Investigating the Effect of Time on the Plasmolysis of Potatoes

Research Question

What causes potatoes to go soft after being stored for a long time?

Aim

The aim of this experiment is to investigate how time affects the amount of water lost by potatoes, by measuring at how much water a cylinder cut from a potato (4cm in length) can take up after various amounts of time, measured in weeks. I will do this by calculating the change of mass of the cylinder, after placing it in water for 1.5 hours, as I predict the amount of water absorbed by the potato cylinder through osmosis, will be the same as the amount of water lost over time

Background Information

Osmosis is the passive transport of water through a partially permeable membrane of a cell. As this transport is passive and not active, no ATP is needed as the water movement occurs along the concentration gradient through the partially permeable membrane. In plant cells, such as potato cells, when water leaves the cell tissue through osmosis, the cytoplasm and plasma membrane are pulled away from the cell wall. The cell wall however, as it is a semi-rigid structure composed mainly of cellulose, maintains its shape. This loss of water and pulling together of the plasma membrane is called plasmolysis. As observable in flowers when they wilt in the absence of enough water, plant cells rely on turgor pressure, water filling up the cytoplasm, for support. This also explains why potatoes get soft over a longer period of time. When exposed an hypertonic environment, meaning the cells contain a higher concentration of water than there is externally, water will gradually move out of the cells by osmosis. Therefore, when potatoes are left for a longer period of time, the water will be drawn out of the cells, through the partially permeable membrane, causing the cells to become flaccid and eventually turgid. The amount of water lost by the cells through osmosis can be evaluated through the change in mass of the potatoes aver a period of time.

When flaccid or plasmolysed cells are placed into a hypotonic solution, with lower osmotic pressure, water will move along the concentration gradient, into the cell cytoplasm. When this movement occurs, the cell cytoplasm will gradually become turgid again until a point of equilibrium is reached. For this reason, the more water removed from the potato cells through osmosis, the larger the capability of water uptake will be, when put into a beaker of water. Therefore it can be predicted that over a period of time, potatoes decrease in mass due to the loss of water through osmosis. When however put into a hypotonic solution, this water can be reabsorbed again.

Hypothesis

I predict that, as potatoes become softer over a period of time, plasmolysis occurs and therefore, the older a potato is, the more water is lost from it. When the plasmolysed potato cells are then placed in water, through osmosis, the cells are able to reabsorb the water that was lost over time, to become turgid again. For this reason, I assume that the older the potato is, the more the potato cube will increase in mass, because it is capable of absorbing more water. For this reason I predict that the whole potato will gradually decrease in mass over time and the change in mass of the potato cylinders, when placed into water, will increase.

Variables

Dependent variable	Amount of water taken up, which I assume will be the same as the amount of water lost. Measured in: -Change in mass (g) ±0.05g
Independent variable	Storage time of potatoes over a period of 5 weeks, taking a measurement every week.
Controlled Variables	Age of potatoes: all potatoes taken from the same batch, assuming they were harvested at about the same time. Temperature: I will place the potatoes in an incubator with a set temperature (20°C). Size of potato cylinder (4cm in length) ±0.1cm Water solution; by using distilled water. Light intensity: placing the potatoes in incubators will eliminate alteration through light. Time of potato cylinders in water (90min) ±0.1min
Uncontrolled Variables	Biological condition of the potatoes: monitored by taking potatoes of the same age, as well as similar size and mass

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Equipment List:

-Potatoes: twenty-five potatoes from the same type and batch, with about the same size and weight.
-Ruler (mm)
-Measuring cylinder (20ml)
-5 Beakers (500ml)
-Distilled water
-Two tiles for cutting
-Cork borer for cutting potato cylinders
-Balance (g)
-Incubator set to 20°C
-Marker pen
-Stop-watch (s)

