Research Question

How does the varying concentrations of NaCl solution affect the rate of mass change of *Solanum tuberosum* (russet potato) tissue placed within it?

Background Information

A group discussion on organ systems led to a conversation about organ transport during organ transplant surgeries, and how they must be placed in specific solutions to maintain homeostasis—errors in the concentrations of solutes within these solutions could render organs ineffective and possibly even cause permanent damage, rendering them ineffective prior to the operation. My interest in surgical procedures intrigued me into investigating solute concentrations and the effect on the process of osmosis.

All functions of life—metabolism, reproduction, homeostasis, growth, response, excretion, and nutrition—require cells' interaction with their extracellular environments in some capacity[1]. Some essential nutrients are required for cellular function but cannot be produced by the animal body including essential vitamins, minerals, fatty acids, and also amino acids. The way in which nutrients needed for cell growth and maintenance enter the cell is through the cellular membrane (plasma membrane). The cellular membrane consists of a semipermeable phospholipid bilayer embedded with proteins/cholesterol which regulates the transport of materials entering and exiting the cell[2]. The cell membrane is semipermeable due to its internally facing non-polar fatty acid tails and the space between its constituent molecules: it does not permit the entrance of large molecules, nor does it permit the passage of non-polar molecules[3]. It also gives the membrane fluidity and prevents free diffusion, keeping internal and external environments separate.

Osmosis is a type of transport in which water or other solvents travel through the semipermeable membrane. It is a type of passive transport which does not require the expenditure of energy (ATP hydrolysis), simply water travels across a semipermeable membrane (but not solute) from an area of lower solute concentration to an area of higher solute

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[1] David H. Nguyen, P. (2017, November 21). How Does the Cell Membrane Play a Role in Homeostasis? Retrieved January 11, 2021,From: https://education.seattlepi.com/cell-membrane-play-role-homeostasis-4707.html

[2] P. (n.d.). *Cell Membrane* (Rep.). Retrieved January 11, 2021 From: https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/cell-membrane

[3] Khan, S. (n.d.). Structure of the plasma membrane (article). Retrieved January 11, 2021, From : https://www.khanacademy.org/science/high-school-biology/hs-cells/hs-the-cell-membrane/a/structure-of-the-plasma-membrane

concentration[4]. Water will continue to move with a net direction towards the area of higher solute concentration equilibrium is reached—i.e, concentration of solute is equal on both sides of the membrane. Solute concentration can be described in relation to semipermeable-membrane enclosed fluids within it as either hypertonic, hypotonic, or isotonic; hyper and hypotonic solutions have greater and lesser concentrations respectively than the solution to which it is compared, while isotonic solutions have an equal concentration.

The process of osmosis is all dependent on the amount of solutes present in both a cell's tissue and the extracellular solution. A solute is a substance that is able to be dissolved within solvents such as water[5]. An example of a solute is Sodium Chloride (NaCl) which is an ionic compound that acts as a polar molecule, due to its partial positive and negative charges (Chlorine-negative, Sodium-positive). The reason for Sodium Chloride's (NaCL) ability to dissolve in water is that water is also a polar molecule, with partial positive and negative charges (Hydrogen- positive, Oxygen- negative). More concisely, the positively charged water molecules attract the negative chloride ions and the negatively charged water molecules attract the positive sodium ions, thus breaking the Sodium Chloride bond causing them to dissociate and dissolve into the solvent (water). The measurement of the amount of solute in a cell tissue and solution can be more precisely stated as "Molarity", which is the moles of solute particles per unit volume of solution[6].

The process of osmosis is essential as it aids in establishing the internal environment of an organism by keeping the water and intracellular fluids levels balanced. It's vast applications include kidney dialysis, preservation of organs, and filtration of undrinkable water[7]. Through the following experiment we will be able to understand the implications, variables, and sensitivities which drives the process of osmosis.

