How different concentrations of sodium chloride influence osmosis in potato cells

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1. Design

1.1 Defining the problem

Research Question

Have you ever accidentally cooked a solanum tuberosum (potato) in high sodium chloride (salt) concentrated water? What was the result? This experiment is to consider how salinity influences osmosis in potato cells. By changing the concentration of salt (0%, 0.2%, 0.4%, 0.6%, 0.8%) within the water, the weight of the potato cube will be lighter or heavier than its original weight because water will exit or enter the cell due to osmosis.

Hypothesis

The hypothesis for this experiment is that as the concentration of the salt increases, the mass of the potato decreases. According to the osmosis theory, when a plant cell is placed in a high concentrated salt solution, the mass will decrease because the potato is less concentrated than the salt solution and the water will move through the membrane of the cell and into the stronger solution. But my prediction is that for the control experiment, the mass of the potato will increase as the pure water has a weaker concentration than the potatoes and thus the water molecules will enter the cell making it heavier.

Background Information

Osmosis

As explained earlier, osmosis is the passage of water from a region of high water concentration through a semi-permeable membrane to a region of low water concentration. (1997 – 2000, Purchon)A semi-permeable membrane refers to a very thin layer of material, also known as a membrane, which allows some substances through its membrane but doesn't allow other substances. (May 2009, Biology-online)The substances which can't go through the membrane are molecules such as sucrose and protein. This is because they are just too large to fit through the membrane. (1997 – 2000, Purchon)A high water concentration can also be called a low chemical concentration. This means that it is a very dilute solution. A low water concentration refers to the opposite, it is a concentrated solution. (1999 – 2010, Wisc-online)

When a plant cell is put into salt water, one of three things will occur. If the medium is hypotonic, the cell will gain water through osmosis. This occurs when the solution surrounding the cell has a high water concentration. (2010, Wikipedia) The second scenario is if the medium is isotonic. This is when the solution has the same water concentration as the cell. As a result, the cell will not gain or lose water. (1999, Brown)But if the medium is hypertonic, the cell will lose water through osmosis. This happens when the water concentration surrounding the cell is low. This effect causes the cell to lose all its water resulting in the whole organism's death. (2006, McGraw-Hill Higher Education)

Effect of Salinity on Potato Cells

High salinity causes plants to lose water through osmosis. (November 2009, Wikibooks)A potato is a plant meaning that it is made up of plant cells. A plant cell has a strong cell wall keeping the shape of the plant rigid. When the cell takes in water through osmosis, they start to swell, but the cell wall prevents them from bursting. (2010, Kimball)When potato cells are put in high water concentration, it becomes turgid. This term means swollen and hard. Inside the cell, the pressure rises and eventually the pressur e reaches its limit and no more water can enter the cell. A plant must be turgid in order to be strong and healthy. (2001, Thinkquest)When potato cells, and other plant cells, are placed in concentrated salt solutions, they will lose water by osmosis, and eventually become flaccid. This term means dehydrated and soft, thus the opposite of turgid. When osmosis is viewed under a microscope, when the cell is flaccid the contents of the cells have shrunk and pulled and pulled away from the cell wall. The opposi te was viewed when the cell was turgid. (Montessori Muddle, 2010)

Salinity Concentrations

A previous experiment on osmosis in potato cells was conducted testing the hypothesis: as the concentration of salt increases, the mass of the potato decreases. According to the osmosis theory, this hypothesis will be most logical. The investigation used salt concentrations of 0%, 2%, 4%, 6%, 8%, and 10% . From the results of the experiment, it was shown that the potato cells took in pure water and the potato strip was lighter, for 2%, 4%, 6%, 8% and 10%. Although it didn't state the amount of solution the potato was surrounded by, nor how long the potato was in the test tube, it stated that: 'at 0%, the weight of the potato strip increased by 4.66 grams and at 10% the weight decreased by 22.6 grams.' Although the weight and size of the potato strip is unknown, if a small piece of potato was to lose 22.6 grams, there will be no potato left! Thus for this experiment, it has been decided that salt concentrations of 4% and above will not be used as there may be no result. (Scienceray, 2010)If sea water kills plants, it is most likely to also be able to kill small potato cubes because the surface area of where osmosis occurs is less than a plant's roots. (wiki answers, 2010) Sea water's salinity percentage is 3%. (Newton, 1991 -2009) But there is one uncertainty with this calculation. It doesn't state how long the plant is affected by sea water. So for this experiment, with the support of background information and previous investigations, the salinity percentages will be 0%, 0.2%, 0.4%, 0.6% and 0.8 %.

