STORAGE TECHNIQUES TO MINIMISE WASTE AND EXTEND SHELF LIFE OF COMMONLY WASTED FOODS IN NEW ZEALAND.

Final Report
Part 1 – Fruit and Vegetables

Submitted to
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This research tested different storage methods for seven fruit and vegetables. Consumer-based techniques were used to determine the effectiveness of each storage method on preserving the quality of the food product. A list of key storage recommendations was then compiled and findings are presented in this report.

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Executive Summary

A literature review was undertaken in order to review and collate storage methods suggested in popular literature, commercial best practice recommendations, and academic literature. Each method was assessed for feasibility and a list of viable test methods was generated for each food product.

Some storage methods were chosen for assessment due to their popularity on the internet, or because they are recommended by influential food writers i.e. sprinkling black pepper on cut pumpkin, storing avocado in an airtight container with a piece of cut onion, or storing carrots in a container filled with water. Other methods were chosen to be tested as they are common practice in many households i.e. storing celery in a jar of water, wrapping the ends of celery in paper towels, sprinkling avocado with lemon juice, and removing seeds from cut pumpkin. Some methods, such as the use of plastic and perforated bags, were recommended as commercial best practice, and other methods were designed to test specialised products available on the market e.g. Honeywraps, avocado savers, lettuce crispers and edible paper.

The products for which changing the storage method would make the most difference were determined to be:

- Avocado – wrap in cling wrap
- Carrots – store in a container lined with a paper towel
- Celery – store in a container lined with a paper towel

One method which consistently helped to preserve product quality was lining and wrapping products in paper towels. The paper towels help to regulate humidity and condensation in the environment surrounding the produce by absorbing and releasing water over time. Carrots, celery, broccoli and lettuce all benefited from storage methods that utilised paper towels.

Urban myths which need to be dispelled are:

- Storing celery in a jug of water
- Sprinkling lemon on avocado

These methods which are commonly recommended on the internet proved to be detrimental to the storage of these products.

In almost all instances fruit and vegetables that were covered in some way had a longer shelf life than products placed unwrapped in the fridge.

Overall factors to control for extended shelf life:

- Moisture loss – in most cases moisture loss was detrimental to quality
- Exposure to air within the fridge – in all cases products exposed to the circulating air in the fridge experienced greater moisture loss than products protected from the air

Overall the most effective storage methods were:

- Avocado – wrap in cling wrap, in fridge. Storing avocado halves in this way could allow them to stay of an acceptable quality for up to 4 times longer than the control.

- Carrots – store in an airtight container lined with a paper towel, in fridge. Storing carrots in this way could maintain an acceptable quality for up to 10 times longer than the control.

- Celery – store in an airtight container lined with a paper towel, in fridge. Storing celery in this way could maintain an acceptable quality for up to 5 days longer than the control.

- Lettuce – lettuce crisper or wrapped in paper towels sealed in a Snaplock bag, in fridge. Storing lettuce in this way could maintain an acceptable quality for up to 4.5 times longer than the control.

- Broccoli – sprinkling the head with water then wrapping it in paper towels and placing in a sealed in a Snaplock bag, in fridge. Storing broccoli in this way could maintain an acceptable quality for up to 2.5 times longer than the control.

- Pumpkin – wrapped in cling wrap, in the fridge. Storing cut pumpkin in this way could maintain a perfect quality for up to 4.5 times longer than the control.

- Bagged lettuce – in an airtight container in the fridge. Storing bagged lettuce in this way could maintain an acceptable quality for up to 2 days longer than the control.

It is important to note that during the trial period the refrigerator had an average temperature of 4.0°C and an average humidity of 87.7% RH. The crisper drawer had an average temperature of 4.6°C and an average humidity of 95.0% RH.

Avocado

17 storage methods for cut avocado halves were trialled. Storage methods included:

- Cling wrap
- Avocado saver[1]
- Honeywraps[2]
- Air tight containers
- Lemon juice
- Olive oil

Quality was defined using a scale of 0 to 5 of physical appearance. Physical appearance in this setting refers to discolouration and observable texture (eg dry or slimy) of the flesh, as the main determinants of quality. 0 out of 5 was the rating given to products with a completely unacceptable physical appearance, including major discolouration, changes to texture (i.e. very dry, very soft/slimy). 5/5 refers to a product that was deemed to be in perfect condition in terms of physical appearance: green colour maintained, texture soft, not slimy.

Wrapping an avocado in cling wrap and forming a tight seal on the cut surface was the most successful method to preserve a cut avocado and resulted in an acceptable visual appearance for up to 8 days. Storing avocado halves in this way could allow them to stay of an acceptable quality for up to 4 times longer than the control.

It is important to note that avocados used in this experiment were ripened from green and cut once they were deemed completely ripe (skin turned dark green and slight softness when squeezed gently.)

Other effective methods were:

- In an airtight container
- In an airtight container with a piece of cut onion
- Avocado savers
- Honeywrap

Two commonly used methods proved to be detrimental to the avocado i.e. they performed worse than the control – an unwrapped avocado with the stone out.

- Lemon juice
- Olive oil

Overall leaving the stone in the avocado resulted in higher percentages of acceptable product across the experiments, 84.4% of acceptable product with the stone in, compared to 67.3% with the stone out.

