Determination of water potential by measuring changes in mass or length

Specification reference:

AS Component: 1.3 **A level Component: Core concepts 3**

Cell membranes and transport

Introduction

If two solutions of different water potentials are separated by a selectively permeable membrane, water will move into the solution with the lower water potential. The cytoplasm and cell sap are solutions and the tonoplast and cell membrane are selectively permeable. The cell can therefore be considered to be an osmotic system in which a solution is surrounded by a selectively permeable membrane. It will lose or gain water by osmosis depending on the water potential of the adjacent cell or bathing solution. Where there is no change in mass or length the water potential of the bathing solution is equal to that of the tissue.

A tissue sample, such as a cylinder of potato or fragment of leaf, contains millions of cells. If it gains water by osmosis, the mass increases. The cells will stretch by a small amount, until prevented from doing so by the cell wall, and so the length of a cylinder of tissue will increase. The converse is also true – if the tissue sample loses water, its mass decreases and the length of a cylinder of tissue decreases.

Apparatus

Vegetable large enough to extract 50 mm cylinders: potatoes, sweet potatoes, yams, beetroots, swede, turnip, parsnip and carrot are suitable.
Chopping board/ white tile
Cork borers: sizes 3 and 4 are suitable
Ruler graduated in mm
Fine scalpel
Fine forceps
5 x boiling tubes
Boiling tube rack
50 cm^3 measuring cylinder
Distilled water
Sodium chloride solutions (0.2, 0.4, 0.6, 0.8 mol dm^{-3})

Method

1. Cut 15 cylinders of tissue, each approximately 50mm long, on the chopping board and use the scalpel to remove any periderm (skin) as its suberin makes it waterproof, and would prevent osmosis.
2. Place 30cm^3 distilled water or solution in to each test tube. Make sure you label each tube.
3. Using the scalpel and forceps, ensure the ends of the cylinder are at 90° to its length.

4. Measure the length of the cylinder to the nearest mm or the mass to the nearest 0.01 g.
5. Using the forceps, place 3 cylinders into each boiling tube.
6. Leave at room temperature for a minimum of 45 minutes, or overnight at 4 °C.
7. Gently blot the cylinders and re-measure the length or re-weigh the cylinders.
8. Record your results in a table.
9. Plot the mean percentage change against the concentration of solution.
10. Estimate the solute potential of the tissue.

Risk assessment

Hazard	Risk	Control measure
Scalpel blades are sharp	may cut skin when cutting cylinders	Cut away from body onto a white tile
Cork borers are sharp	may cut skin when cutting cylinders	The cylinders of tissue must be cut on the chopping board with the force directed downwards.

Technicians notes

Making solutions – masses per dm^3 are given in the table below. The weighed solutes should be dissolved in a minimum volume of water and then the solution made up to 1 dm^3 with distilled water.

concentration of solution / mol dm^{-3}	mass sodium chloride per dm^3 solution / g
0	0
0.2	11.7
0.4	23.4
0.6	35.1
0.8	46.8

Alternatively, a 1 mol dm^{-3} solution may be made and diluted as needed. To make up a 1 mol dm^{-3} solution 58.5 g of sodium chloride is required.

Sample results

Concentration of bathing solution mol dm^{-3}	Initial length / mm	Final length / mm	Length change / mm	% length change	mean % length change
0	52	57	5	10	10
	49	55	6	12	
	50	54	4	8	
0.2	48	49	1	2	3
	50	52	2	4	
	50	51	1	2	
0.4	58	55	-3	-5	-2
	50	48	-2	-4	
	53	54	1	2	
0.6	50	48	-2	-4	-6
	52	48	-4	-8	
	50	47	-3	-6	
0.8	49	41	-8	-16	-13
	50	43	-7	-14	
	52	48	-4	-8	

When there is no change in length, the concentration of the cell contents is equal to that of the bathing solution, which is read at the x-intercept. The equivalent solute potential can be read from the table. At incipient plasmolysis, $\psi_P = 0$, $\therefore \psi_{cell} = \psi_S \therefore$ this figure gives he water potential of the cells.

Molarity / mol dm^{-3}	Solute potential / kPa
0.05	-130
0.10	-260
0.15	-410
0.20	-540
0.25	-680
0.30	-860
0.35	-970
0.40	-1120
0.45	-1280
0.50	-1450
0.55	-1620
0.60	-1800
0.65	-1980
0.70	-2180
0.75	-2370
0.80	-2580
0.85	-2790
0.90	-3000
0.95	-3250
1.00	-3500

- If cylinders are left for too short a time before re-measuring, results are still valid. The intercept would be the same but less water will have entered or left the cells, giving a smaller gradient. The error in measurement is proportionally greater and the experiment, therefore, less accurate.

- In biology, it is normal to join data points to construct a line on a graph. Where an intercept is to be read, a line/ curve of best fit may be used. This takes into account all the data, rather than only the two points either side of the intercept.

Further work

- Different plant material may be used to test a hypothesis relating to dissolved sugar concentration and relative sweetness of the vegetables. An example would be to compare the intercepts of using cylinders of potato and sweet potato. It could be hypothesised that the line for sweet potato would intercept the horizontal axis at a higher concentration and lower solute potential because sweet potato has a higher concentration of dissolved sugars.

Practical techniques

- use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)