)$
Stopwatch		$\frac{0.01}{144000} \times 100 = 6.94 \times 10^{-5}, negligible$
Total % uncertainty		$\pm 8.55 + \frac{10}{x}\ \%$

Figure 3.1 and 3.2: Some of the apparatus labeled (these pictures were taken at the end of the experiment)

Procedure:

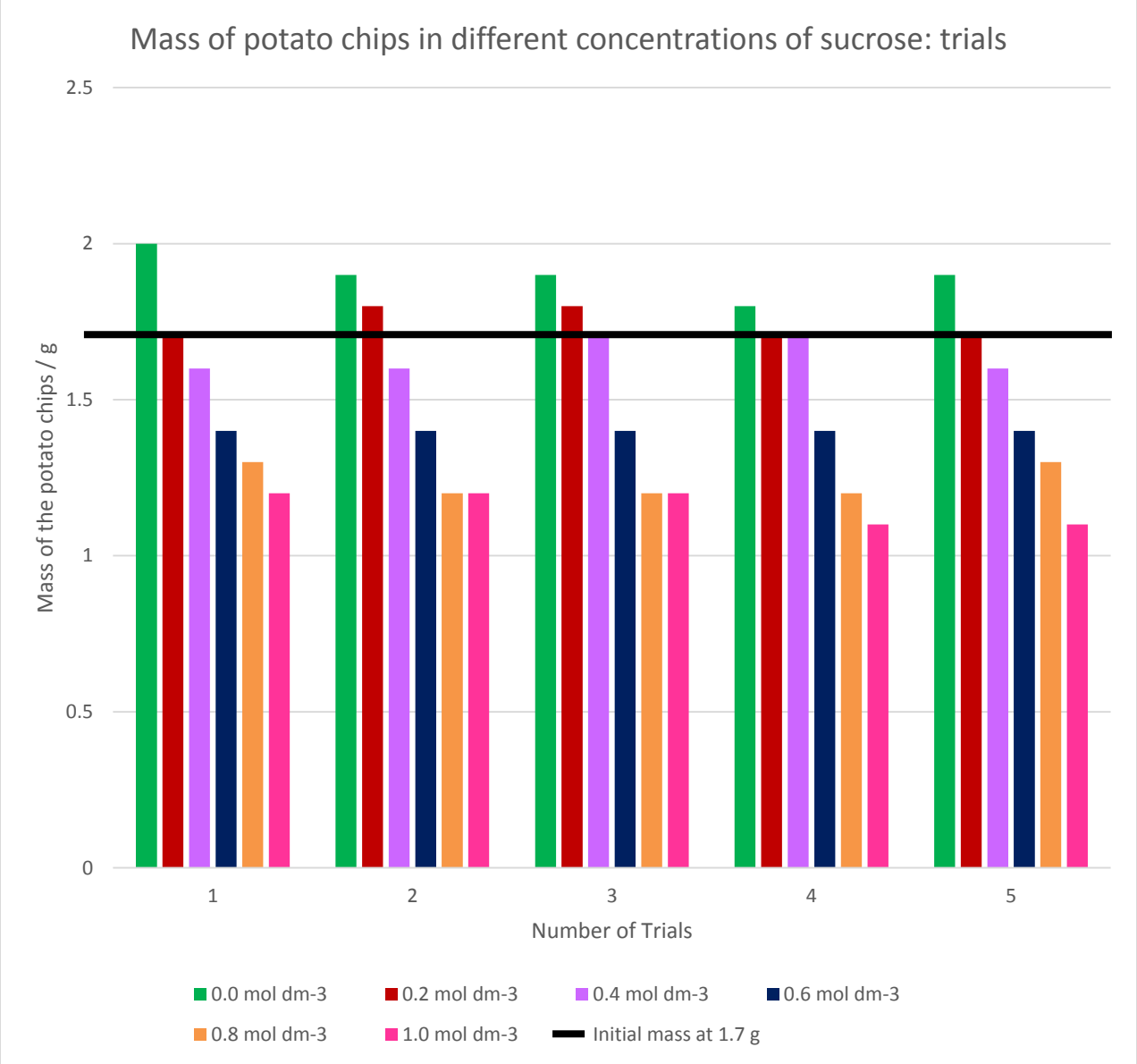
1. Clear the working area and place a large white tile.
2. Take out at least 10 potatoes that look most similar to each other. The color and the approximate size should help in deciding that.
3. Use a 0.6 cm diameter borer to form the potato chips. Try to use as few potatoes as possible to produce 30 potato chips.
4. To ensure that the chips are of same diameter throughout, insert the borer quickly in a potato while keeping it straight so that one end of the borer comes out of the other side. Put the chips on the white tile.
5. Now that all the 30 chips are on the white tile, use a scalpel to peel off any remaining skin on the potatoes. Do this process one by one until all the chips are clean.
   Caution: Scalpels are very sharp; use them carefully.
6. Separate the longer chips from the shorter ones. Using a 15 cm ruler, check if any of the long ones are longer than 6 cm to be evenly cut in half. This will save time.
7. Use the scalpel to cut all the chips to be accurately 3 cm long using the same ruler each time.
8. Once all the chips are 3 cm long, weigh their mass one by one by using a balance.
9. Make sure they are all within 0.1 g difference of each other.
10. Record this data in the "Initial Mass" section of the table.
11. Take out the tray containing beakers of pre-prepared sucrose solutions- concentrations 0.0 mol dm^{-3}(distilled water), 0.2 mol dm^{-3}, 0.4 mol dm^{-3}, 0.6 mol dm^{-3}, 0.8 mol dm^{-3} and 1.00 mol dm^{-3}.
12. To ensure that the volume of the solutions is 200 cm^3, use a measuring cylinder. This has to be repeated twice because the measuring cylinder is 100 cm^3 (hence double the uncertainty). The lower meniscus should touch the 100 cm^3 mark.
13. With the help of someone else, ensure that you immerse 5 potato chips in each of the beakers *and* start the stopwatch at the same time**.** The 5 potato chips represent trials of each concentration.
14. Once the stopwatch is running, name the tray containing all the beakers. The experiment can be left unmonitored in the lab for 4 hours.
15. When the time nears 4 hours, difference in the size of potato chips is noticeable, however to have quantitative evidence, potato chips must be weighed.
16. After exactly 4 hours, remove the potato chips from the solutions using a spatula carefully, ensuring none of the potato chips break or get squashed.
17. Try to blot all 30 potato chips using a paper towel equally and weigh them once again.
18. Record the mass of each in the "Final Mass" section of the table.
19. All the lab work is completed for this experiment. Clear the area and clean the apparatus if required.