TABLE 1: Practical Investigations Variables

Independent Variable	• The salinity concentrations in the water • (0%, 0.2%, 0.4%, 0.6%, 0.8%)
Dependent Variable	• Mass of the potato cubes (compare the mass of the potato cube before and after 20 hours)
Controlled Variables	• Amount of water in each test tube (15ml) • Amount of salt diluted into each test tube (grams) • The time the potato cubes are in the test tubes (20 hours) • Size of the test tubes • Place (in a laboratory) • Type of potato • Size of potato cube (1cm x 1cm x 1cm)
Uncontrolled Variables	• Changes in light intensity • Changing temperature • Humidity • Moisture content in the air and mould

TABLE 2: Replicate Options

Options	Description	Advantages	Disadvantages
Option 1	• 4 potato cubes per investigation • 1 test tube per cube Or • 4 cubes per test tube	• Shorter amount of time to cut and place potato cubes into the test tubes	• Fairly accurate results
Option 2	• 5 potato cubes per investigation • 1 test tube per cube Or • 5 cubes per test tube	• Accurate results	• Takes reasonable amount of time to cut and place potato cubes into the test tubes
Option 3	• 6 potato cubes per investigation • 1 test tube per cube Or • 6 potatoes per test tube	• Very accurate results	• Takes long amount of time to cut and place potato cubes into the test tubes

This table shows the 4 options for replication. The options are to create 4, 5 or 6 replicates. Each of the options has different strengths and weaknesses. The biggest factors are about the amount of potato cubes to be used per investigation and how many potatoes per test tube. If the experimenter only cut a few pieces of potato per investigation, (option 1) it lacks in the accuracy of results. On the other hand, if the experi menter cut many potato cubes, (option 3) it would take a long time and thus, there would be a slight difference in the first and last potato cube due to the uncontrollable variables , such as moisture and temperature changes, affecting the primarily cut potatoes for a longer period of time than the potato cubes cut just before they are placed into the test tubes. So, option 2 which contains a reasonable amount of 5 potato cubes and accurate results would be the best option. But for all the experiments, if th ere is a short time limit, approximately 30 minutes or less, it would be wise to put 5 potato cubes per test tube because it will be faster. There is a large weakness to this option, as each potato cube's surface area will not completely be covered by the salt water, because the cubes are on top of each other. But there is also an upside to this choice. Not only will it be time efficient, all the potatoes will be in the exact same volume and concentration of salt water.

1.2 Controlling Variables

Control Experiment

This experiment investigates how salinity influences the effect of osmosis in potatoes. The independent variable is the salinity concentrations in the water. This states that the control experiment is no salt, just a 1cm x 1cm x 1cm potato cube in 15ml of plain water for 20 hours. Keep all variables the same except for the independent.