Method

1) Select twenty-five potatoes, with approximately the same size and mass, from the same batch and divide them into five groups. Label them accordingly: potatoes in group 1 with the labels 1a, 1b, 1c, 1d, 1e, potatoes in group 2 with the labels 2a, 2b etc.
2) Weigh each potato and record the mass.
3) Place potatoes in groups 2 to 5 into an incubator and turn the temperature to 25°C.
4) Take the 5 potatoes of group 1 and using a cork borer, cut a cylinder out of the centre of each potato.
5) Place each cylinder onto a tile and label these tiles according to the potato from which the cylinder was cut from. Carefully, using a millimetre ruler to cut each cylinder to a length of 4cm.
6) Take five 500ml beakers and label them a to e.
7) Fill the beakers with 500ml of distilled water each.
6) Using an mg balance, weigh each cylinder and record the mass in a table.
8) Place each cylinder into one of the prescribed beakers and be careful to start the stopwatch at the same time.
9) After 1.5 hours, take each cylinder out of the beaker and place it on a separate tile, with the prescribed labels a to e.
10) Using a mg scale, weigh the mass again.
11) Record the new results in the table.
12) In intervals of one week, repeat the steps 3 to 10 for the potatoes in each group, so that group two is investigated in week two, group three in week three etc.
13) Make sure to record the mass of the whole potato before cutting the cylinder.

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Table 1: Data collected for the change of mass of whole potatoes over a period of 5 weeks.

Time (weeks)	Potato	Initial Mass / (g) ±0.05g	Final Mass / (g) ±0.05g	Change in mass / (g) ±0.05g	Mean change in mass
Week 0 (Group 1)	A	140.6	140.6	0	0
	B	162.6	162.6	0	
	C	167.1	167.1	0	
	D	180.7	180.7	0	
	E	186.7	186.7	0	
Week 1 (Group 2)	A	172.3	169.9	-2.4	-3.16
	B	202.4	199.2	-3.2	
	C	206.3	203.3	-3	
	D	184.7	179.9	-4.8*	
	E	180.0	177.6	-2.4	
Week 2 (Group 3)	A	187.1	182.4	-4.4	-4.42
	B	165.5	161.5	-4	
	C	231.7	226.4	-4.9	
	D	164.6	160.0	-4.6	
	E	171.1	166.4	-4.2	
Week 3 (Group 4)	A	187.1	180.1	-7	-6.78
	B	168.6	161.98	-6.02	
	C	208.0	200.3	-7.7	
	D	213.4	206.7	-6.7	
	E	182.3	175.8	-6.5	
Week 4 (Group 5)	A	141.3		-8.4	-8.00
	B	156.6	148.9	-7.7	
	C	187.3	179.4	-7.9	
	D	161.9	154.4	-7.9	
	E	200.9	192.8	-8.1	

When measuring the mass of each whole potato, an uncertainty error of ±0.05g has to be taken into consideration, as the scale used was accurate to the nearest 0.01g.

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Table 2: Data collected for the change of mass of potato cylinders, cut out of the whole potatoes measured in Table 1, when put into a beaker filled with water for 1.5 hours.

Time (weeks)	Potato	Initial Mass / (g) ±0.05g	Final Mass / (g) ±0.05g	Change in mass / (g) ±0.05g	Mean change in mass
Week 0 (Group 1)	A	4.09	4.27	0.18 !	0.16 !
	B	4.04	4.19	0.15	
	C	4.12	4.28	0.16	
	D	4.05	4.21	0.167	
	E	4.09	4.23	0.14	
Week 1 (Group 2)	A	4.24	4.54	0.30	0.32
	B	4.08	4.36	0.28	
	C	4.19	4.45	0.26	
	D	4.12	4.57	0.45*	
	E	4.25	4.56	0,31	
Week 2 (Group 3)	A	4.04	4.39	0.35	0.47
	B	4.13	4.48	0.35	
	C	4.08	4.42	0.34	
	D	4.13	4.50	0.37	
	E	4.10	4.46	0.36	
Week 3 (Group 4)	A	3.83	4.30	0.47	0.47
	B	4.00	4.48	0.48	
	C	3.94	4.40	0.46	
	D	3.97	4.43	0.46	
	E	4.08	4.56	0.48	
Week 4 (Group 5)	A	4.01	4.57	0.56	0.58
	B	3.86	4.49	0.63	
	C	4.12	4.69	0.57	
	D	3.90	4.51	0.58	
	E	4.06	4.59	0.57	

Likewise to the measurements for the whole potatoes, an uncertainty error of ±0.05g has to be taken into consideration, as the same scale was used, which was accurate to the nearest 0.01g.

The Mean average in both Tables 1 and 2, was calculated by adding the measurements for each potato, or each cylinder, and dividing the sum by the number of measurements taken for each sample, which in this case is 5.