Data collection:

Table 3: Raw data collection table of the masses of potato chips before and after immersing them in various concentrations of sucrose solution.

Sucrose solution concentration(mol dm^{-3})	Trial	Initial Mass (g) (±0.1 g)	Final Mass (g) (±0.1 g)
0.0	1	1.7	2
	2	1.7	1.9
	3	1.7	1.9
	4	1.7	1.8
	5	1.7	1.9
0.20	1	1.7	1.7
	2	1.7	1.8
	3	1.7	1.8
	4	1.7	1.7
	5	1.7	1.7
0.40	1	1.7	1.6
	2	1.7	1.6
	3	1.7	1.7
	4	1.7	1.7
	5	1.7	1.6
0.60	1	1.7	1.4
	2	1.7	1.4
	3	1.7	1.4
	4	1.7	1.4
	5	1.7	1.4
0.80	1	1.7	1.3
	2	1.7	1.2
	3	1.7	1.2
	4	1.7	1.2
	5	1.7	1.3
1.00	1	1.7	1.2
	2	1.7	1.2
	3	1.7	1.2
	4	1.7	1.1
	5	1.7	1.1

Graphing Raw Data:



Graph 1: Effect of sucrose concentration on potato cell mass: trials

This graph shows the variations within the trials of each concentration of sucrose solution. The colors represent a specific concentration and are repeated 5 times. Note that they do not always have the same final mass. The black horizontal line indicates the initial 1.7 g mass.

Qualitative analysis:

Apart from the above quantitative analysis, a lot of other physical changes in the potato chips were observed. An obvious one was the size, which was indicative of the mass changes. The potato ships in distilled water were noticeably 'fatter' or thicker whereas the potato chips in 0.8 mol dm^{-3} and 1.0 mol dm^{-3} looked as if they shrank.

Upon taking the chips out of the beakers using spatulas, the rigidity of the potatoes in distilled water could be noticed while the chips in the latter two concentrations felt more flaccid.

The level of water in the 0.0 mol dm^{-3} & 0.2 mol dm^{-3} beakers was below the original level of 200 cm^3 whereas the volume of water in the beakers containing 0.6 mol dm^{-3}, 0.8 mol dm^{-3} and 1.0 mol dm^{-3} increased above the 200 cm^3 mark.

A slight color change was also visible. Distilled water and 0.2 mol dm^{-3} concentration potato chips looked lighter in color and more towards white whereas 0.8 mol dm^{-3} and 1.0 mol dm^{-3} concentration potato chips had a brighter color than the initial color. The concentrations in between also exhibited some of these changes but they did so less noticeably.