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[4] Khan, S. (n.d.). Osmosis and tonicity review (article). Retrieved January 11, 2021, From: https://www.khanacademy.org/science/high-school-biology/hs-energy-and-transport/hs-osmosis-and-tonicity/a/hs-osmosis-and-tonicity-review#:~:text=%22In%20osmosis%2C%20water%20moves%20from%20areas%20of%20low%20concentration%20of,of%20high%20concentration%20of%20solute.%22&text=So%20osmosis%20only%20occurs%20with%20a%20semipermeable%20membrane%2C%20and%20even,net%20flow%20up%20the%20gradient.

[5] Intermediate, C. (n.d.). Chemistry for Non-Majors. Retrieved February 01, 2021, From: https://courses.lumenlearning.com/cheminter/chapter/solute-and-solvent/#:~:text=The%20solute%20is%20the%20substance,examples%20in%20the%20Table%20below.

[6] Anne Marie Helmenstine, P. (n.d.). What Does It Mean to Measure the Molarity of a Solution? Retrieved February 01, 2021, From: https://www.thoughtco.com/molarity-definition-in-chemistry-606376

[7] Saini, H., & 09, A. (2020, April 09). Osmosis and Its Role in Human Biology and Health. Retrieved January 11, 2021, From: https://letstalkscience.ca/educational-resources/stem-in-context/osmosis-and-its-role-in-human-biology-and-health

Hypothesis

H_0 (null) : Changing the table salt (NaCl) concentration in 100 ml(±5ml) of distilled water will not affect the mass of the potato strips submerged in the solution.
H_1(alternative) : Increasing the table salt (NaCl) concentration in 150 ml(±5ml) of distilled water will show a negative correlation between NaCl concentration (moles/L) and the change in mass of the *Solanum tuberosum* strips submerged for 24 hours. Hence the mass of the strips decreases as more table salt is added to the 150 ml(±5ml) of distilled water. This is due to the difference in concentration between the cell's cytoplasm and the extracellular solution which results in the movement of water across the cell membrane[8].

Variables

Independent Variable: The varying amounts of NaCl (0g, 1g, 2g, 3g, 4g, 5g, 6g, 7g, 8g, 9g, 10g ±1g) used to create a concentrated solution in 150 ml (±5ml) of distilled water (0M, 0.11M, 0.23M, 0.34M, 0.46M, 0.57M, 0.68M, 0.80M, 0.91M, 1.03M, 1.14M Molar Concentration).
Dependent Variable: The mass of the potato strips(±1g) submerged into the 150 ml (±5ml) concentrated solution.

Figure 1: Controlled Variables, Reason for Controlling, and Method of Controlling

Control Variable:	Reasons for Controlling:	Method of Controlling:
1)Source of Potatoes	To minimize the possibility of varying results of the potato's mass. Due to biological variation, different potatoes are grown in varying manners resulting in a differentiation in the amount of water and starch consisting inside the potato.	Ensure the same types of potatoes are being prepared (Russet Potato), meaning differentiating potatoes with different qualitative features such as smell, texture, and molding.
2)Size/Shape of Potato	To ensure that the results do not vary, as the size of the potato affects the mass measured prior and after the experiment. Also, the size of the potato would affect the amount of materials being transported between the membrane, as the membrane would have a greater surface area.	Ensuring that all potatoes extracted using a cork borer have the same length (6.0cm) and the same width of the cork borer (1.3cm).
3)Temperature of Distilled Water	To minimize the varying rates that osmosis could occur in the different cups. Higher temperatures cause an increase in chemical reactions in water, leading to the faster movement of water molecules across the semipermeable membrane. The temp of distilled water in every cup must be relatively the same to ensure accurate data results.	Storing the cups in a location that does not have air conditioning or heating, as the slightest temperature fluctuation of the room could alter data results.
4)Homogeneity of Solutions	If the solutions are left standing around for elongated	Using a stirring rod to stir each solution

[8] Libretexts, B. (2020, August 15). 5.2E: Osmosis. Retrieved February 01, 2021, From: https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_General_Biology_(Boundless)/5%3A_Structure_and_Function_of_Plasma_Membranes/5.2%3A_Passive_Transport/5.2E%3A_Osmosis#:~:text=Osmosis%20occurs%20until%20the%20concentration,allow%20diffusion%20of%20the%20solute.

	periods of time, compounds of the solution will separate based on density, potentially influencing the rate of diffusion into the potato and thus the final results of the experiment. The stirring of each solution before the placement of potato strips inside them, ensured the liquids were uniform and that the concentration of each liquid was not affected.	for 10.0(±0.5) sec. before transferring the potato strips inside them.
5)Incubation Period of Potato	To ensure all the potato strips are undergoing the process of Osmosis for the same amount of time, allowing for accurate and precise comparisons between the varying concentrated solutions.	By placing the potato strips inside the solution at the same time. Also by having a timer that would be counting down from 24 hours.