Mean Average $\frac{a1+a2+a3+a4+a5}{5}$

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Calculation of Standard Deviation and Relative Percentage Value

Table 3: Standard Deviation and Relative Percentage Value for measurements taken for the change of mass of the whole potatoes.

Time (weeks)	Mean decrease in mass / (g) ±0.05g	Standard deviation	Relative percentage value (%)
Week 0	0	0	0
Week 1	3.16*	0.98	31.01
Week 2	4.42	0.35	7.92
Week 3	6.78	0.62	9.14
Week 4	8.00	0.26	3.25

Table 4: Standard Deviation and Relative Percentage Value for measurements taken for the change of mass for each potato cylinder.

Time (weeks)	Mean decrease in mass / (g) ±0.05g	Standard deviation	Relative percentage value (%)
Week 0	0.16	0.015	8.33
Week 1	0.32*	0.075	24.44
Week 2	0.35	0.011	3.14
Week 3	0.47	0.01	2.13
Week 4	0.58	0.027	4.65

The Standard Deviation, recorded in Tables 3 and 4, was calculated in Excel. It shows how widely values are dispersed from the average mean. The relative Percentage value shows the relationship between the standard deviation and the mean average. Dividing the standard deviation by the mean average, and multiplying the result by 100, gives this percentage value.

Calculation of the Percentage Value for the change of mass.

The percentage value is calculated by dividing the mean decrease in mass, by the mean initial mass taken each week. As the initial masses for both the whole potatoes and the potato cylinders vary due to biological factors, a proportional comparison between the changes of mass cannot be made. As the percentage value however, considers the relationship between the initial mass and the change in mass, it can be considered a more accurate form of evaluation.

Table 4: The Percentage Value for the mean change in mass of the whole potatoes.

Time (weeks)	Mean initial mass / (g) ±0.05g	Mean decrease in mass / (g) ±0.05g	Percentage value for change in mass (%)
Week 0	167.54	0	0
Week 1	189.14	3.16	1.67
Week 2	184	4.42	2.40
Week 3	191.88	6.78	3.53
Week 4	169.6	8.00	4.72

Table 5: The Percentage Value for the mean change in mass of the potato cylinders.

Time (weeks)	Mean initial mass / (g) ±0.05g	Mean increase in mass / (g) ±0.05g	Percentage value for change in mass (%)
Week 0	4.08	0.16	3.92
Week 1	4.18	0.32	7.66
Week 2	4.11	0.35	8.52
Week 3	3.96	0.47	11.87
Week 4	3.99	0.58	14.54

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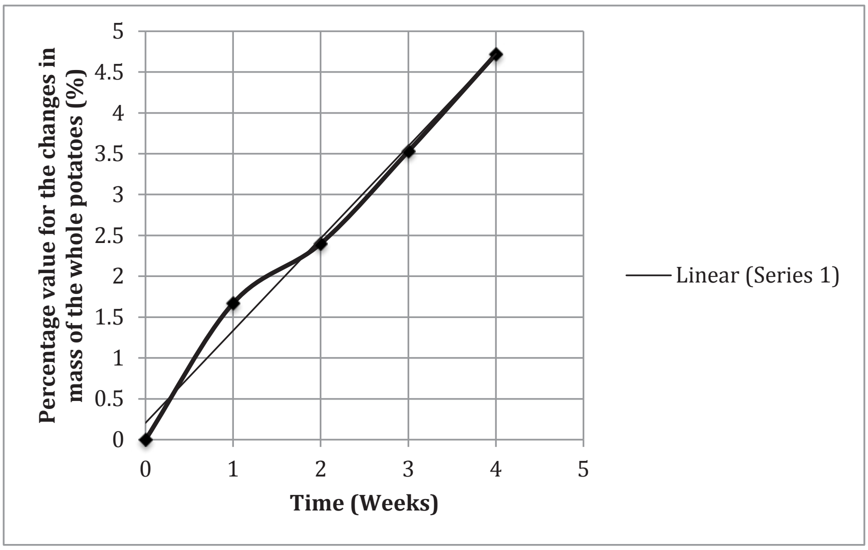
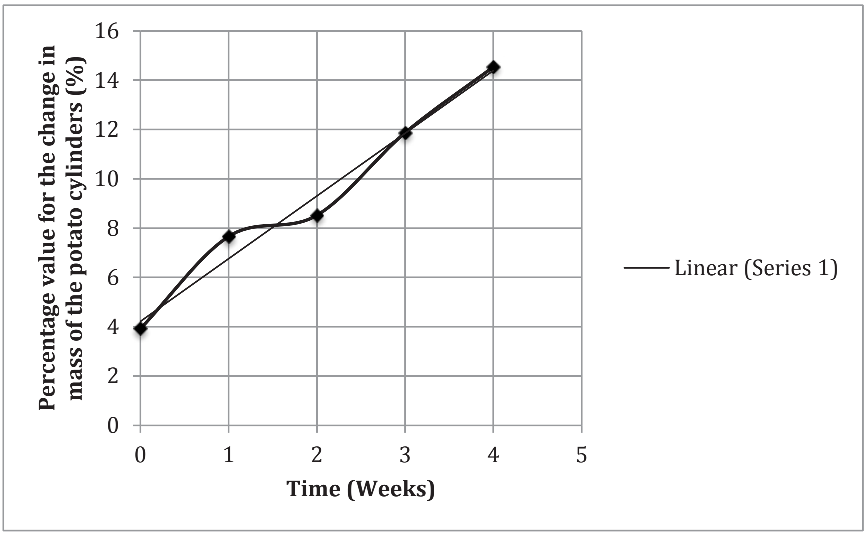
Graph 1: Percentage Value for the mean change in mass of whole potatoes over a period of 5 weeks.