[1] An avocado saver is a plastic gadget designed to protect cut avocado halves. The pit is aligned over an indentation, and then the avocado secured with tan adjustable rubber strap, which creates a tight seal against the plastic base.

[2] Honeywrap is made with 100% organic cotton blended with beeswax, tree resin and jojoba oil and is a waste free alternative to cling film.

For zero waste advocates, using a reusable container, avocado saver or Honeywrap to store an avocado would be the most effective methods to preserve quality.

Results

Seventeen storage methods were trialled for avocado halves. Each method was trialled in triplicate. The trial period lasted 8 days.[3]

Table 1 Methods for avocado experiments

Method no.	Description of method	Preparation of sample
1	Control – unwrapped (stone out)	Cut avocado with stone removed, placed directly in fridge.
2	Wrapped in cling wrap (stone in)	Cut avocado with stone in, wrapped tightly in cling wrap and pressed against flesh to form a tight seal. Placed in fridge.
3	Wrapped in Honeywrap (stone in)	Cut avocado with stone in wrapped tightly in a Honeywrap to cover entire fleshy surface. Placed in fridge.
4	Unwrapped (stone in)	Cut avocado with stone left in, placed directly in fridge.
5	Lemon juice (stone out)	Cut avocado, stone removed. Spray flesh with approximately 1/2 teaspoon of lemon juice and place in fridge.
6	Lemon juice (stone in)	Cut avocado, stone left in. Spray flesh with approximately 1/2 teaspoon of lemon juice and place in fridge.
7	Lemon juice – wrapped in cling wrap (stone in)	Cut avocado, stone left in. Spray flesh with approximately 1/2 teaspoon of lemon juice, wrapped tightly with cling wrap to form a seal on flesh and place in fridge.
8	Lemon juice –wrapped in Honeywrap (stone in)	Cut avocado, stone left in. Spray flesh with approximately 1/2 teaspoon of lemon juice, wrapped tightly with a Honeywrap and place in fridge.
9	Lemon juice –wrapped in wax paper (stone out)	Cut avocado, stone left in. Spray flesh with approximately 1/2 teaspoon of lemon juice, place a square of wax paper on fleshy surface and press down lightly to form a seal, place in fridge.
10	Olive oil (stone in)	Cut avocado, stone left in. Rub flesh with a thin film of olive oil, place in fridge.
11	Olive oil (stone out)	Cut avocado, stone removed. Rub flesh with a thin film of olive oil, place in fridge.

[3] Note trial periods were not predetermined. Trials were continued until all methids apart from 1 received a rating of 0/5.

12	Olive oil wrapped in honey wrap (stone in)	Cut avocado, stone left in. Rub flesh with a thin film of olive oil, wrapped tightly with Honeywrap and place in fridge.
13	Olive oil wrapped in wax paper (stone out)	Cut avocado, stone removed. Rub flesh with a thin film of olive oil, place a square of wax paper on flesh and press to form a seal, place in fridge.
14	Avocado saver (stone in)	Cut avocado, leave stone in. Place flesh down in the avocado saver, fasten rubber strap and place in fridge.
15	In a container with cut onion (stone in)	Cut avocado, leave stone in. Place in an airtight container with a wedge of cut onion. Seal container with lid and place in fridge.
16	In a container, no onion (stone in)	Cut avocado, leave stone in. Place in an airtight container. Seal container with lid and place in fridge.
17	Olive oil – wrapped in cling wrap (stone in)	Cut avocado, stone left in. Rub flesh with a thin film of olive oil, wrapped tightly with cling wrap to form a seal on flesh and place in fridge.

All samples were stored in a refrigerator with the temperature set at 4°C. Two measures were used to determine which storage method was most effective, weight and visual assessment of physical quality. Each sample was removed from the fridge daily, unwrapped and sample 'A' for each method was photographed. All products were weighed using scales to monitor moisture loss or gain. Visual assessment was carried out using the physical appearance scale to assess the physical quality of each sample. Observations were recorded and then entered into Microsoft Excel. At the end of the 8-day trial period the amount of acceptable flesh was also weighed, and recorded.

Overall the three most successful methods of preserving the quality of cut avocado were:

- Method 2 - Cling wrap
- Method 15 - Container with a cut onion
- Method 16 - Container with no onion

The trial period lasted for 8 days. At the end of the trial any discoloured and inedible avocado was discarded and any avocado remaining was weighed. Due to health and safety issues the avocado flesh was not tasted.

Percentage of acceptable product

Table 2 Methods which maintained the greatest percentage of acceptable product at end of the trial period, compared to the control (1) and the most detrimental method (5)

Top 5 methods	%acceptable product
(2) Wrapped in cling wrap (stone in)	97.5
(15) In a container with cut onion (stone in)	94.8
(16) In glad container no onion (stone in)	93.1
(3) Wrapped in Honeywrap (stone in)	92.7
(14) Avocado saver (stone in)	92.2
(1) Control – In fridge (stone out)	77.3
(5) Lemon juice (stone out)	40.3

Method 2 had the greatest percentage of acceptable product remaining, closely followed by methods 15, 16, 3 and 14.