Materials/Apparatus

- *Solanum tuberosum* "Russet Potatoes" (20)
- 330g Windsor Table Salt (NaCL) (±1g)
- 8,250 ml distilled water (±5ml)
- Measuring cup (1) ±5ml
- Electronic Balance (1) (±1g)
- Plastic cups (55)
- Peeler (1)
- Cylindrical Food Borer(1)
- Knife (1)
- Cutting mat (1)
- Ruler (1) (±0.05cm)
- Timer (1)
- Stirrer (1)
- Paper Towels (11)
- Bowl (1)
- Funnel (1)
- Tongs (1)

Procedure

1. **Prior To Preparing and Executing Experiment:**
    a. This experiment was prepared and executed in an area with zero temperature fluctuation (0 A.C/Heating) and with similar light exposure throughout the area. This ensured that variables are controlled and that there were no factors affecting the results of the experiment, such as temperature.
2. **Preparation of the *Solanum tuberosum* (russet potato) Strips:**
    a. 20 Russet Solanum tuberosum Potatoes which were similar in texture, smell, and contained no mold were collected. This was to ensure every potato has the exact same qualitative properties, to prevent any alteration in results.

b. 55 cylindrical strips of potatoes were made using a cork borer. The cork borer was completely placed through the top of the potato and the narrower piece was used to push the potato strip out. This process was repeated until 55 cylindrical strips of potatoes were created.
c. Once the 55 strips were collected, all the skins were removed by the knife.
d. All of the potato strips needed to be the same length. The potato strip was placed by a 15 cm ruler and 4.0cm(± 0.05cm) was measured, the excess piece was cut off. While cutting, the knife remained perpendicular to the surface to ensure straight ends of the potato strips. This process was repeated until all 55 potato strips were exactly 6.0cm (± 0.05cm) in length. Once finished, all strips were placed into a bowl.

3. **Assigning Groups For Each *Solanum tuberosum* (russet potato) strip:**
   a. 11 pieces of paper towel were gathered and placed separate from each other. On each paper towel, the numbers from 0-10 were written using a permanent marker.
   b. From the 55 strips in the bowl, 11 groupings with 5 strips each were made. Each grouping was placed on a separate piece of paper towel with each strip aligned behind one another. The number on the paper towels represented how much grams of table salt (NaCl) the potato strips placed on that towel would be submerged into.
   c. 55 plastic cups were obtained and 5 were placed behind each paper towel, forming 11 columns of 5 plastic cups each. Each plastic cup was labeled using a permanent marker depending on which paper towel they were placed behind. (Example- Plastic cups placed behind paper towel 1, will all be labeled 1). The label on each cup indicated how much (±1g) of NaCl will be placed.
4. **Measuring the Initial Mass of the *Solanum tuberosum* (russet potato) strips:**
   a. The initial mass of each potato strip was measured using the electronic balance to the nearest gram (±1g).The tare button was pressed after the measurement of each potato strip, this function had reset the balance ensuring no additional error in measurement. The initial measurements for the mass of each individual potato strip was recorded on a spreadsheet. After the measurement of the initial mass, all potato strips were placed back onto the paper towel.
5. **Preparation of the Concentrated Solutions:**
   a. 150 ml (±5 ml) of distilled water was poured into a measuring cup, and then transferred into each plastic cup using a funnel. This was repeated until each plastic cup had contained 150 ml (±5 ml) of distilled water.
   b. The tare button on the electronic balance was pressed to get a starting point of 0.0g. Table salt (NaCl) was placed on the electronic balance until it read 1.0 g (±1g). The table salt (NaCl) was then transferred into cup 1 using a funnel. This step was repeated until all cups received the appropriate amount of table salt

(NaCl), which was indicated by the labelling on each cup. (Example- all cups being labeled 9, had 9g (±1g) of salt in it)

c. Once each plastic cup contained the appropriate amount of table salt (NaCl), a metal stirrer was used to dissolve the table salt (NaCl) in the distilled water. Stirring was done for approximately 10 seconds per plastic cup(±0.5 seconds).