TABLE 3: Control Treatment of Variables

Controlled Variables	**Control Treatment**
Volume of water in each test tube	Put 15ml of water in each test tube. This is the best option because it's not too less or too much. If it was too less, the whole potato may not be fully covered by the salt water and if the volume of water is too large, when the potato cube is put into the test tube, it may cause the water to spill. Thus, if a test tube holds 25ml, 15 ml would be an appropriate volume for this experiment.
The time the potato cubes are in the test tubes	There should be 20 hours from the start until the end of the experiment for all the investigations. This may be enough time for the osmosis process to start.
Size of the test tubes	There should be 5 test tubes (if there is a short time limit) and 25 test tubes (if there is no time limit), all the same size in order to achieve accurate results from the experiment. Each test tube should be able to hold a 1cm x 1cm x 1cm potato cube and 15ml of salt concentrated solution.
Place	This experiment should be conducted indoors to reduce the number of uncontrolled variables. If this experiment was conducted outdoors, it would increase the risk of bugs, weather danger and the temperature change would be wider. As a consequence the results would not be as accurate as conducting the experiment indoors.
Type of potato	The best method to control the type of the potato is to use just one potato.
Size of potato cubes	Try and equally cut 1cm x 1cm x 1cm potato cubes. This is a good size because the glass of the test tube won't hit the potato cube meaning that the salt water will fully cover the whole potato cube.

1.3 Experimental Method

TABLE 4: Materials

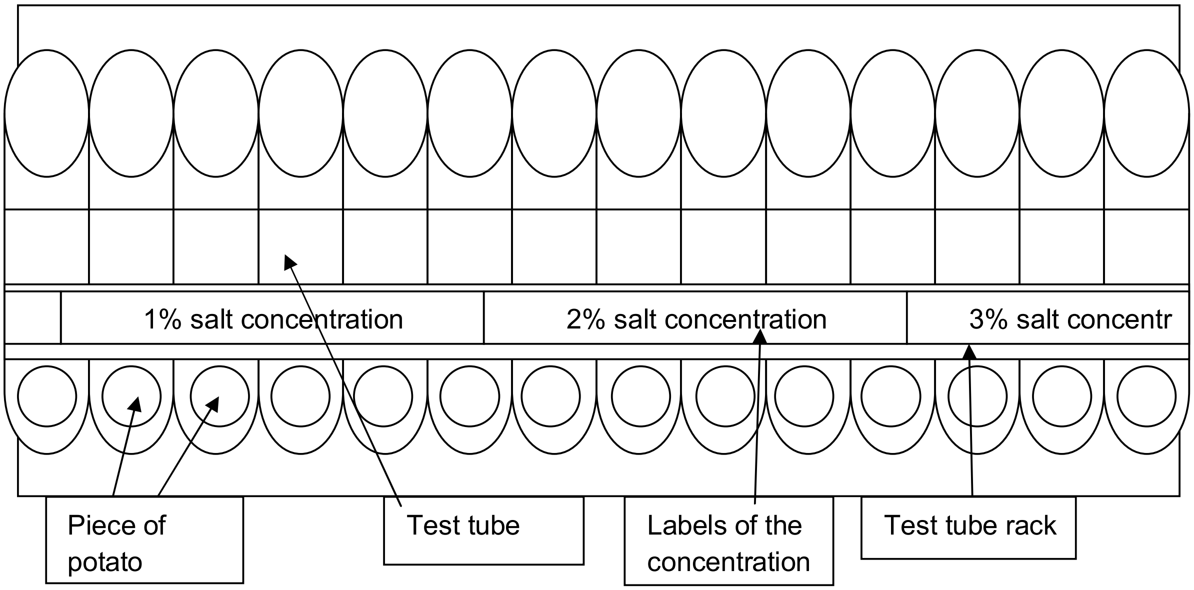
This table below shows the apparatuses needed to perform the experiment.

