Determining the water potential of potato tuber cells

I will carry out an investigation that will enable me to determine the water potential of the tested potato tuber cells.

Water Potential is the measurement of the tendency of water molecules to move from one place to another. (Ridge 1991) Water always moves down the water potential gradient, therefore moving from an area of higher water potential to an area of lower water potential.

Equilibrium is reached when the water potential in one region is equal to the water potential in another region. For example, if a plant cell (like the potato tuber cells) is in equilibrium with an external solution of such a concentration that there is no net gain or loss of water then the water potential of the external solution will be equal to the water potential of the cell. (Roberts 1991)

By convention, the water potential of pure water is set at zero. Knowing that solutes make the water potential of solutions lower, solutes make solutions negative. Solute potential is the amount that the solutes lower the water potential of a solution.

Pressure potential is especially important in plant cells. If a plant, for example the potato tuber cells, is placed in pure water (or a dilute solution), the water (or solution) has a higher water potential than the plant cell. This causes the movement of water to the cell due to the higher water potential in the cell. Water enters a cell through the partially (semi) permeable membrane by osmosis.

Osmosis is the movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane.

The diagram below shows the water potential changes in a plant cell in a solution of different water potentials (Cambridge 2000)

The different changes shown in the diagrams are caused because all plant cells, unlike animal cells, have a cell wall.

A plant cell wall is extremely inelastic. This property allows very little water to enter a plant cell - preventing the cell from bursting.

For plant cells water potential consists of a combination of solute potential and pressure potential.

Solute potential can be defined as the amount that the solute molecules lower the water potential. (Cambridge 2000) It is evidently always negative.

On the other hand, the pressure potential is always positive. This is because it causes the water potential to be less negative. Pressure potential can be defined as the contribution made by pressure to water potential (Cambridge 2000)

The following equation expresses the relationship between water, solute and pressure potential:

$$\psi = \psi + \psi$$

Taking into account that water always moves down the water potential gradient, I am able to form a prediction for the outcome of this investigation.

I predict, using scientific knowledge that, as the concentration increases the water potential will decrease. I think this is because as the concentration of the sucrose increases there are more solute molecules in the solution. As the solute potential is always negative consequently the water potential is made more positive.

Using a table that expresses the relationship between molarity and water potential (Roberts 1991) and referring to other scientific evidence (W D Phillips and T J Chilton) I know that the if there is no change in weight in my potato tuber cell samples then the water potential in both the regions have reached equilibrium.

Taking into account all the scientific knowledge that I have researched I predict that the water potential will be within the range of minus 1200 kPa and minus 200 kPa for a normal potato tuber cell.

I think this because minus 1200 kPa is the suggested water potential, (for a quantity of 0.45 molar sucrose) for a plasmolysed cell. Minus 200 kPa is the suggested water potential, (for a quantity of 0.1 molar sucrose) for a maximum turgid cell. My potato tuber cell samples will be within these two amounts.

The aim of this investigation is to determine the water potential (ψ) of a plant cell. In this case potato tuber cells are to be investigated.

Equally sized and weighed samples of potatoes will be immersed in a sucrose concentration ranging in different strengths of molarity.

I will repeat each experiment three times in order to ensure my investigation is fair and accurate.

In each experiment I will change the same single variable, in this case the sucrose concentrations, in all three experiments. I will use the same strengths of molarity in all experiments in order to compare my results

The sucrose concentration will be the only aspect of all three experiments to change. I will ensure all other variables are kept constant. For example the mass / size of the potato tuber cells used must all be the same. In order to ensure this I will measure and weigh each sample and record the results in a table.

The surface area of the sample cell is also a variable I must keep constant. ⮝ larger or smaller surface area exposed to the sucrose will certainly affect my results and consequently the accuracy of my investigation.

The volume of the solution must also be kept constant. Without continuity of the volume I will not be able to compare my results, once collected.

In order to lessen the complications of the investigation I have decided to carry out all experiments at room temperature.

⮝ vital variable that must remain constant is the origins of the potato tuber samples within the potato itself.

Key: RED = Section to be used
TURQUOISE = Section to be disposed

The diagram above shows the section of potato cut by the cork borer. Only the middle section of the potatoes, all of which are the same type, will be used in my investigation. The outer section of the potatoes, shown as turquoise on the diagram, will be much drier than the middle sections of the potato and this will affect the accuracy of my results.

To ensure all variables remain constant I will record the necessary information before and after each experiment has been carried out.