6. **Placement of Russet Solanum tuberosum Strips Into Glass Beakers:**
    a. To retain homogeneity of each solution step 5e was repeated for each plastic cup again.
    b. Each potato strip that was on the paper towel had been placed into the appropriate plastic cup, which were the 5 cups behind the paper towel. One potato strip had been placed into a single plastic cup.
    c. Once all the potato srips were placed into the appropriate plastic cups, a timer for 24 hours had been started and the cups were left in an environment with zero temperature fluctuations and similar light exposure, to ensure accurate results.
7. **Data Measurement and Recording:**
    a. After 24 hours the mass of all the potato stips were measured. Each potato strip was extracted using a pair of tongs and placed onto the electronic balance. The mass of each potato strip was measured to the nearest gram (±1 g), and the results for each individual potato strip were recorded beside the initial mass of the exact potato on a Spreadsheet.
    b. The initial and final mass of the potato strips were compared and conclusions were drawn.

Safety: Certain apparatus such as the kitchen knife and a cork borer were handled carefully by an experienced adult. No ethical concerns were involved during the experiment.

<u>Qualitative Observations</u>

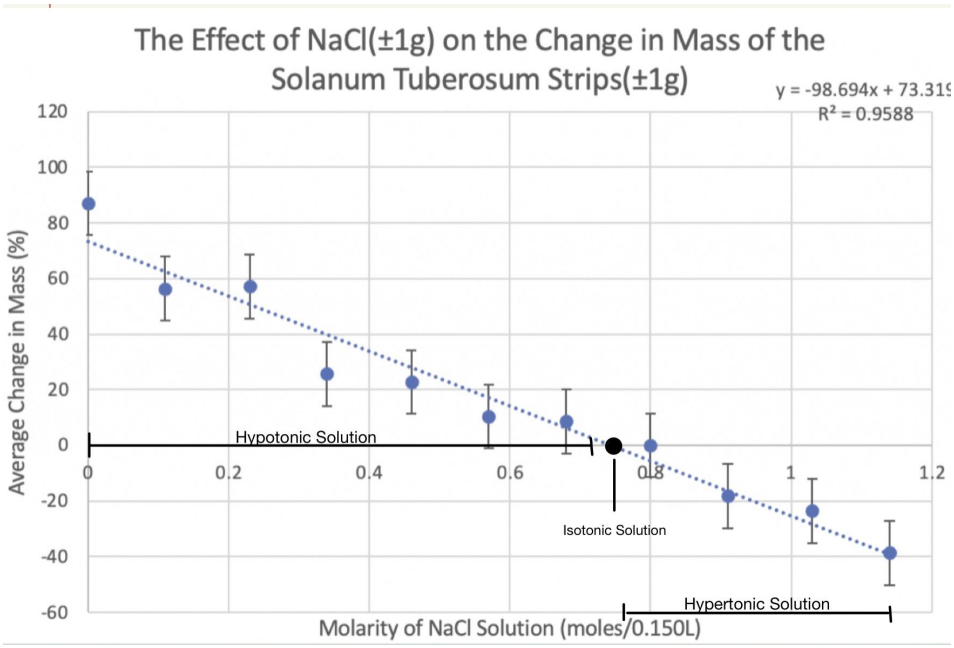
- The uncertainty for the *Solanum tuberosum* strips incubation period was increased from ±2 seconds to ±2 minutes based on the approximate time for the individual to place the strips into all 55 plastic cups.
- Salt had partially dissolved, while portions of individual grains began to settle at the bottom of the plastic cups. This was mostly observed in the plastic cups containing 7,8(±1g) of NaCl.
- Turgor occured for the *Solanum tuberosum* strips placed in (0-6 ±1g) NaCl solutions. Plasmolysis occured for the *Solanum tuberosum* strips placed in (8-10±1g) NaCl solutions.
- The *Solanum tuberosum* strips submerged into higher concentrated solutions were relatively softer compared to the strips placed in lower concentrations, which were very soft.
- Small layers of the *Solanum tuberosum* strips were detached from the cylindrical piece and were floating in the plastic cups containing the range of 7-10g (±1g) of NaCl.
- The colour of the strips submerged in 9/10(±1g) NaCl were partially black, compared to the rest of the strips which did not change drastically in colour.