Graph 2: Percentage Value for the mean change in mass of potato cylinders when put into water for 90 minutes, over a period of 5 weeks.



Anomalous Results

Through graphs 1 and 2, it can be seen that the data point for the percentage value calculated of both the whole potatoes and the potato cylinders, in the first week, do not fit to the general trend and therefore lie off the predicted line of the graph. When looking back at the raw data collected for the change in mass of the whole potatoes as well as the cylinders, it is noticeable that the results taken from Potato D in Week 1, do not fit into the general pattern of results, as they are higher. This is clearly supported by tables 3 and 4, by the standard deviation and relative percentage value.

Through the relative percentage value, the spread of the data can be compared, as it shows the relationship between the standard deviation and the mean average. When the standard deviation is less than 33% of the mean, it can be considered small, meaning the values are close together. As illustrated in tables 3 and 4, the relative percentage value for all measurements, lie below 33%. However, it is noticeable that the calculations taken for Week 1, give a higher relative percentage value than those of any other week. As pointed out in table 3, a value of 31.01%, lies just under 33%, meaning that the data is quite spread out. The same can be said for the

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results taken for the potato cylinders in Week 1, which have a percentage value of 23.44%.

This led me to look back at the raw data collected in Week 1 and eliminate the measurements taken from Potato D. These results are marked with a *, to indicate that they are anomalous and should not be included in the calculations. Tables 6 and 7, show repeated calculations of the percentage value for the change in mass of the whole potatoes and potato cylinders, in which the anomalous data from Potato D in week 1 had been left out.

Table 6: The Percentage Value for the mean change in mass of the whole potato in Week 1, excluding the anomalous result {Potato D).

Time (weeks)	Mean initial mass / (g) ±0.05g	Mean decrease in mass / (g) ±0.05g	Percentage value for change in mass (%)
Week 1	190.25	2.75	1.45

Table 7: The Percentage Value for the mean change in mass of the potato cylinders in Week 1, excluding the anomalous result {Potato D).

Time (weeks)	Mean initial mass / (g) ±0.05g	Mean increase in mass / (g) ±0.05g	Percentage value for change in mass (%)
Week 1	4.19	0.28	6.68

Table 8: Standard Deviation and Relative Percentage Value for measurements taken for the change of mass of the whole potatoes in Week 1, excluding the anomalous result (Potato D)

