# Experiment to Explore the Dynamics of Osmosis: The Impact of Varying Glucose Concentrations and temperature on osmosis.

**Keywords**: osmosis, ideal osmosis, hypertonic, hypotonic, isotonic, turgid, plasmolysis, osmolarity.

**Aim**

To determine the correlation between glucose concentrations and the influence of temperature on osmosis in a potato.

**Introduction:**

Osmosis is the net movement of water through the semi-permeable membrane from a region of high-water concentration to an area of low water concentration. The semi-permeable membrane introduces a barrier that prevents a direct mixing of the solution but divides it into high or low water concentrations. Osmosis can still occur with some permeability of solute particles, but ideal osmosis is only the movement of pure water molecules (Lopez and Hall, 2023).

A hypertonic solution has a high solute concentration, low water concentration and more significant osmotic pressure than a potato cell; hence, the net water movement will be out of the cell. The cell membrane in a hypertonic solution will shrink, causing plasmolysis. In an isotonic solution, there is no net movement of water. A hypotonic solution has a low solute concentration and a high-water concentration; hence, more free water molecules pass through the cell membrane protein called aquaporins from the solution into the cell. The cell in a hypotonic solution will become turgid (Maldonado and Mohiuddin, 2024). Figure 1 explains the difference between plant and animal cells when placed in different concentrations.

Osmolarity refers to the concentration of osmotically active solvents in the liquid. The measured osmolarity describes the osmotic pressure of a solution. Osmotic pressure can be calculated with the van 't Hoff equation, which states that osmotic pressure depends on the number of solute particles, temperature, and how well a solute particle can move across a membrane (Marbach and Bocquet, 2019).

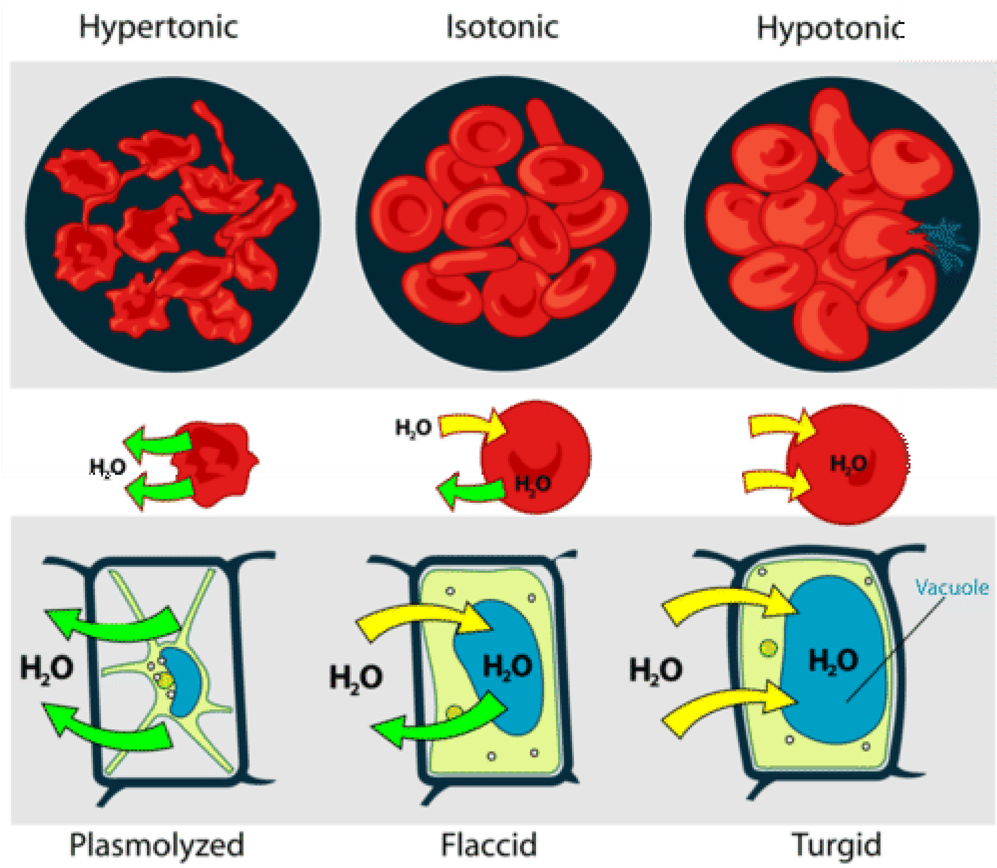


Figure 1. **Comparing Animal and Plant Cells in Hypertonic, Hypotonic, and Isotonic Environments.** The cell shrinks (plasmolysis) in a hypertonic solution, and a plant cell pulls away from the cell wall. Animal cells swell and burst in a hypotonic solution**,** while plant cells remain turgid due to the cell walls (LibreTexts Biology, 2016).