Figure 3 depicts photos taken of 'Sample A' of the five methods that obtained the greatest percentage of acceptable product at the end of the trial period. Photos were taken at the beginning and end of the trial period. Visually, method 2 (cling wrap) appears to be in the best condition at the end of the trial period.

Visual Observations

The physical appearance scale used in the present study was modified from the Waste and Resources Action Programme's (WRAP)[4] scale for visually assessing quality. Their scale awarded an acceptable product 'A' and a not acceptable product 'NA'. In the present study, this scale was adapted to form a 5 point system to define physical acceptability. Using a five-point scale allows for increased detail to be provided.

Point on scale	Characteristics of point on the scale
0	Not acceptable product – Complete/near complete browning across the entire product, alterations to texture (i.e. dryness or sliminess)
1	Not acceptable product – Extensive browning, alterations to texture apparent
2	Just acceptable product- Advanced browning and alterations to texture, however some chance of salvaging part of the product
3	Acceptable – Discolouration and changes to texture present- some useable portion of product remaining
4	Acceptable – Product in very good condition. Minor discolouration and changes to texture. Majority of the product can still be used.
5	Acceptable – Perfect condition, close to original product state. Green appearance still prominent and no major alterations to texture

Figure 1 Physical Appearance Scale - Avocado

[4] D. Johnson, N. Hipps, and S. Hails, "Helping consumers reduce fruit and vegetable waste: Final report," Waste and Resources Action Programme (WRAP), U.K., Tech. Rep., 2008.

According to the physical appearance scale used to code visual observations in **Appendix 1**, method 2 (cling wrap) and 15 (in an air tight container with a piece of cut onion) were the most successful at protecting the quality of the avocado with a final rating on the physical appearance scale of 4/5. This was followed by methods 16 (air tight container no onion) and 14 (avocado saver) with a final score of 3/5. Fifth place according to visual assessment was method 3 (Honeywrap) with a final rating of 2/5.

Weight Measurements

Appendix 2 includes the weight measurements taken throughout the trial period for each sample. Weight gain over the trial period appeared to be detrimental to the physical appearance of the avocado. Samples 7 (Lemon juice – wrapped in cling wrap - stone in) and 17 (Olive oil – wrapped in cling wrap - stone in) experienced weight gain over the trial period. They were both awarded 0/5 on the visual scale at the end of the trial period. Both samples went mushy and condensation may have added to weight gain.

Those that experienced the smallest amount of weight loss, methods 2, 16 and 15, also performed the best with visual assessment as well as having the highest percentages of acceptable product at the end of the trial.

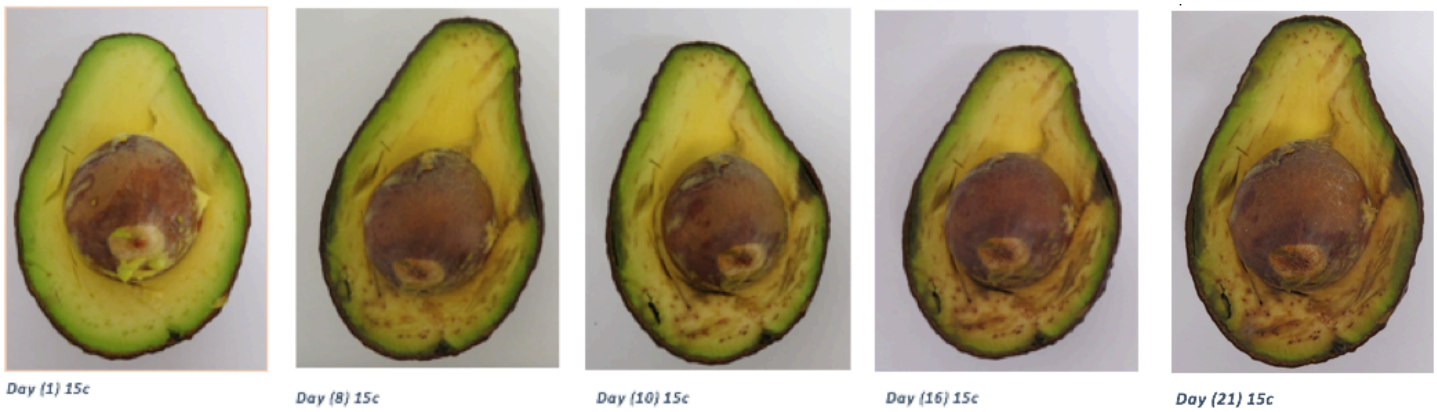


Figure 2 Sample 15c (stored in a container with a piece of cut onion)

Of the 47 samples tested, sample 15C (method 15 – in an air tight container with a piece of cut onion) was the most effective individual sample overall (depicted above). It remained edible up to 21 days. However, samples 15A and 15B had a shelf life of only 8 days, so it may well be that sample C was an anomaly. It is important to note that this study did not assess the alteration in taste of the product due to storage with onion.

Conclusion

Wrapping an avocado in cling wrap was the most successful method to preserve a cut avocado.