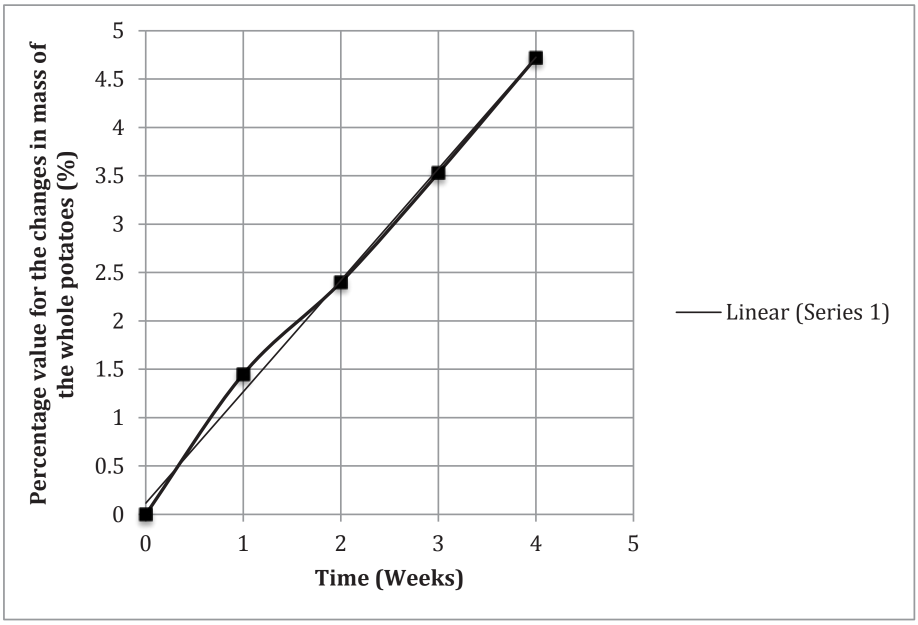
Time (weeks)	Mean decrease in mass / (g) ±0.05g	Standard deviation	Relative Percentage Value (%)
Week 1	2.75	0.41	14.91

Table 9: Standard Deviation and Relative Percentage Value for measurements taken for the change of mass of the potato cylinders in Week 1, excluding the anomalous result (Potato D)

Time (weeks)	Mean decrease in mass / (g) ±0.05g	Standard deviation	Relative Percentage Value (%)
Week 1	0.28	0.022	7.86

The decrease of the relative percentage value from 31.01% to 14.91%, for the whole potatoes in Week 1, and from 23.44% to 7.89% for the cylinders, verifies that Potato D was an anomalous result. The new processed data for Week 1, is a lot closer to the mean and therefore more reliable.

Graph 3: Percentage Value for the mean change in mass of whole potatoes, over a period of 5 weeks, excluding the anomalous result.



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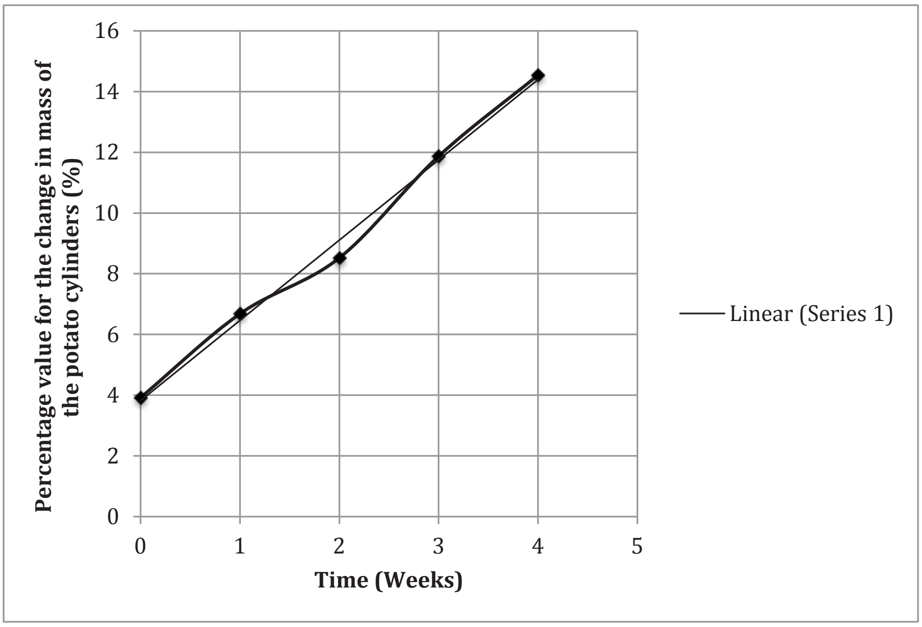
Percentage Value for the mean change in mass of the potato cylinders when put into water for 90 minutes, over a period of 5 weeks, excluding the anomalous result.



Conclusion

As Graph 3 demonstrates, over a period of five weeks, the mean average percentage change in mass of a whole potato followed a more or less linear upward trend. Starting at an average weight of 167.54g, a percentage of 4.72% was approximately lost over a period of five weeks. As illustrated on Graph 3, this was a gradual decrease.