Before carrying out my investigation I will need to collect the following equipment:

- ⮝ cork borer of 1 cm diameter
- 6 beakers

- labels
- filter paper
- a balance
- a sharp knife (scalpel)
- a pipette
- distilled water
- sucrose solution

NOTE – 10 cm measuring cylinder is vital to ensure measurements are to the most accurate quality achievable. Balance to be preferably digital to avoid mistakes such as misreading

1. Add a mixture of distilled water and sucrose solution. The quantities are shown in the following table:

Beaker number	Amount of distilled water (cm)	Amount of sucrose solution (cm)	Total volume (cm)	Final Concentration (Molars)
1	0	100	100	1
2	20	80	100	0.8
3	40	60	100	0.6
4	60	40	100	0.4
5	80	20	100	0.2
6	100	0	100	0

These measurements allow me to investigate molarities ranging from one molar to zero. The total volume in all six beakers, for all three experiments is 100 cm .

2. I will add labels to the beakers indicating the amount of water and solution in each one.

3. Using a cork borer with a one centimetre diameter I will prepare six solid cylinders from the centre of the potato (see diagram at top of previous page). Samples should be exactly 15mm long. Placing each sample with care onto a separate piece of filter paper.

4. I will then weigh each sample in turn, recording the results in a table. I will ensure when weighing not to include the mass of the filter paper in my table figures.

5. Once weighed I will put one sample into each of the labelled tubes and leave them, ensuring they are fully submerged in the solution. I will leave them for 24 hours.

6. After the time is up I will carefully remove the samples from each tube and remove any surplus fluid from them quickly using filter

paper. I will take care to ensure to use the same 'standard' procedure for all of them.

7. I will then re-weigh the samples and record the new masses of each of the samples.

8. I will then plot a graph to show my results and enable myself to compare the change in mass to the molarity of the sucrose solution.

Before and whilst carrying out my investigation I must consider safety. The most obvious danger in this investigation is the knife needed to cut the potato tuber cell to the necessary shape. I must take great care when handling the knife and ensure it is put away when not in use.

The knife is not the only safety aspect I need to consider. Although there are no other immediate safety hazards, like the knife, I will wear safety goggles at all times during the course of the experiments just to be sure that the either solution or the water being dealt with do not enter my eye and cause unnecessary irritation. I also need to clear any obstacles from the laboratory, for example objects that I could trip on – like a stool.

Here are the results from my investigation.

CONCENTRATION OF SUCROSE SOLUTION (M)	AVERAGE INITIAL WEIGHT OF POTATO (g)	AVERAGE FINAL WEIGHT OF POTATO (g)	AVERAGE CHANGE IN WEIGHT (g)	AVERAGE PERCENTAGE CHANGE IN WEIGHT (%,g)
1	4.38	2.12	- 2.26	- 52
0.8	3.97	1.86	- 2.11	- 53
0.6	3.93	2.25	- 1.68	- 43
0.4	4.30	3.12	- 1.18	- 27
0.2	4.57	4.55	- 0.02	- 0.44
0	4.37	4.76	+ 0.39	+ 8.94

The results table above shows the total weight of the three potato samples before and after the samples were placed in the different concentrations of sucrose solution. I have then calculated the average change in weight for all the potato samples and the average percentage change in weight. This allows me to easily compare my results obtained while carrying out the experiment.

During the experiment I looked out for any unexpected activities or observations and I noted these down. I noticed that once I had placed the potato samples into the solutions at the beginning of the experiment all the samples, in the 1 molar solution, were floating. I came to the conclusion that this was because the potato samples were not as dense as the solution.

The floating samples sank at different speeds. For example, the samples in the 1 molar solution lost less water due to the fact that there was not much difference in the amount of solute in the cytoplasm and in the solution.

The results above and the graph both show that as the molarity decreases the percentage change in weight increases. As shown in the table, the change in mass depends on the concentration of the solution. This is because the amount of water that was lost or gained, by osmosis, depends on how concentrated the solution was. If the solution had more solutes than the cytoplasm of the sample, water would move out of the sample by osmosis, following the concentration gradient of water causing the sample to decrease in weight.

This can clearly be seen in the results from my investigation. The solutions, from 1 mole to 0.4 moles show that the change in weight depended on the concentration of the sucrose solution. For example, if the solution had less solute than the cytoplasm of the sample, water would move into the sample by osmosis, evidently causing the sample to loose weight. The potato cells in the solution of 0.2 moles lost only a

small amount of mass and the solution containing 0 moles in fact gained weight. My results justify the fact that water always moves down the water potential gradient (Cambridge 2000), by osmosis, from an area of higher water potential to an area of lower water potential.