Figure 2: The Effect of Varying Mass/Concentrations of NaCl (±1g) on the Mass of the Solanum tuberosum strips (±1g) submerged for a 24 Hour (±0.5) Period

	The Effect of Varying Mass/Concentrations of NaCl (±1g) on the Mass of the Solanum tuberosum Strips(±1g) for a 24 Hour (±0.5 hour) Period						
Group	**Mass of Salt in Solution (±1g)**	**NaCl Molarity in Solution (Mol/0.150L)**	**Trial**	**Initial Mass (±1g)**	**Final Mass (±1g)**	**Change in Mass (%)**	**Average Change in Mass (%)**
0	0.0g	0M	1	7.0	14.0	100	87.1
			2	8.0	14.0	75.0	
			3	7.0	13.0	85.7	
			4	8.0	14.0	75.0	
			5	7.0	14.0	100	
1	1.0g	0.11M	1	8.0	12.0	50.0	56.42
			2	8.0	13.0	62.5	
			3	8.0	12.0	50.0	
			4	7.0	11.0	57.1	
			5	8.0	13.0	62.5	
2	2.0g	0.23M	1	8.0	12.0	50.0	57.12
			2	7.0	12.0	71.4	
			3	7.0	11.0	57.1	
			4	7.0	11.0	57.1	
			5	8.0	12.0	50.0	
3	3.0g	0.34M	1	6.0	9.0	50.0	25.72
			2	8.0	10.0	25.0	
			3	7.0	8.0	14.3	
			4	7.0	8.0	14.3	
			5	8.0	10.0	25.0	
4	4.0g	0.46M	1	7.0	9.0	28.6	22.8
			2	7.0	8.0	14.3	
			3	7.0	9.0	28.6	
			4	7.0	9.0	28.6	
			5	7.0	8.0	14.3	
5	5.0g	0.57M	1	8.0	9.0	12.5	10.36
			2	7.0	8.0	14.3	
			3	8.0	8.0	0.0	
			4	8.0	9.0	12.5	
			5	8.0	9.0	12.5	
6	6.0g	0.68M	1	7.0	8.0	14.3	8.58
			2	7.0	7.0	0.0	
			3	7.0	8.0	14.3	
			4	7.0	8.0	14.3	
			5	7.0	7.0	0.0	
7	7.0g	0.80M	1	7.0	8.0	14.3	11.48
			2	7.0	9.0	28.6	
			3	7.0	7.0	0.0	
			4	7.0	8.0	14.3	
			5	8.0	8.0	0.0	
8	8.0g	0.91M	1	7.0	7.0	0.0	
			2	8.0	5.0	-37.5	
			3	8.0	8.0	0.0	
			4	8.0	6.0	-25	
			5	7.0	4.0	-28.6	

							-18.2
9	9.0g	1.03M	1	7.0	6.0	-14.3	-23.6
			2	8.0	5.0	-37.5	
			3	7.0	6.0	-14.3	
			4	8.0	5.0	-37.5	
			5	7.0	5.0	-28.6	
10	10.0g	1.14M	1	7.0	4.0	-42.9	-38.6
			2	7.0	5.0	-28.6	
			3	7.0	4.0	-42.9	
			4	7.0	5.0	-28.6	
			5	8.0	4.0	-50.0	

Figure 3: A Graph Depicting the Mean Growth (%) of Solanum tuberosum Strips Incubated in Varying Mass/Concentrations of NaCl For a 24 Hour Period