## Hypothesis

As the solution's glucose concentration increases, the potato strip's mass decreases compared to its previous mass. That isotonic concentration can be interpolated from the two opposing regions (the hypotonic and hypertonic). Increased concentration causes less water inside the potato cell than outside; water flows from an area of higher concentration to a lower concentration to maintain dynamic equilibrium (Lopez and Hall, 2023).

The mass of the potato strip in 35°C water will be less than that at room temperature. This is because the increase in temperature increases the average kinetic energy; there is more frequency of collision between the non-permeable solution glucose and the semipermeable membrane, hence increasing the osmotic pressure (Kiil, 1982).

## Method

At room temperature (20°C), potatoes were manually peeled and cut into 2cm long and diameter of 1cm cylinders using cork borers. The osmotic solutions were prepared using glucose concentrations ranging from 0.2M to 1.0M (Table 1), including distilled water control. Osmosis occurred in a batch system; the potato strips were carefully blotted to eliminate excess moisture, and the initial weight was measured before immersion in their respective glucose solution. A 20-minute incubation period ensued, after which the potatoes were extracted and blotted dry, and their final masses were measured to assess any changes during the immersion process. The experiment also considered a 35°C temperature variation and was performed in triplicate. The evaluation of mass exchange between the solution and the potato strips involved the following parameters: initial mass, MI (g), and final mass MF(g) to calculate for percentage change in mass (Libretexts Biology, 2019).

| Table 1. Estimation of the total glucose concentration from stock solution | | | | | | |
|---|---|---|---|---|---|---|
| Glucose concentration (M) | 1 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| Volume of 1M glucose stock solution (ml) | 10 | 8 | 6 | 4 | 2 | 0 |
| Distilled water (ml) | 0 | 2 | 4 | 6 | 8 | 10 |

## Result

| Table 2. Mean percentage change in mass with glucose concentration of potato slices at two temperatures | | | | | | |
|---|---|---|---|---|---|---|
| The concentration of glucose (M) | Experiment 1 at 20°C | | | Experiment 2 at 35°C | | |
| | Mean mass difference (g) | Mean percentage change in mass (%) | Standard deviation ± | Mean mass difference (g) | Mean percentage change in mass (%) | Standard deviation ± |
| 0.00 | 0.01 | 6.06 | 2.336 | 0.05 | 21.88 | 8.133 |
| 0.20 | -0.003 | -1.69 | 3.039 | 0.01 | 4.29 | 0.105 |
| 0.40 | -0.01 | -3.33 | 7.557 | -0.03 | -10.81 | 2.466 |
| 0.60 | -0.02 | -9.52 | 5.524 | -0.04 | -20.97 | 2.520 |
| 0.80 | -0.04 | -19.40 | 4.564 | -0.05 | -24.24 | 2.796 |
| 1.00 | -0.05 | -22.22 | 6.111 | -0.06 | -26.56 | 4.291 |