When looking at Graph 4, it can be seen that the potato cylinders also follow a linear upward trend of percentage change in mass. This graph however represents how much weight the potato cylinders gained when put into water for 1.5 hours. It can be seen that while the potatoes, investigated in Week 0, only gained an average of 3.92% of their mass, potatoes, which had been left until Week 4, gained 14.54%. As the percentage change gradually increased over time, it is indicated that the longer the potatoes were left in the incubator, the more water could be reabsorbed by the potato cylinders, when placed into a water filled beaker.

Comparing the data collected for the change in mass of the whole potatoes to the change in mass of the potato cylinders, it can be said that as the whole potatoes became lighter, the change of mass of the potato cylinders increased. This can be explained by the concept of osmosis. When the potatoes were placed into the incubator, the concentration of waterin the air was lower than the concentration of water inside the cell cytoplasm causing the water to gradually pass though the partially permeable membrane of the potato cells along the concentration gradient. The loss of water from the potato cells gradually caused a loss of turgor pressure, making the cells flaccid and thus the potato softer. This is supported by the collected data because the loss of water from the potato cells also caused a decrease in mass.

The investigation of change in mass of the potato cylinders after being placed into a beaker of water for 1.5 hours, supports the fact that the loss of water through osmosis is responsible for the softening of potatoes over a period of time. As my results show, the percentage increase of mass of the potato cylinders rose steadily, indicating that in increasing amount of water was absorbed per week. This demonstrates that the potato cells, which were left for a longer period of time and thus lost more water through osmosis, had a greater potential in reabsorbing the water again as the concentration gradient between the water in the beaker and the inside of the cells was steeper. The potatoes, which were only left for a short length of time, for example those in Week 0, were still turgid and therefore, when placed into the beaker, not as much water moved into the cells through osmosis, resulting in an increase of only 3.92%.

As already mentioned, during the processing of raw data, I eliminated an anomalous result; Potato D in Week 1. By evaluating the standard deviation of the raw data, through the relative percentage value, I noticed that the data for both the whole potato, as well as the cylinder of Potato D in Week 1, was spread far from the mean. In addition, by looking at Graph 1 and Graph 2, it can be seen that the processed data does not fit to the trend of the rest of the data collected. Eliminating the measurements taken for this potato and drawing graphs from the new processed data, illustrate a steadier upward trend. This lead me to conclude that because of biological factors, such

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as damaged cell walls, Potato D in Week 1 was anomalous.

To conclude, by investigating the percentage change in mass of whole potatoes and potato cylinders when placed into a beaker of water, over a period of five weeks, it is evident that potatoes lose water through osmosis and therefore become lighter and softer. The collected and processed data supports my hypothesis, as it demonstrates that water gradually moves out of the potato cell cytoplasm, by osmosis, making the cells less turgid and the potato softer.

Evaluation of Results:

At first, the standard deviation, calculated for both the data for the whole potatoes and the potato cylinder, recorded in Tables 3 and 4, indicated that the data collected on Week **1** was spread quite far from the mean. The relative percentage value calculated for Week 1, gave 31.01% for the measurements of the whole potatoes, and 23.44% for the cylinders. Even though these values still lie under 33%, which is considered to be the percentage at which the standard deviation can be considered large, as the other measurements gave a much smaller percentage value, I considered looking back at the raw data and to eliminate Potato D as anomalous. As illustrated in Tables 8 and 9, the relative percentage value for the whole potatoes decreased to 14.91%, and to 7.86%, for the cylinders, demonstrating an increase in reliability.

Eliminating the anomalous result and processing the data without Potato D, made the calculations for the mean more exact and therefore the overall results more reliable.

Evaluation of Method

Controlled Variables:

Temperature: As higher temperature would have made the water evaporate more quickly and therefore increased the rate of osmosis through the cell walls, leading to a greater loss of mass, it was important to keep the temperature which the potatoes would be stored, constant. I did this by placing the potatoes in an incubator, set at 20 °C.

Water Solution: As osmosis depends on the movement of water along concentration gradient, different solutions of water would have varied the amount of water absorbed by the potato cylinders. To control this variable, I used distilled water so that the concentration of water would remain constant and therefore make the data more precise.