Apparatus	**Quantity**
Absorbent paper	5
Measuring scale ±0.001g	1
250ml beaker	1
Whole potato	1
Corer	1
Scalpel	1
Tile	1
50ml measuring cylinder	5
Test tube holder	1
Fat test tubes (holds at least 25 ml)	25 (if there is no time limit), 5 (if there is a time limit)
Forceps	1
300mm ruler	1
0.2%,0.4%, 0.6%,0.8 % salt water	75ml each (75ml x 4 = 300 ml) if there is no time limit 15ml each (15ml x 4 = 60ml) if there is a short time limit
Diluted water	75ml

Method

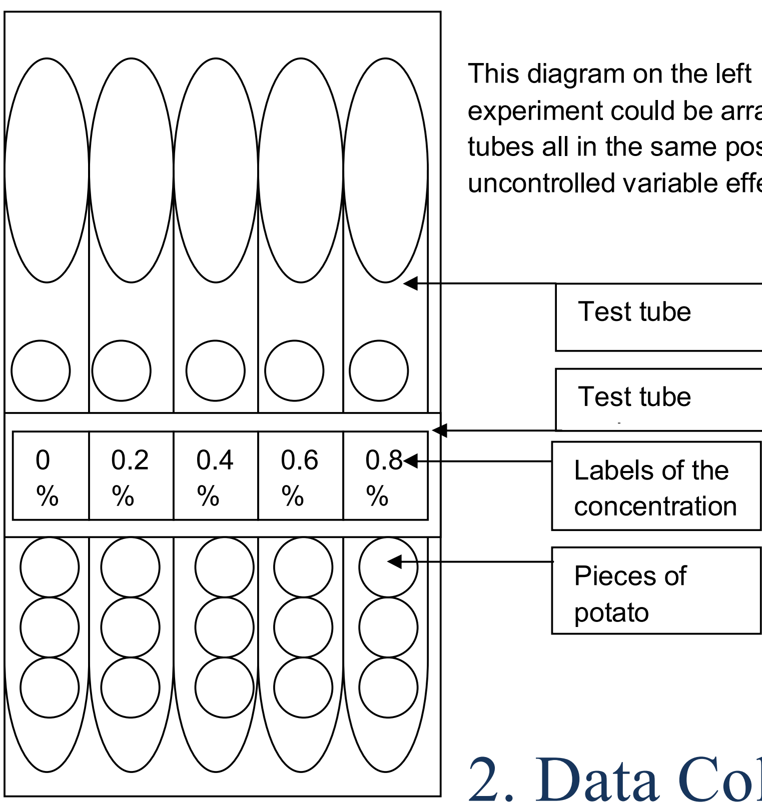
1. Collect the all the apparatuses to start the experiment. Gather everything on the list above.
2. Once all the apparatuses are ready for use, stab the corer into the potato several times.
3. Cut the potato strands into measurements of 1cm by 1cm using a scalpel
4. After 25 potato cubes have been cut, measure each one of them using a measuring scale so that they are all the same weight.
5. Record the weight of each potato cube.
6. Pour 15ml of diluted wa ter using a measuring cylinder for 5 test tubes.
7. Pour 15ml of 1% concentrated salt water using a measuring cylinder for another 5 test tubes. Repeat this process but using a different concentration each time.
8. Place a piece of potato into each test tube.
9. Leave the experiment for 24 hours.
10. Come back to the place where the experiment was conducted and take the potato pieces out of the test tube one by one.
11. Briefly wipe each potato piece before measuring each potato cube
12. Once you measure a potato piece, (using the measuring scale), record the result, and then move to the next potato piece out, etc.
13. Once all the data is recorded analyse the results.

DIAGRAM 1: Experimental Set Up 1 (No time limit)



The diagram above shows how this experiment could be set up. This experiment is set indoor to reduce the number of uncontrolled variables affecting the investigation. Try and place the experiment in front of a wall rather than a window, to reduce the difference in light intensity and temperature. The experimenter should label each investigation on the test tube rack to decrease the risk of getting confused.

DIAGRAM 2: Experimental Set Up 2 (Short time limit)



This diagram on the left shows another way this experiment could be arranged. Try and keep the test tubes all in the same position to reduce the risk of an uncontrolled variable effecting a single investigation.