Note: *After examining several lines of best fit, the linear trend line was ultimately chosen as it had the R^2 value closest to 1 (0.9588). A scatter plot was chosen as the data is continuous. The error bars represent ± 1 standard deviation determined in the processed data, standard deviation values are also shown in Figure 4.*

Sample Calculations: (Using 1.14M/10.0g NaCl Solution as an Example)

Mean: Mean = sum of terms/number of terms
1)Calculate difference of mass for each trial and add them up:
(4-7)+(5-7)+(4-7)+(5-7)+(4-8)= -14

2)Divide sum of differences by number of terms:
-14/5=-2.8

Standard Deviation: $\mathrm{SD} = \sqrt{\frac{\sum |x-\mu|^2}{N}}$
1)Find the mean (calculated above) = -2.8
2)For each data point, find the square of its distance to the mean:
$((-3)-(-2.8))^2=0.04$, $((-2)-(-2.8))^2=0.64$, $((-3)-(-2.8))^2=0.04$, $((-2)-(-2.8))^2=0.64$, $((-4)-(-2.8))^2=1.44$
3)Add results from step 2:
0.04+0.64+0.04+0.64+1.44=2.8
4)Divide by number of trials:
2.8/5=0.56
5)Take the square root:
√ 0.56= 0.75, round to 0.8

Note: This processing method was used to determine the mean difference in Change of mass of the *Solanum tuberosum* strips, standard deviation, which was used to determine error bars on the graph.

Figure 4: ANOVA Test Screenshot For the Change in Mass (g) for Each Potato Strip in Varying [NaCl]

Group 1= 0g NaCl
Group 11= 10g NaCl

Data Summary				
Groups	N	Mean	Std. Dev.	Std. Error
Group 1	5	6.4	0.5477	0.2449
Group 2	5	4.4	0.5477	0.2449
Group 3	5	4.2	0.4472	0.2
Group 4	5	1.8	0.8367	0.3742
Group 5	5	1.6	0.5477	0.2449
Group 6	5	0.8	0.4472	0.2
Group 7	5	0.6	0.5477	0.2449
Group 8	5	0.8	0.8367	0.3742
Group 9	5	-1.6	1.5166	0.6782
Group 10	4	-2.5	1	0.5
Group 11	5	-2.8	0.8367	0.3742

ANOVA Summary					
Source	Degrees of Freedom DF	Sum of Squares SS	Mean Square MS	F-Stat	P-Value
Between Groups	10	410.6481	41.0648	65.398	0
Within Groups	43	27.0006	0.6279		
Total:	53	437.6488			

Note: *For the ANOVA test/Standard Deviation, I decided to use the change in mass (g) data instead of the change in mass (%). This is due to the fact that even a slight change in (g) would lead to a huge (%) difference, completely altering the Standard Deviation (how close the values are around the mean).*

Statistical Analysis

A single factor ANOVA test was performed on the change in mass for the *Solanum tuberosum* strips(± 1g) submerged in various concentrated solutions of NaCl, through an online calculator[9]. The P value calculated through the system was 0 with an F-critical value of 65.398. The calculated P value is less than 0.05, indicating that there is a large significant difference in the *Solanum tuberosum* strips submerged into different concentrations of NaCl. Thus, despite error bars overlapping, the data is quite reliable and the null hypothesis is rejected. It can be concluded with 95% confidence that there is a correlation between the concentration of NaCl and the rate of osmosis.

Data Analysis

As illustrated by the processed data and graph above, the results are mostly in concordance with the alternative hypothesis indicating a strong negative correlation between increasing [NaCl] and change in mass of *Solanum tuberosum* strips over an incubation period of 24 hours. As shown on the graph, almost all data points either lie on the line of best fit or match it with their standard deviation indicated by the error bars on each data point. Alongside quantitative data, the qualitative data observed throughout the experiment aids in supporting the

[9] ANOVA Test Calculator, Retrieved From: https://goodcalculators.com/one-way-anova-calculator/

alternative hypothesis. Certain observations such as the difference in rigidity between strips placed in varying concentrations of NaCl can indicate that there has been a movement of water in and out the cell (osmosis), which ultimately changes the physical property of the *Solanum tuberosum* strips.