Other effective methods were:

- In an airtight container

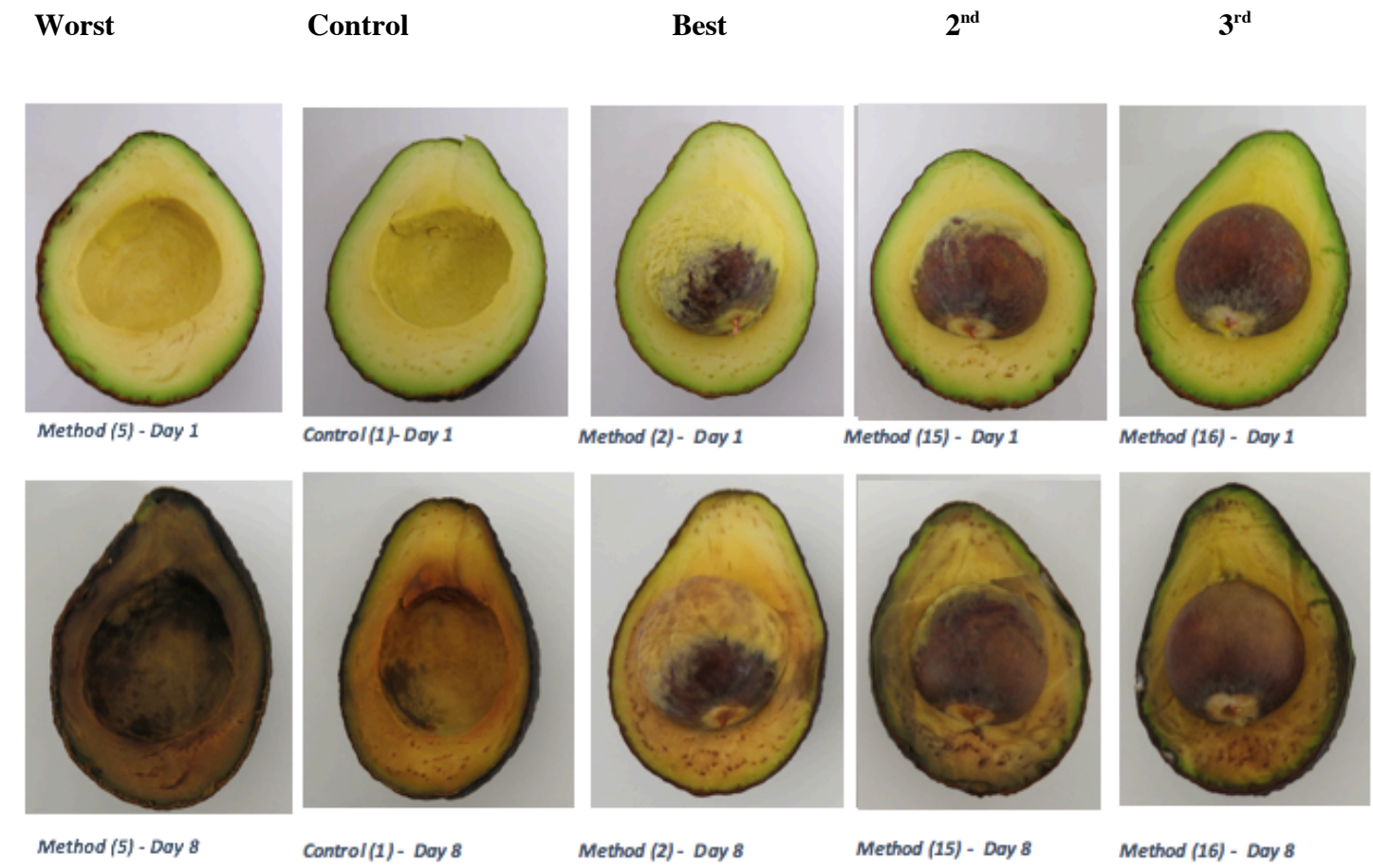
- In an airtight container with cut onion
- Using an avocado saver
- Wrapping in a Honeywrap