Data Processing:

The data collected above had to be processed in order to draw meaningful conclusions from it. Calculating the change in mass and then converting it to a percentage was one of the most basic calculations that helped identify the difference between the initial and final masses. Calculating the mean was also important because the trials have slightly different values each, but for the graph, only one set of values that represented the average of the data points was needed. Finally, standard deviation was calculated to summarize the spread of values around the mean.

Sample calculations:

1. Final mass – Initial mass = **mass change**
   2 g – 1.7g = 0.3 g

2. **Percentage change** $= \frac{mass\ change}{initial\ mass} \times 100 = \frac{0.3}{1.7} \times 100 = 17.7\%$

3. **Mean % change** $= \frac{sum\ of\ percentages}{total\ number\ of\ percentages} = \frac{17.7+11.8+11.8+5.88+11.8}{5} = 11.8\%$

4. **Standard Deviation**: This was generated using the STDEV function in Microsoft Excel and selecting all of the results for each concentration (e.g. 17.7%, 11.8%, 11.8%, 5.88%, etc. for the 0.0 mol dm^{-3} concentration, for example)

Solute Concentration (mol dm^{-3})	Trial	Change in mass (±0.2 g)	% Change in mass	Mean % Change	Standard Deviation
0.00	1	0.3	17.7	11.8	4.16
	2	0.2	11.8		
	3	0.2	11.8		
	4	0.1	5.88		
	5	0.2	11.8		
0.20	1	0	0.00	2.35	3.22
	2	0.1	5.88		
	3	0.1	5.88		
	4	0	0.00		
	5	0	0.00		
0.40	1	-0.1	-5.88	-3.53	3.22
	2	-0.1	-5.88		
	3	0	0.00		
	4	0	0.00		
	5	-0.1	-5.88		
0.60	1	-0.3	-17.6	-17.6	0.00
	2	-0.3	-17.6		
	3	-0.3	-17.6		
	4	-0.3	-17.6		
	5	-0.3	-17.6		
0.80	1	-0.4	-23.5	-27.1	3.22
	2	-0.5	-29.4		
	3	-0.5	-29.4		
	4	-0.5	-29.4		
	5	-0.4	-23.5		
1.00	1	-0.5	-29.4	-31.8	3.22
	2	-0.5	-29.4		
	3	-0.5	-29.4		
	4	-0.6	-35.3		
	5	-0.6	-35.3		

Table 4: Processed data collection table of the mass change, the mage change % and the mean change % of potato chips.