Through the results collected, the tonicity of varying concentrations can be identified, which is the classification of the ability of an extracellular solution to make water move into or out of a cell by osmosis. Based on Figure 3, solution's with a molarity of NaCl ranging from (0M-0.72M/0.150L solution) can be deemed as a Hypotonic solution, due to the fact that *Solanum tuberosum* strips placed in these solutions experienced an average increase in mass (±1g). A Hypotonic solution has a lower osmolarity(osmol/L-measure of solute concentration), meaning the fluid surrounding the cell has a lower [solute] than the cell's cytoplasm. Since the process of osmosis involves the flow of water from low to high [solute], water would enter the *Solanum tuberosum* strips causing turgor (Cytoplasm expands), which was seen in the qualitative observations. Next, the solutions with a molarity of NaCl ranging from (0.74M-1.14M/0.150L solution) can be deemed as a Hypertonic solution, as the *Solanum tuberosum* strips placed in these solutions experienced an average decrease in mass (±1g). Hypertonic solutions have a higher osmolarity, meaning the fluid surrounding the cell has a higher [solute] than the cell's cytoplasm. Thus, water would flow from within the *Solanum tuberosum* strips into the extracellular solution, causing plasmolysis(Cytoplasm shrinks), as seen in the qualitative observations.

The point where the line of best fit crosses the x axis (0.73M NaCl/0.150L), is the isotonic solution, in which there is no net movement of water. At this point there is an equilibrium of [solute] inside the *Solanum tuberosum's* cytoplasm and the extracellular solution, water does freely move in and out of the cell, however, the rate of movement is the same in both directions. This isotonic point can also be identified as the overall molarity (moles/L) of the *Solanum tuberosum*, or the total amount of [solute] contained inside. The *Solanum tuberosum* contains a variety of elements/nutrients which are soluble, such as Potassium, Sucrose, and Glucose. The totality of the many solutes is equivalent to 0.73M/0.150L solution, as there would be no net movement of water. The *Solanum tuberosum* also contains 80% water[10], meaning that the process of osmosis would only occur until all the water within the strip has moved to the extracellular solution. If Figure 3 was extrapolated further, the line of best fit would reach an asymptote, as the *Solanum tuberosum* strip would not contain any water to be moved across the cell membrane. Different types of *Solanum tuberosum* will also have similar data curves as the *Solanum tuberosum* (russet potato) utilized within this experiment, although, the ranges of

[10] Potatoes, nutrition and diet. (n.d.). Retrieved February 01, 2021, From : http://www.fao.org/potato-2008/en/potato/factsheets.html#:~:text=Freshly%20harvested%2C%20it%20contains%20about,potato%20is%20low%20in%20fat.

Isotonic, Hypotonic, and Hypertonic solutions will vary depending on the properties of the different *Solanum tuberosum* (Nutrition Values/Environmental Factors).

Outliers

The ANOVA test and data collection indicated the presence of outliers. These may be explained by trials 1, 2&4 of the 7g (±1g) of NaCl solution, all having unusually large changes in *Solanum tuberosum* mass compared to trials 3 and 5(see figure 3). As noted in the qualitative data, cups that contained 7g (±1g) of NaCl had many grains that did not dissolve, affecting osmosis, as the water molecules did not bond with either (Na^+/Cl^-), altering the amount of free water molecules in the solution. If these 3 values are removed, the mean difference of mass (g) is reduced from 0.8g to 0g with a SD of 0, raising the R^2 value from 0.9471 to 0.9682.

The uncertainties from the apparatus and human error is another contributing factor to the outlier within the graph: 7g (±1g) NaCl. First, the electronic balance had an uncertainty of (±1g) which affected the amount of NaCl placed into the plastic cups. The electronic balance would round to the nearest gram, meaning that all of the NaCl placed into each cup was not the exact measurement. This uncertainty may have caused the outlier, as different [NaCl] changes the rate at which osmosis would occur. Another contributing factor towards the outlier within the graph is the uncertainty for the *Solanum tuberosum* incubation period, which had increased from ±2 sec to ±2 min, due to the time taken to place all the strips into each plastic cup. The more time the strips are present within the solution, there is a greater chance for more water transfer to occur between the cell's cytoplasm and the extracellular solution. The high uncertainties for both the apparatus and also human error are factors which heavily contribute towards outliers within the data collected.