Light Intensity: Similar to temperature, the light intensity at which the potatoes would be exposed to during the five week, would alter the rate of osmosis. By placing the potatoes into an incubator, sealed from light, the light intensity would not alter the results.

Biological Uncertainties:

Although I used potatoes taken from the same batch, with approximately the same size and weight, biological differences made it more difficult to measure precise data. Even though I made sure to choose potatoes of the same size, due to biological factors, the initial weight of the potatoes varied. To prevent this for altering the results, I made sure to calculate a mean average out of five repeats for each week. This ensured that my data collected was precise as I was able to recognize anomalous results and exclude them the processing of the data. By evaluating the standard deviation of the mean, through a relative percentage value, I identified an anomalous result, caused by biological uncertainties, such as damaged cell walls. As a result, even though biological differences were present, I was able to recognize irregular data, which would significantly have changed the result of the investigation, and eliminate these. Through this, the results processed from the collected data were still precise.

Instrument Uncertainties

Mass of potatoes and potato cylinders:
To measure the mass of the potatoes and potato cylinders I used the same scale, which measure to an accuracy of the nearest 0.01g. For this reason an uncertainty of ±0.05g has to be taken into consideration.

Size of potato cylinders:

To ensure the diameter of the potato cylinders was kept constant, I used a cork borer to cut them out of the whole potatoes. For the length, I used a ruler that measured up to the nearest 0.0lcm. As an uncertainty of ±0.05cm has to be taken into consideration for both the starting and ending point of the cylinder, a total uncertainty of ±0.1cm has to be considered.

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Time of Potato cylinders in water:

I used a stopwatch with accuracy to the nearest 0.01min, giving an uncertainty of ±0.05min for both when stopped and started. Resulting in a total uncertainty of ±0.1min.

Overall these instrument uncertainties are of little significance to the overall results of the investigation. As the time measured for the potato cylinders to be placed into water was large, 90min, compared to the uncertainty of ±0.1min, this does not effect the measurements to a significant extent. In addition, by using a cork borer, I ensured that the diameter of the potato cylinders was kept constant. When looking at the uncertainty for the mass of the potato cylinders, it becomes clear that for measurements ranging from 3.85g to 4.25g, an uncertainty of ±0.05g does suggest that for a more accurate measurement, a different scale would have been more appropriate. However, as shown through Table 4 and later Table 9, the standard deviation demonstrates that the measurements were nevertheless precise.

Weaknesses and Possible Improvements

When first planning my investigation, I intended to cut cubes out of the potatoes rather then cylinders. However, during the preparation I noticed that it was difficult to cut cubes with the exact measurements of $2cm^3$. As varied sizes of the potato cubes would alter the precision of the collected data, I decided to use a cork borer to cut cylinders out of the potato instead. This then ensured that the potato cylinders each had the same diameter and only the length had to be cut to 4cm.

As I only took five repeats with five different potatoes each week, the reliability of my mean average was limited. To increase the reliability of my data, I could have taken more cylinders from each potato and compared their change in mass. Also, I could have taken measurements at intermediate stages of the week to have more data points on the graphs and therefore drawn a more reliable best-fit line. This would have shown a more reliable trend of the graph.

As I excluded one anomalous result from the processed data, the repeats taken for Week 1 was reduced to 4. This again would have been more reliable if more repeats had been taken. To improve the investigation I should be aware of biological uncertainties and possible anomalous results and therefore do more repeats, using more potatoes.

By using the same scale to measure the mass of the whole potatoes and of the cylinders, the uncertainty was the same, 0.05g. This did have a great effect on the reliability of the mass of the whole potatoes, as they had a larger mass. For the potato cylinders, however, having a smaller mass, a scale measuring in milligrams (mg) would have been more reliable.

A factor, which might have had an influence on how much water was lost by the potato cells through osmosis, is the situation of the cells in the potato. As cells in the middle of the potato are not exposed to such a great concentration gradient as the cells on the outermost layer of the potato, they might have lost less water and thus their potential of reabsorbing water was more limited than that of the outermost cells. Even though I controlled this factor by always cutting the potato cylinders out of the centre of the whole potato, to improve my experiment, I could have compared the gain in mass of cylinders taken from the edge of the potato to those taken from its centre. This would have shown more precisely how water moves out of the potato and perhaps demonstrated that over a period of time potatoes gradually become softer on the outside to the inside.

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