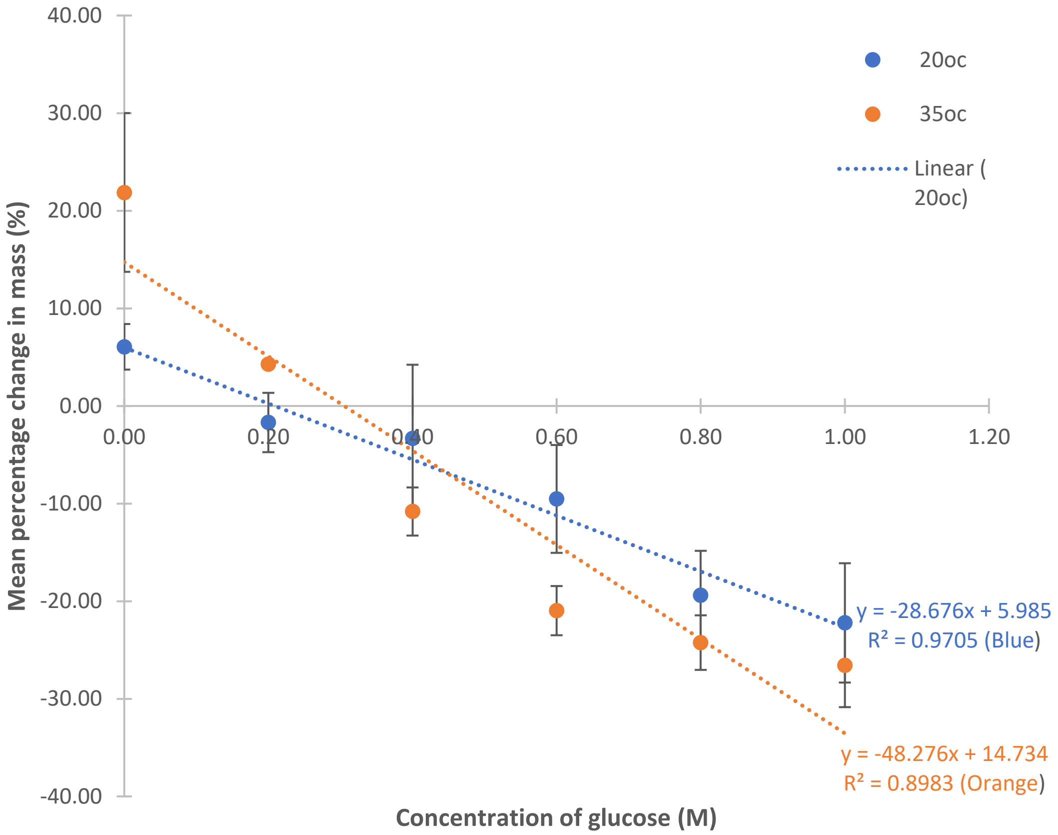


Figure 2. **Graph of concentration of glucose against the mean percentage change in mass**. The graph shows a strong negative correlation between glucose concentration and mean mass percentage. The trendline slope indicates the osmosis rate, revealing higher percentage change in mass in higher temperature.

The findings in Table 2 indicate a negative correlation between glucose concentration and the mean percentage change in mass. This implies that an increase in glucose concentration corresponds to a decrease in the mass of potato strips. Figure 2 illustrates variations in osmosis rates between the two potato groups. The line equation for potatoes in a 20°C water bath ($y = -28.676x + 5.985$) can be utilised to determine the isotonic point (x-intercept), which is found to be 0.209 mol/dm3. Similarly, the line equation for potatoes in a 35°C water bath ($y = -48.276x + 14.734$) can be employed to ascertain the isotonic point (x-intercept), identified as 0.305 mol/dm3.

## Discussion and Conclusion

Generally, the mass of potato strips decreases as the glucose concentration increases, which correlates with the hypothesis. Figure 2 shows that osmosis occurred due to the decrease in the mass of the potato strips. This observation indicates that increased glucose concentration increased solution hypertonicity. Therefore, water moved from the potato cells to the surrounding solution(Lopez and Hall, 2023).

Initially, when the potato was immersed in distilled water, the potato strips gained mass. Distilled water has no dissolved molecules, which is an excellent control to show that water will move into the potato cells when placed in a hypotonic solution(Lopez and Hall, 2023).

This underscores the maintenance of water homeostasis in plant cells. Water is the most limiting abiotic factor, and it is transported through the roots to the shoot and then to the atmosphere. Gradients govern water movement in plants through water potential, which encompasses osmotic, gravimetric, air pressure, and matric potential, influencing hydraulic conductance in plant cells (Scharwies and Dinneny, 2019).

The result of the experiment demonstrated a faster rate of osmosis in the potato strips immersed in a 35ºC water bath compared to those at room temperature. This difference in rate is attributed to a difference in temperature, which also resulted in a shift of the isotonic point. The effect of low temperature leads to the slowing down of molecular processes as molecules have less energy at low temperatures, and more loss is noticed when solutions are warmed; hence, more glucose solution is needed for the isotonic point (Goodford, 1971).

Raising the temperature by 10ºC will increase the average kinetic energy, increase metabolic rate by 2-3-fold, and outline a Q10 relationship (Kiil, 1982).