Conclusion

The results obtained clearly indicate a statistically significant (p value: $0 < 0.05$) negative correlation between increasing [NaCl] and change in mass of the *Solanum tuberosum* strips over an incubation period of 24 hours. The statistical tests, qualitative and quantitative data observations/analysis are mostly in concordance with the alternative hypothesis and suggest that the amount of [solute] affects the rate of osmosis across a semipermeable membrane.

Evaluation & Improvements

Strengths: All the materials used were relatively easily obtained from a local supermarket or found in any standard laboratory. The highly controlled environment that had 0 fluctuation in temperature and even distribution of light across the room helped minimize fluctuation in data, increasing the precision of the results gathered, forming strong data values and correlations illustrated on the graph (Figure 3). The wide ranges of [NaCl] (i.e. 0M, 0.11M, 0.23M, 0.34M, 0.46M, 0.57M, 0.68M, 0.80M, 0.91M, 1.03M, 1.14M per 0.150L) contributed to more precise results further supporting the conclusion and making the data more reliable. Having 5 trials per

[NaCl] concentration helped reduce the Standard Deviation, enabled more comparable results and increased precision.

Figure 5: Several Limitations, their Impact, and Suggested Improvements:

Limitation:	Impact of Limitation:	Suggested Improvement:
1)Temperature of the Water (Systematic Error)	Different temperatures of water will affect the rate of reaction of water molecules, affecting the rate at which osmosis will occur.	Using a thermometer to measure the temperature of the water prior and after the potato strips are submerged into the solutions would ensure that the temperature is kept fairly constant.
2)How the *Solanum tuberosum* Strips Were Stored (Systematic Error)	By leaving the *Solanum tuberosum* strips in the bowl for extensive periods of time they were exposed to the external environment. This may have caused oxidation to occur in which electrons are lost, which could result in the breakdown of the strips overtime	Covering the *Solanum tuberosum* with Saran Wrap would minimize the exposure to the external environment. This would allow the strips to be fresh, allowing for accurate results.
3)Which Part of the *Solanum tuberosum* Was Used (Systematic Error)	Different parts of the potato may have different consistency and density. This could have affected the *Solanum tuberosum's* water concentration, and its ability to take in water from its surroundings	Ensure that all strips being used are collected from the same part of the *Solanum tuberosum* (ex. Middle). This would ensure more precise results.
4)Human Error (Random Error)	When starting and stopping the stopwatch, while mixing solutions with a metal stirrer, human reaction time will slightly vary, thus resulting in lesser precision, influencing results.	Using the same person to start and stop the watch can help reduce error, however it cannot be eliminated.
5)Uncertainty of Electronic Balance (±1g) (Systematic Error)	The high uncertainty of the electronic balance impacted the amount of salt being placed into each cup and the measurement of the initial and final mass of the *Solanum tuberosum* strips, leading to inaccurate data collection.	Purchasing an electronic balance which provides measurements with a couple decimal places, to ensure accurate results.

Future Suggestions and Real-World Applications

Alongside plant cells, it would be useful to extend research into a broader range of organisms such as animal cells. Osmosis is very important for the preservation of meat, where the process of osmosis draws salt into the meat, thus preventing the intrusion of bacteria[11]. A

[11] Osmosis - Real-life applications. (n.d.). Retrieved February 01, 2021, from: http://www.scienceclarified.com/everyday/Real-Life-Chemistry-Vol-2/Osmosis-Real-life-applications.html

future experiment can be conducted with 2 different meat sources such as Chicken and Turkey to see which concentrated solutions will reduce the intrusion of bacteria at a more efficient rate in a given time period. It is important to prevent the intrusion of bacteria within meats, as the bacteria can lead to food borne illnesses. The various concentrated solutions will give a better idea into which type of solution is the most effective for preventing intrusion of bacteria, aiding in future preparations, cooking techniques, and shelf life.

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