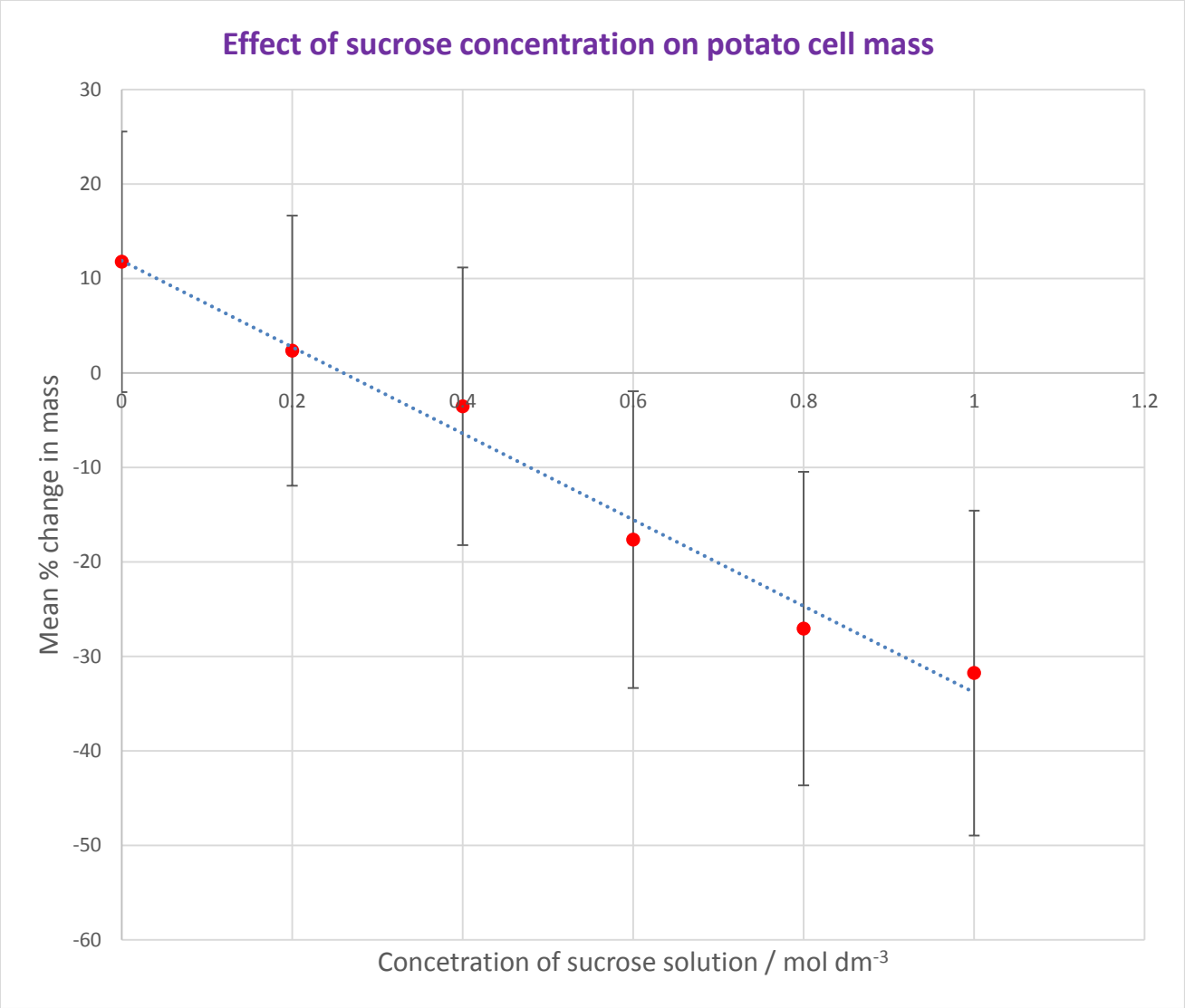
Percentage uncertainty calculations

$$\pm 8.55 + \frac{10}{x}\ \%$$

Now that the final mass values are known, the total percentage uncertainty can be calculated without any variables and it can be utilized as error bars in the processed data graph. In order to do that, the final masses of all different concentrations are taken and inserted into the equation above. For example, the first trial in distilled water x or final mass of a potato chip is 2 g, therefore equation is $\pm 8.55 + \frac{10}{2}$ =13.5. After percentage uncertainty for all trials is found, a mean can be taken so that it can used in the graph.

Table 5: Total percentage uncertainty calculations

Sucrose solution concentration(mol dm^{-3})	Trial	Final Mass (g) (±0.1 g)	Total % uncertainty	Mean total % uncertainty
0.0	1	2	13.5	13.8
	2	1.9	13.8	
	3	1.9	13.8	
	4	1.8	14.1	
	5	1.9	13.8	
0.20	1	1.7	14.4	14.3
	2	1.8	14.1	
	3	1.8	14.1	
	4	1.7	14.4	
	5	1.7	14.4	
0.40	1	1.6	14.8	14.7
	2	1.6	14.8	
	3	1.7	14.4	
	4	1.7	14.4	
	5	1.6	14.8	
0.60	1	1.4	15.7	15.7
	2	1.4	15.7	
	3	1.4	15.7	
	4	1.4	15.7	
	5	1.4	15.7	
0.80	1	1.3	16.2	16.6
	2	1.2	16.9	
	3	1.2	16.9	
	4	1.2	16.9	
	5	1.3	16.2	
1.00	1	1.2	16.9	17.2
	2	1.2	16.9	
	3	1.2	16.9	
	4	1.1	17.6	
	5	1.1	17.6	



Graph 2: Effect of sucrose concentration on potato cell mass: mean percentage change in mass. The error bars represent total percentage uncertainty at that data point.

Conclusion:

The data in this experiment seems to support the hypothesis that the mass of potato chips will decrease if they are put into a more concentrated solution and that the mass would increase if potato chips are put in a dilute solution. This can be seen in the downward sloping graph on the previous page indicating a negative correlation.

The largest mass change was produced by the chips in 0.80 mol dm^{-3} and 1.00 mol dm^{-3} concentrations of sucrose. They lost about 0.5 g on average. This suggests that the higher the concentration was, the more the water went out of the potato cells. In distilled water, even though the potato chips gained mass as per the hypothesis, they only gained 0.2 g on average.

In some of the trials of 0.20 mol dm^{-3} and 0.40 mol dm^{-3} concentration, there was no percentage mass change at all. This suggests that the original solute concentration in the cells is between those two concentrations. Osmosis is defined as the passive movement of water molecules from a region of lower solute concentration to a region of higher solute concentration across a partially permeable membrane[5]. If the solute concentration is the same on both sides of the membrane, there is no net movement, hence there is no mass increase or decrease.