2. Data Collection &

Processing

2.1 Recording Raw Data

2.1.1: TABLE 5 Quantitative Data

The mass of *solanum tuberosulmon* (potatoes)cubes before and after osmosis						
Experiment no.		Distilled water (0% salinity)	0.2% Salinity	0.4% Salinity	0.6% Salinity	0.8% Salinity
1	Mass before (+0.001g)	0.970	0.919	0.837	0.917	1.169
	Mass after (+0.001g)	1.041	0.940	0.8	0.89	1.101
2	Mass before (+0.001g)	0.953	1.031	1.004	0.894	1.012
	Mass after (+0.001g)	1.065	1.071	0.994	0.854	0.976
3	Mass before (+0.001g)	0.862	0.931	0.987	0.906	1.146
	Mass after (+0.001g)	0.977	0.966	0.956	0.891	1.006
4	Mass before (+0.001g)	0.953	1.182	0.890	0.844	1.072
	Mass after (+0.001g)	1.024	1.198	0.813	0.712	0.971
5	Mass before (+0.001g)	0.848	0.918	0.977	0.938	1.063
	Mass after (+0.001g)	0.956	0.942	0.959	0.881	0.945

The table above shows the raw data from the conducted experiment. There are a total of 50 measurements (2 measurements, before and after, for each potato cube). The reason as to why the mass of each potato cube is different is because they were cut by the experimenter using the naked eye and a ruler, thus it is impossible for the masses to all be exactly the same. Another reason is because the electronic scale had an uncertainty of +0.001 grams. This means that the chance of all the results to be exactly the same mass just using instincts and a ruler, with an uncertainty of +0.5mm, will be impossible. To clarify, these potato 'cubes' are shaped like small cylinders and were cut into pieces of 1cm height to 1cm diameter. 5 potato cubes were placed inside each salt concentrated test tube with 15ml of the solution inside it. The 'mass after' refers to 20 hours after the experiment. An assumption was made that 20 hours is enough time for osmosis to have affected each potato cube.

2.1.2: TABLE 6 Qualitative Data

This table records the observations recorded by the experimenter for this experiment. Unfortunately a camera was unavailable, thus there are no photos produced to show raw data but a detailed description is provided to create an image in the mind.

Qualitative Observations				
Experimental salinity percentages	**Colour of Potato on a white background in the solution**	**Colour of surrounding solution on a white background**	**Sense of touch**	**Other**
0% (distilled water)	Pearl-white	Very clear water	Very firm and slippery	
0.2%	Pearl-white	A bit cloudy under the potato cube but clear above it	Firm and not slippery	Short fur-like coat around the whole piece of potato
0.4%	Marble-white	A bit cloudy around the piece of potato	Firm and not slippery	Short fur-like coat around the whole piece of potato
0.6%	Marble-white, a few brown dots	The whole solution looks cloudy	Feels a bit mushy but not slippery	Hard to see if there is a fur-like coating because the colour of the potato and solution appear similar.
0.8%	Concentrated marble - white	The whole solution looks cloudy	Feels drier than the others	Holding the potato firmly may cause the piece of potato to crumble.

2.2 Processing Raw Data

2.2.1 TABLE 7: Mass of potato cubes after osmosis

Mass of potato cubes after osmosis (g)					
Experiment no.	**Distilled water (0% salinity)**	**0.2% Salinity**	**0.4% Salinity**	**0.6% salinity**	**0.8% salinity**
1	1.041 – 0.97 = 0.071	0.94 – 0.919 = 0.021	0.800 – 0.837 = -0.037	0.890 – 0.917 = -0.027	1.101 – 1.169 =-0.068
2	1.065 – 0.953 = 0.112	1.071 – 1.031 = 0.04	0.994 – 1.004 = -0.010	0.854 – 0.894 = -0.04	0.976 – 1.012 = -0.036
3	0.977 – 0.862 =0.115	0.966 – 0.931 =0.035	0.956 – 0.987 = - 0.031	0.891 – 0.906 = -0.015	1.006 – 1.146 =-0.140
4	1.024 – 0.953	1.198 -1.182 = 0.016	0.813 – 0.890	0.712 – 0.844	0.971 – 1.072

	=0.071		= - 0.077	=-0.132	= -0.101
5	0.956 – 0.848 =0.108	0.942 -0.918 = 0.024	0.959 – 0.977 = -0.018	0.881 – 0.938 =-0.057	0.945 – 1.063 =-0.118

This table shows the increase or decrease in the mass of each potato cube. 0% and 0.2% experiments all gained mass but 0.4%, 0.6% and 0.8% lost mass meaning that the potato cubes have a lower concentration of salt than 0.4% but a higher concentration than 0.2%.