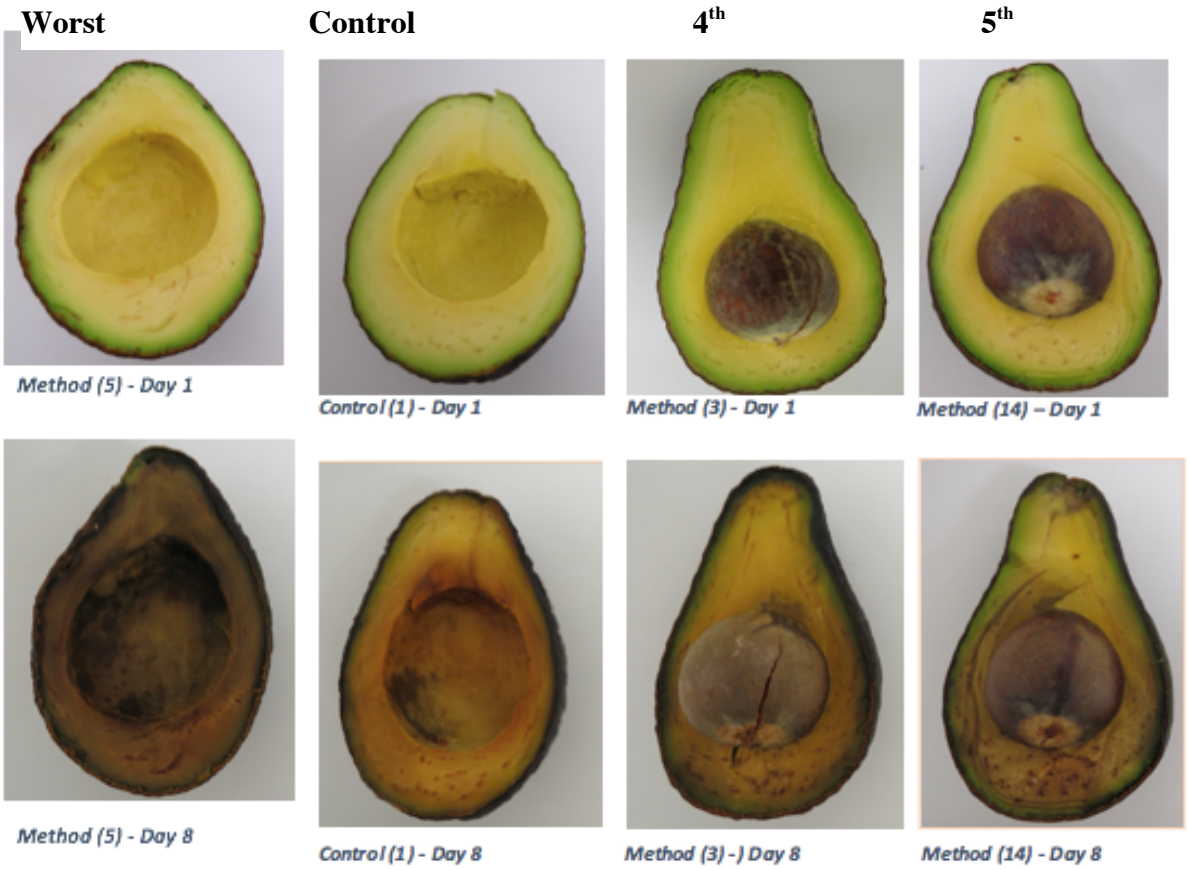
Two commonly used methods proved to be detrimental to the avocado i.e. they performed worse than leaving the control – an unwrapped avocado with the stone out.

- Lemon juice
- Olive oil

For zero waste advocates, using a reusable container, avocado saver or Honeywrap to store an avocado would be the most effective methods to preserve quality.

Figure 3 –Day 1 and Day 8 of the trial period comparing the five best methods (2,15,16,3,14) with the control (1) and worst method (5).





Carrots

Nine storage methods for carrots were trialled. Storage methods included:

- Unwrapped in fridge (control)
- Unwrapped in crisper
- In a plastic bag
- In a perforated bag
- Stored in airtight container

Quality was defined using a scale of 0 to 5 of physical appearance. Physical appearance in this setting refers to discolouration and the observable texture of the carrot as the main determinants of quality. 0 out of 5 was the rating given to products with a completely unacceptable physical appearance, including extensive changes to texture (i.e. discoloured, bendy and dry). 5/5 refers to a product that was deemed to be in perfect condition in terms of physical appearance: bright orange colour, firm texture, not bendy at all and not dry.

Placing carrots in an airtight container lined with a paper towel was the most successful method to preserve the quality of carrots and resulted in an acceptable visual appearance for up to four weeks. Storing carrots in this way could maintain an acceptable quality for up to 10 times longer than the control.

Other effective methods were:

- Storing in an air tight container filled with water
- Wrapped in paper towels and sealed in a Snaplock bag

Methods which resulted in the poorest preservation of carrots:

- Unwrapped in fridge (control)
- In a perforated bag in the fridge

For zero waste advocates using an airtight container lined with a tea towel or reusable cloth would have a similar affect to paper towels.

Results

Nine storage methods were trialled for carrots. Each method was trialled three times. The trial period was 29 days.

Table 3 Methods used for carrot experiments

Method no.	Description of method	Preparation of sample
1	Control – Unwrapped in fridge	Place directly in fridge.
2	Wrapped in a plastic bag, in fridge	Place the carrot in a plastic bag, spin open end of the bag around to seal and place in fridge.
3	In an airtight container filled with water	Fill a container ¾ full with cold tap water. Submerge the carrot in the water and seal the lid.
4	In an airtight container lined with a paper towel	Line an airtight container with a paper towel, place carrot inside and seal the lid.
5	Wrapped in a paper towel and then place in a Snaplock bag, in fridge	Take a paper towel, wrap the entire carrot in the length of paper towel. Place this in a Snaplock bag and seal, squeeze out excess air.
6	Unwrapped in the crisper drawer	Place directly in the crisper drawer, unwrapped.
7	Wrapped in plastic bag, in the crisper drawer	Place the carrot in a plastic bag, spin open end of the bag around to seal and place in crisper drawer.
8	Placed in a perforated bag in the fridge	Place the carrot in perforated bag, twist end to seal and place in fridge.
9	Placed in a perforated bag, in crisper drawer	Place the carrot in perforated bag, twist end to seal and place in crisper drawer.

All samples were stored in a refrigerator with the temperature set at 4°C. Two measures were used to determine which storage method was most effective: weight and visual assessment of physical quality. Each sample was removed from the fridge every four days, unwrapped and sample 'A' for each method was photographed. All products were weighed using scales to monitor moisture loss or gain. Visual assessment was carried out using the physical appearance scale to assess the physical quality of each sample. Observations were recorded and then entered into Microsoft Excel.