Recognise that ideal osmosis in potatoes is limited due to the membrane's imperfect selectivity for water, allowing glucose diffusion. Elevated temperature in hypertonic solutions accelerates water loss more than solute gain, attributed to diffusional differences based on molar masses. Higher temperature improves water transfer at high glucose concentrations due to reduced osmotic medium viscosity. However, a 35°C temperature increase did not significantly impact the potato strip's mass despite increased solute gain. (Eren and Kaymak-Ertekin, 2006).

This underscores the importance of understanding how high temperatures can enhance metabolic reactions and emphasises the need to maintain an optimal temperature range. Furthermore, the experiment highlights avenues for future research, including investigating how elevated ambient temperatures can affect water content in food and impact crop yields (Kim and Lee, 2019).

**Appendix 1.**

| Table 3. Result for weights of potato strips in 20°c water bath with their corresponding glucose concentration | | | | |
|---|---|---|---|---|
| The concentration of glucose (mol/dm3) | Initial mass (g) | Final mass (g) | Mass difference (final mass - initial mass)(g) | Percentage change in mass (%) |
| 0.00 | 0.23 | 0.25 | 0.02 | 8.70 |
| 0.00 | 0.22 | 0.23 | 0.01 | 4.55 |
| 0.00 | 0.21 | 0.22 | 0.01 | 4.76 |
| 0.20 | 0.19 | 0.18 | -0.01 | -5.26 |
| 0.20 | 0.19 | 0.19 | 0.00 | 0.00 |
| 0.20 | 0.21 | 0.21 | 0.00 | 0.00 |
| 0.40 | 0.22 | 0.2 | -0.02 | -9.09 |
| 0.40 | 0.20 | 0.19 | -0.01 | -5.00 |
| 0.40 | 0.18 | 0.19 | 0.01 | 5.56 |
| 0.60 | 0.24 | 0.22 | -0.02 | -8.33 |
| 0.60 | 0.20 | 0.19 | -0.01 | -5.00 |
| 0.60 | 0.19 | 0.16 | -0.03 | -15.79 |
| 0.80 | 0.20 | 0.17 | -0.03 | -15.00 |
| 0.80 | 0.25 | 0.19 | -0.06 | -24.00 |
| 0.80 | 0.22 | 0.18 | -0.04 | -18.18 |
| 1.00 | 0.20 | 0.17 | -0.03 | -15.00 |
| 1.00 | 0.20 | 0.15 | -0.05 | -25.00 |
| 1.00 | 0.23 | 0.17 | -0.06 | -26.09 |

| Table 4. Result for weights of potato strips in 35$^{o}$c water bath with their corresponding glucose concentration | | | | |
|---|---|---|---|---|
| The concentration of glucose (mol/dm3) | Initial mass (g) | Final mass (g) | Mass difference (final mass - initial mass)(g) | Percentage change in mass (%) |
| 0.00 | 0.23 | 0.26 | 0.03 | 13.04 |
| 0.00 | 0.21 | 0.27 | 0.06 | 28.57 |
| 0.00 | 0.20 | 0.25 | 0.05 | 25.00 |
| 0.20 | 0.24 | 0.25 | 0.01 | 4.17 |
| 0.20 | 0.23 | 0.24 | 0.01 | 4.35 |
| 0.20 | 0.23 | 0.24 | 0.01 | 4.35 |
| 0.40 | 0.25 | 0.22 | -0.03 | -12.00 |
| 0.40 | 0.25 | 0.23 | -0.02 | -8.00 |
| 0.40 | 0.24 | 0.21 | -0.03 | -12.50 |
| 0.60 | 0.21 | 0.16 | -0.05 | -23.81 |
| 0.60 | 0.21 | 0.17 | -0.04 | -19.05 |
| 0.60 | 0.20 | 0.16 | -0.04 | -20.00 |
| 0.80 | 0.22 | 0.16 | -0.06 | -27.27 |
| 0.80 | 0.21 | 0.16 | -0.05 | -23.81 |
| 0.80 | 0.23 | 0.18 | -0.05 | -21.74 |
| 1.00 | 0.19 | 0.13 | -0.06 | -31.58 |
| 1.00 | 0.19 | 0.14 | -0.05 | -26.32 |
| 1.00 | 0.26 | 0.2 | -0.06 | -23.08 |

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