2.2.2 TABLE 8: Sample Calculation

Statistical Analysis	Formulae	Sample Collection
Average	$\overline{X}$ means the average or mean ΣX sum of sample measurements n number of samples Formulae: $\overline{X} = \frac{\sum X}{n}$	$\overline{X}$ = (0.071+0.112 +0.115+0.071 + 0.108)/5 =0.0954 The average gained mass for the distilled water experiment is 0.095 grams.
Standard Deviation	$\overline{X}$ X means each individual value. $(x - \overline{x})^2$ deviation of the mean N-1 degrees of freedom.Formulae: $s = \sqrt{\frac{\sum (x - \overline{x})^2}{N-1}}$	= 0.022 The standard deviation for the distilled water experiment is 0.022 grams.

The table on the previous page shows the two calculations that are used when processing the data: the average and the standard deviation. The standard deviation is a statistical measure of the precision for series of repetitive measurements. (C.Wylie 2010) A worked example has been shown for the average and standard deviation of the distilled water investigation.

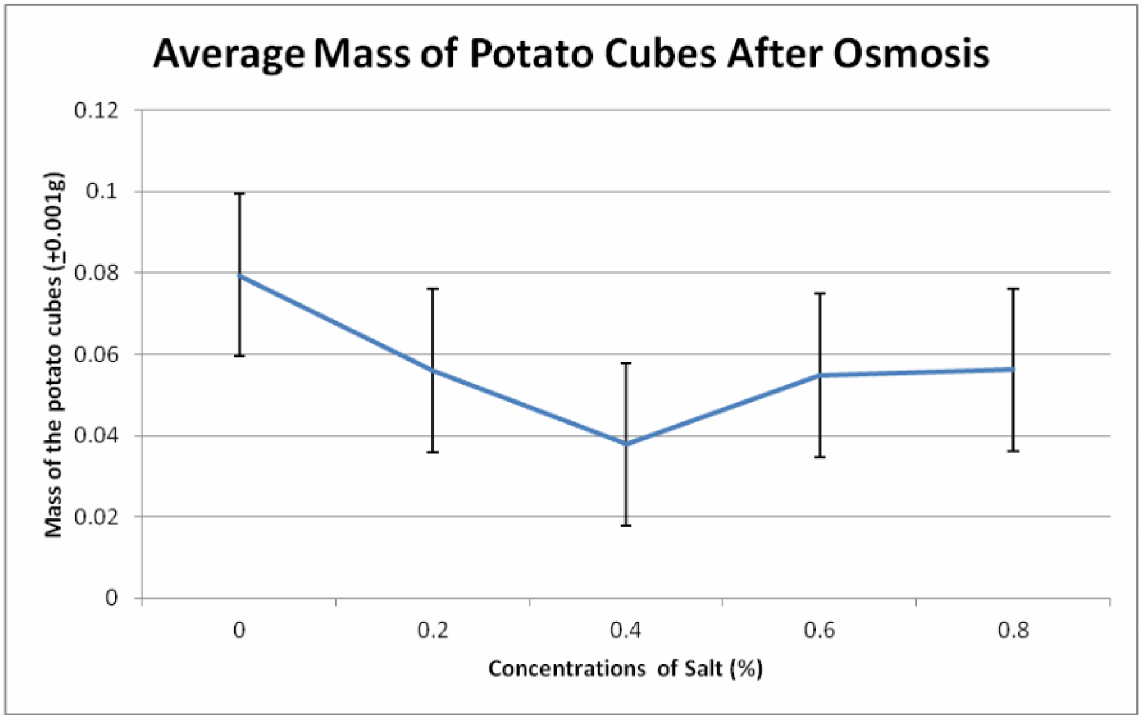
2.3 Presenting Processed Data

2.3.1 TABLE 9: Results Table

Average and Standard Deviation for the whole experiment		
Concentration of salt (%)	**Average difference (±0.001g)**	**Standard deviation**
0	0.095	0.022
0.2	0.027	0.01
0.4	-0.035	0.026
0.6	-0.054	0.046
0.8	-0.093	0.041

This table shows the average difference and standard deviation for each salt concentration investigation.

2.3.2 GRAPH 1: Results Graph



This graph shows the average mass of potato cubes after osmosis. At first, as the concentrations for salt increases, the mass of the potato cubes decreased. But once the concentration of salt reached 0.4%, as the concentration of salt increased, the mass of the potato cubes increased as well. This may suggest that the isotonic point is around the 0.4%.

3. Conclusion

3.1 Conclusion

The hypothesis for this experiment was that as the concentration of the salt increases, the mass of the potato decreases. The hypothesis was correct for 0% and 0.2% salt concentrated investigations but the trend d id not continue, thus the hypothesis was refuted. The possible suggestions as to why, may be because there was a short time limit, the potatoes weren't all the same size and weight and because the measuring scale was highly sensitive.

3.2 Evaluating Procedures

3.2.1 Reliability

As explain in 'Table 2 Replicate Options', a decision was made before the experiment as to how many potato cubes per investigation and also how many per test tube. Because there was a time limit on the experiment, it was decided tha t the decision should be based on time efficiency but still have reasonable reliability. Another reliable source is the electronic measuring scale. It reads up to 3 decimal places so the experimenter can record very accurate results when used properly.