Overall the most successful method of preserving the quality of carrots was:

- Method 4 – In an air tight container lined with a paper towel

Visual Observations

The physical appearance scale used in the present study was modified from the Waste and Resources Action Programme's (WRAP)[5] scale for visually assessing quality. Their scale awarded an acceptable product 'A' and a not acceptable product 'NA'. In the present study, this scale was adapted to form a 5 point system to define physical acceptability. Using a five-point scale allows for increased detail to be provided.

Point on scale	Characteristics of point on the scale
0	Not acceptable product – Extensive alterations to texture (i.e. bendy, dry and discoloured)
1	Not Acceptable product – Advanced alterations to texture apparent
2	Just acceptable product - Alterations to texture, however some chance of salvaging part of the product
3	Acceptable – Changes to texture present- some useable portion of product remaining
4	Acceptable – Product in very good condition, minor changes to texture, majority of the product can still be used.
5	Acceptable – Perfect condition, close to original product state. No major alterations to texture (i.e. crisp and dewy).

Figure 4 Physical Appearance Scale - Carrot

According to the physical appearance scale used to code visual observations in **Appendix 3**, Method 4 (in an air tight container lined with a paper towel) was the most successful at preserving the quality of carrots with a final rating on the physical appearance scale of 5/5. This was closely followed by Method 3 (in an airtight container filled with water) and Method 5 (wrapped in a paper towel, placed in Snaplock bag) which scored 4.5/5 at the end of the trial period. Methods 1 (unwrapped) and 8 (in a perforated bag) were awarded 0/5 at the end of the trial period, as they were bendy, dry and discoloured.

Weight Measurements

Appendix 4 includes the weight measurements taken throughout the trial period for each sample. Larger amounts of weight loss were detrimental to the texture of the carrots. Method 1 (unwrapped) experienced an average weight loss of 79.5g over the trial period, and this method resulted in the most visually deteriorated sample. Method 8 (in a perforated bag) experienced the second greatest amount of weight loss of all the samples, with an average of 16.8g weight loss over the course of the trial. Method 3 (in an airtight container with water) resulted in 2.2g of weight gain over the trial period, as the carrots were in a completely saturated environment, with 100 % humidity. The remaining samples experience weight loss between 0.5 and 7.4g across the trial period, and were all awarded visual appearance scores between 3.5/5 and 5/5. From this it was concluded that minimising the weight lost (i.e. moisture loss) of carrots, and the condensation on the surface of the carrot, during storage

[5] D. Johnson, N. Hipps, and S. Hails, "Helping consumers reduce fruit and vegetable waste: Final report," Waste and Resources Action Programme (WRAP), U.K., Tech. Rep., 2008

will result in increased shelf life of the carrots and a higher quality product for a longer period of time.

Conclusion

Placing carrots in an airtight container lined with paper was the most successful method for preserving quality. Using this method resulted in the carrots remaining at an acceptable standard for up to four weeks.

Other effective methods were:

- Storing in an airtight container filled with water,
- Wrapped in paper towels and sealed in a Snaplock bag

Methods which resulted in the poorest preservation of carrots were:

- Unwrapped in fridge (control)
- In a perforated bag in the fridge

For zero waste advocates, line a re-useable container with a small tea towel/ reusable towel.

Figure 5 – Day 1 and Day 29 for the best method (Method 4) and the control/worst method (Method 1).

Worst Method **Best Method**

Method 1 (unwrapped in fridge) - Day 1

Method 4 (In a container lined with paper towel, in fridge) - Day 1

Method 1 (unwrapped in fridge) - Day 29

Method 4 (in container lined with paper towel, in fridge) - Day 29

Celery

Six storage methods for celery were trialled. Storage methods included:

- Unwrapped in fridge (control)
- In a plastic bag
- Wrapped in tinfoil
- Standing in a container of water
- Stored in an airtight container

For five of the six methods tested the celery was whole (i.e. attached to the base). For one method (stored in an airtight container), the celery was chopped into sticks, with the base of the celery discarded.

Quality was defined using a scale of 0 to 5 of physical appearance. Physical appearance in this setting refers to visible deterioration and the observable texture of the celery as the main determinants of quality. 0 out of 5 was the rating given to products with a completely unacceptable physical appearance, including extensive changes to texture (i.e. discoloured, bendy and dry). 5/5 refers to a product that was deemed to be in perfect condition in terms of physical appearance: bright green colour, firm texture, not bendy at all and not dry.

The most successful method of maintaining the quality of the whole celery was wrapping the base of the celery in a paper towel and refrigerating in a Snaplock bag.

Placing chopped celery in an airtight container lined with a paper towel was the most successful method overall to preserve the quality of the green celery stalks. Storing celery in this way could maintain an acceptable quality for up to 5 days longer than the control. However, this method could discourage people from eating celery hearts and the whiter parts of the stalk.

Other effective methods were:

- Storing in tinfoil in the fridge
- Storing in a plastic bag in fridge

Methods which resulted in the poorest preservation of celery were:

- Unwrapped in fridge (control)
- Standing in a glass of water in the fridge

For zero waste advocates using a reusable container with a cloth/ tea towel would be the most effective storage solution.