In my results I have identified several features. Every sample of potato that I used in my experiment followed the water potential gradient by either loosing or gaining weight. For example, as shown in the table, in the beaker containing the most concentrated sucrose solution – which in this case was 1 mole, more weight was lost. Evidently this is due to the fact that the concentration of the external solution was higher than that of the internal solution of the potato cells and therefore the water moved from the region of higher water potential to the region of lower water potential through a partially permeable membrane by osmosis. In the beaker containing the least concentrated sucrose solution osmosis also occurred, however the opposite happened. The potato sample gained weight. The internal solution was of a higher concentration than the external solution and so the water moved down the water potential gradient – hence into the potato cell. The cell became fully plasmolysed over the 24 hour period in which the investigation took place.

Plasmolysis occurred in the experiment with the 0 mole concentration of the external solution due to the fact that water was leaving the cell by osmosis because the cell was placed in a solution of a lower water potential. The protoplast of the cell gradually shrunk and began to pull away from the cell wall. This process is called plasmolysis and only occurs in plant cells. If I ever was to carry out this particular investigation again, but this time using animal cells I would expect the animal cell to burst when placed in a dilute solution (for example 0 moles)or pure water. The animal cell will burst because plasmolysis cannot take place in an animal cell. This is because animal cells do not have a cell wall. When a plant cell is plasmolysed the protoplast shrinks away from the cell wall, the external solution has passes through the cell wall and becomes in direct contact with the shrunken protoplast.

Another feature that I identified whilst processing my results was that the potato cell that was placed in the sucrose solution of 0.2 mole concentration only lost 0.02 grams in weight over the 24 hour period in which my investigation took place. This shows that the potato cell reached equilibrium. Equilibrium is reached when the water potential in one region is equal to the water potential in another region. This particular potato cell was in equilibrium with the external solution of 0.2 moles. During the 24 hour period there would have been very little net gain or loss of water and this is shown in my results. There was evidently some movement of water however only very little and therefore the

potato cells in this concentration of solution only lost a mere 0.02 grams of weight.

From my results I am able to conclude that for the particular type of potato tuber cell I used, the water potential is (0.2 moles) minus 540 kPa. I am able to determine this because of several reasons all identified in my results.

Firstly, the potato tuber cell in the sucrose solution of 1 mole concentration lost weight. This means that water moved into the potato cell following the water potential gradient. This shows that the water potential of the potato cell was less than 1 mole.

Secondly, the potato tuber cell in the sucrose solution of 0 mole concentration gained weight. This means that the water moved into the potato cell and this shows that the water potential of the potato tuber cell is higher than 0 mole (approx. minus 130 kPa) yet lower than 1 mole (minus 3500 kPa).

Lastly, from my results I was able to identify that the potato cell in the sucrose solution of a concentration of 0.2 moles had reached equilibrium with the external solution thus meaning that the water potential of the potato tuber cells used in my investigation is minus 540 kPa.

The investigation in which I obtained these results, had several limitations. One limitation is the fact that the potato was squeezed during cutting, causing water to be lost. The cork borer required quite a substantial force to cut through the potato. If a method was used, which did not involve the potato being handled as much during the preparation process a minimal amount of water would be lost and so the results obtained would be nearer their actual values and perhaps more accurate. This could be achieved by using a machine to prepare the potato samples, however a machine as such was not available when carrying out my investigation.

Another less significant limitation during the preparation of the samples was the fact that the sample could have unintentionally been placed on a drop of water or a wet paper towel, while weighing it. This extra water may have caused the sample to have less solute in it than the solution, making it less dense. This extra water also had an effect on the results due to the fact that more water would have been lost by osmosis.

My results are accurate and reliable. Nevertheless there were several aspects of my investigation that I would definitely change if I ever was to re-do this investigation in the future. My accuracy of observations and noting down any other significant information down efficiently during the experiments could be improved. I did not record

the actual type of potato I used in my investigation, this was important as there are hundreds of types of white potatoes.

Also, most importantly, I would ensure that I recorded the individual weights of each individual potato sample before and after the experiments take place. I only recorded the average weight of all three experiments with the same concentrations of sucrose solution. If I had recorded this information it would have significantly improved the accuracy of my results and made it much easier for me to identify any anomalous results or errors.

Due to the fact that there were several sources of error in my investigation there are uncertainties in my results and therefore also uncertainties in the validity of my conclusions. However despite the possible improvements my results justify my prediction which was based on scientific knowledge. Before carrying out the investigation I predicted that the water potential of the potato tuber cells would be within the range of minus 1200 kPa and minus 200 kPa. My prediction was correct and my results justify this despite the accuracy factors that could be improved. This shows that the uncertainties in the evidence I collected are not a significant problem, in fact they did not effect the validity of my results at all.

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