3.2.2 Limitations/ weaknesses/ errors in laboratory investigations

Time as the main issue

In the '1.0 Design' section of this report, it stated that time is a big factor that affects the accuracy of the data. When the experimenter conducted this experiment, a short time limit was set, thus there was a lot of pressure which may have affected the experimenter's concentration and patience. This co -relates with the fact that the potatoes weren't all the same size. If there was no time limit set, the experimenter m ay have cut the potatoes more slowly and carefully. This also relates with the potato cube's surface area. It is very likely that when two objects were made out of the same element, but each had a different weight, one must be bigger than the other, thus h ave more surface area. This is also a big problem because if a piece of potato had a much larger surface area (than a piece of potato with the average mass), when osmosis occurred, that piece of potato may lose or gain more mass depending on the solution i t is placed in.

Measuring Scales

One major problem with the measuring scale was the time. These types of scales take some time to get an accurate reading, but if there is a time set for the experiment, and there wasn't much time left before the end of the set time, the experimenter may fall into the trap of leaving the mass of the object on for just a second or so, and recording the data. This is an easy error but it is also a major one because the mass could be many hundred milligrams off the experimental mass. Another negative factor about the measuring scale is the sensitivity. With the measuring scales that were used for the experiment, they were extremely sensitive. Whenever pressure is applied around a 30cm radius (approximate estimation) from the measuring scale, the measurement on the scale changes, thus making the experiment take longer and also making the results inaccurate. The experimenter may be left with no choice but to record false data if there is time set because waiting for the correct recording may take many ten seconds. The investigations recorded closer to the time limit (0.6% & 0.8%) were the only investigations that didn't agree with the hypothesis. Perhaps the experimenter fell into the measuring scale time trap, and recorded faulty results.

3.3 Improvements

There is only one main improvement that will fix all or most errors. That is time. If there was no time limit, there would not have been any pressure nor fallen for the measuring scale trap and the experimenter may have cut the potato cubes with care.

5. Reference List

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