Results

Six storage methods were trialled for celery. Each method was trialled three times. For five of the six methods tested the celery was whole (i.e. stalks attached to the base). For one method (stored in an airtight container), the celery was sliced into sticks with the base discarded. The trial period was 24 days.

Table 4 Methods used for celery experiments

Method no.	Description of method	Preparation of sample
1	Control – Unwrapped, in fridge	Place directly in fridge
2	Wrapped in a plastic bag, in fridge	Place the celery in a plastic bag, spin open end of the bag around to seal and place in fridge.
3	Standing in a container full of water in the fridge	Fill a tall container with 2-3cm cold tap water. Stand the celery in the water and place in fridge.
4	Root end wrapped in a paper towel and then place in a Snaplock bag, in fridge	Wrap the root end of the celery in the paper towel. Place this in a Snaplock bag and seal, squeeze out excess air.
5	In an airtight container lined with a paper towel	Cut off base and celery heart. Line an airtight container with a paper towel, place celery stalks inside and seal the lid.
6	Wrapped in tinfoil	Wrap the entire stem and base in tinfoil so that there is no exposed surface.

All samples were stored in a refrigerator with the temperature set at 4°C. Two measures were used to determine which storage method was most effective; weight and visual assessment of physical quality. Each sample was removed from the fridge every four days, unwrapped and sample 'A' for each method was photographed. All products were weighed using scales to monitor moisture loss or gain. Visual assessment was carried out using the physical appearance scale to assess the physical quality of each sample. Observations were recorded and then entered into Microsoft Excel.

Overall the most successful method of preserving the quality of green celery stalks was:

Method 5 – In an airtight container lined with a paper towel

Overall the most successful method of preserving the quality of celery with heart intact was

Method 4 - Root end wrapped in a paper towel and then place in a Snaplock bag, in fridge

Visual Observations

The physical appearance scale used in the present study was modified from the Waste and Resources Action Programme's (WRAP)[6] scale for visually assessing quality. Their scale awarded an acceptable product 'A' and a not acceptable product 'NA'. In the present study, this scale was adapted to form a 5 point system to define physical acceptability. Using a five-point scale allows for increased detail to be provided.

Point on scale	Characteristics of point on the scale
0	Not acceptable product – Extensive alterations to texture (i.e. bendy, dry and discoloured, parts disintegrating)
1	Not acceptable product – Advanced alterations to texture apparent
2	Just acceptable product Alterations to texture, however some chance of salvaging part of the product
3	Acceptable – Changes to texture present, some useable portion of product remaining
4	Acceptable – Product in very good condition. Minor changes to texture. Majority of the product can still be used.
5	Acceptable – Perfect condition, close to original product state. No major alterations to texture (i.e. crisp and dewy).

Figure 6 Physical Appearance Scale - Celery

According to the physical appearance scale used to code visual observations in **Appendix 5**, Method 5 (in an air tight container lined with a paper towel) was the most successful at protecting the quality of celery with a final rating on the physical appearance scale of 4/5. This was followed by Method 4 (wrapped in a paper towel, placed in Snaplock bag) which scored 3.5/5 at the end of the 24-day trial period. Methods 1 (unwrapped in fridge) and 3 (standing in a container full of water) were awarded 0/5 at the end of the trial period, as they were bendy, dry and discoloured. Method 3 also experienced major disintegration of the celery stems.

Weight Measurements

Appendix 6 includes the weight measurements taken throughout the trial period for each sample. Larger amounts of weight loss were detrimental to the texture of the celery. Method 1 (unwrapped in fridge) experienced an average weight loss of 61.4g over the trial period, and this method resulted in the most visually deteriorated sample. One stem completely disintegrated in Sample A of Method 3 (standing the celery in a jar of water) which resulted in the second greatest amount of weight loss of all the samples, 46.3g weight loss over the course of the trial. Method 5 (in an airtight container lined with a paper towel) which was the most successful method in terms of visual appearance also experienced the least weight loss

[6] D. Johnson, N. Hipps, and S. Hails, "Helping consumers reduce fruit and vegetable waste: Final report," Waste and Resources Action Programme (WRAP), U.K., Tech. Rep., 2008

over the trial period with an average weight loss of 0.9g. As weight loss increases, visual appearance score decreases. From this it can be concluded that minimising the weight lost (i.e moisture loss) and condensation around the celery during storage will result in increased shelf life and a higher quality product for a longer period of time. However, excess water absorption i.e. standing the celery in a jar of water, is detrimental to the quality of the product. Excess water causes the cells within the celery to swell and become turgid. Overtime excess water may accelerate the breakdown of connections between cells.

Conclusion

Placing celery in an airtight container lined with paper was the most successful method for preserving the quality of celery. Using this method resulted in the celery remaining at an acceptable standard for up to 24 days. The most successful method of maintaining the quality of the celery with the core left in was wrapping the core in a paper towel and refrigerating in a Snaplock bag.

Other effective methods were:

- Storing in tinfoil in the fridge
- Storing in a plastic bag in fridge

Methods which resulted in the poorest preservation of celery were:

- Unwrapped in fridge (control)
- Standing in a glass of water in the fridge.