The processed data elaborates the conclusion so far. The highest mean percentage change was for 1.00 mol dm^{-3} at -31.8% which means that at this concentration, the potato chips lost 31.8% of their mass due to the water leaving the cells into the hypertonic environment of a highly concentrated sucrose solution. At the other end, chips immersed in distilled water on average gained 11.8% of their mass because they were in a hypotonic solution and water rushed into the potato cells. The isotonic environment for potato cells is between 0.2 mol dm^{-3} & 0.4 mol dm^{-3} sucrose concentrations, but closer to the former rather than the latter. This is because 2.35% mass was gained on average in 0.2 mol dm^{-3} but a slightly more percentage 3.53% was lost in 0.4 mol dm^{-3}.

The qualitative analysis further consolidates the hypothesis and it's in agreement with the background information presented earlier. The potato chips in distilled water and 0.2 mol dm^{-3} (hypotonic) solutions were indeed turgid and whereas the chips in 0.8 mol dm^{-3} & 1.00 mol dm^{-3} were clearly flaccid and felt a little bit squashy.

The trials produced slightly different mass changes from one another. This is visible in Graph 1 and also in the non-linear decrease in Graph 2. The data point for 0.4 mol dm^{-3} is the most 'off point' from the trendline however it is not significant enough to be called anomalous. This can be attributed large total percentage uncertainties calculated in table 5 and these are discussed

[5] Newworldencyclopedia.org. n.d. *Osmosis - New World Encyclopedia*. [online] Available at: http://www.newworldencyclopedia.org/entry/osmosis[Accessed: 28 Feb 2014]

in the section overleaf, or due to the fact that in this experiment, the origin or the age of the potatoes is not known and they were not controlled.

Evaluation:

The experimental design was fairly well suited for this experiment. It was easy to manage all the controls; the process itself wasn't too complicated either. The use of a borer for cutting out the potato chips was particularly helpful in providing a constant surface area to volume ratio and saved a lot of time. It was also much safer than using a knife or a scalpel but the downside was that more potatoes were wasted in the process.

The solutions were pre-prepared by the lab assistant; their accuracy cannot be commented on. One major aspect that should be a control but couldn't be realistically controlled in this experiment was the type and the age of potato used. There was no practical way to deduce that they are of the same type, age, plant etc.

There are large percentage uncertainties in this experiment, and they grow as the concentration increases because each time lesser final mass of the potato chip remains. The highest is for 1.00 mol dm^3 sucrose solution at 17.2%. Some of the apparatus used in this investigation has a lot of room for improvement. For instance, simply using a ±0.01 g uncertainty balance would have made this problem much smaller. Some controlled variables such as blotting cannot be achieved uniformly, even if one might like to attempt that, and an important variable like temperature should be controlled more precisely, as the heat outside the lab and sunlight would fluctuate over the course of a school day. However, in spite of all of this, the results of the experiment are fairly reliable because there were five trials and the differences in their results were small (this can also be seen in the relatively low standard deviation values) and the ensuing trend they produced is supported by biology literature elsewhere.

Table 6 overleaf shows major weaknesses in this investigation & their suggested improvements.

Weakness	Significance	Improvement(s)
Uncertainty on measuring equipment	Referring back to tables 2 and 5, the uncertainties of the equipment caused a relatively large total percentage uncertainties for the experiment. This can be accounted for in the different results in each of the trials. While it didn't change the outcome of the experiment as a whole, the results could have been even more reliable if more precise equipment was used.	1) Use of more precise equipment, for instance a ±0.03 cm^3 uncertainty burette to measure volume rather than a ±1 cm^3 measuring cylinder. 2) Use of a balance with ±0.01 uncertainty. This would have a profound effect on the values in Table 5. For instance, the first concentration mean uncertainty ±13.8% would become just ±3.78%
Controlling Temperature	In this experiment, only the air conditioning of the lab was relied on. However, this is not enough to maintain a constant temperature as the lab door would open often bringing heat from the outside.	A water bath could be used to provide a cheap & effective method for maintaining a homogeneous temperature.
Time given	Due to it being the last weekday, it was not possible to leave the experiment for a whole day. It was collected after 4 hours, when school ended. This is significant because if it was kept for longer, it might have been possible to see clearer results with much larger changes in mass.	Conduct the experiment on a day when the results are collectable after 24 hours and notice if there is any difference in the outcome or the change in mass is more or less the same with a limited amount of time.

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