For zero waste advocates using a reusable container with a cloth or tea towel would be the most effective storage solution.

Figure 7 – Day 1 and Day 24 for the control (Method 1), the least effective method (Method 3) and the most effective method (Method 5).

Control **Worst** **Best**

Method 1 (unwrapped in fridge) - Day 1

Method 3 (standing in jar of water in fridge) - Day 1

Method 4 (airtight container in fridge) - Day 1

Method 1 (unwrapped in fridge) - Day 24

Method 3 (standing in jar of water in fridge) - Day 24

Method 4 (airtight container in fridge) - Day 24

Iceberg Lettuce

Six storage methods for iceberg lettuce were trialled. Storage methods included:

- Unwrapped in fridge (control)
- Unwrapped in crisper drawer
- In a plastic bag
- In a perforated bag
- Wrapped in a paper towel and then in a Snaplock bag
- In a lettuce crisper (an airtight plastic container which has a small tray in the bottom to elevate the lettuce)

Quality was defined using a scale of 0 to 5 of physical appearance. Physical appearance in this setting refers to the observable texture of the lettuce as the main determinant of quality. 0 out of 5 was the rating given to products with a completely unacceptable physical appearance, including extensive deterioration of leaves, changes to texture (i.e. wilting, slimy appearance). 5/5 refers to a product that was deemed to be in perfect condition in terms of physical appearance: crisp leaves, not dry or wilted.

Wrapping lettuce in a paper towel then placing it in a Snaplock bag, and also using a lettuce crisper were the most successful methods to preserve the quality of iceberg lettuce and resulted in an acceptable visual appearance for up to four weeks. Storing lettuce in this way could maintain an acceptable quality for up to 4.5 times longer than the storing it unwrapped in the fridge.

Other effective methods were:

- Storing in a plastic bag in the fridge
- Storing in the crisper drawer

Methods which resulted in the poorest preservation of lettuce were:

- Unwrapped in fridge (control)
- In a perforated bag in the fridge

Results

Six storage methods were trialled for iceberg lettuce. Each method was trialled three times. The trial period was 28 days.

Table 5 Methods used for iceberg lettuce experiments

Method no.	Description of method	Preparation of sample
1	Control – unwrapped in fridge	Place directly in fridge.
2	Placed unwrapped in the crisper drawer	Placed directly in the crisper drawer of the fridge.
3	Wrapped in a plastic bag, in fridge	Place the lettuce in a plastic bag, twist end to seal and place in fridge.
4	Wrapped in paper towels and then place in a Snaplock bag, in fridge	Take three paper towels, still joined together. Roll the entire lettuce in the length of paper towels, and press around the lettuce. Place this in a Snaplock bag and seal, squeeze out excess air.
5	In lettuce crisper, in fridge	Place the entire lettuce in a lettuce crisper (container), seal lid and place in fridge.
6	Placed in a perforated bag in the fridge	Place lettuce in perforated bag, twist end to seal and place in fridge.

All samples were stored in a refrigerator with the temperature set at 4°C. Two measures were used to determine which storage method was most effective; weight and visual assessment of physical quality. Each sample was removed from the fridge every two days, unwrapped and sample 'A' for each method was photographed. All products were also weighed using scales to monitor moisture loss or gain. Visual assessment was carried out using the physical appearance scale to assess the physical quality of each sample. Observations were recorded and then entered into Microsoft Excel.

Overall the two most successful methods of preserving the quality of lettuce were methods:

- Method 4 – Wrapped in paper towels, placed in Snaplock bag, placed in fridge
- Method 5 – In a lettuce crisper, placed in fridge.

Percentage of acceptable product

Table 6 Methods which maintained the greatest percentage of acceptable product at end of the 28 day trial period, compared to the control/least wffective storage method (1)

Top 5 methods	%acceptable product
(5) In lettuce crisper	79.0
(4) Wrapped in paper towels, in Snaplock bag	78.3
(3) In a plastic bag	69.1
(2) In vegetable crisper drawer	69.1
(6) In a perforated bag	41.3
(1) Unwrapped in fridge	28.4

At the end of the trial the spoiled leaves were removed from the lettuce and the amount of acceptable product remaining was weighed. This was then taken as a percentage of the weight of the product. After 28 days of storage, Methods 5 and 4 had the greatest percentage of acceptable product remaining.

Visual Observations

The physical appearance scale used in the present study was modified from the Waste and Resources Action Programme's (WRAP)[7] scale for visually assessing quality. Their scale awarded an acceptable product 'A' and a not acceptable product 'NA'. In the present study, this scale was adapted to form a 5 point system to define physical acceptability. Using a five-point scale allows for increased detail to be provided.

Point on scale	Characteristics of point on the scale
0	Not acceptable product – Extensive alterations to texture (i.e. dryness or sliminess)
1	Not acceptable product – Advanced alterations to texture apparent
2	Just acceptable product - Alterations to texture, however some chance of salvaging part of the product
3	Acceptable – Changes to texture present- some useable portion of product remaining
4	Acceptable – Product in very good condition. Minor changes to texture. Majority of the product can still be used.
5	Acceptable – Perfect condition, close to original product state. No major alterations to texture.

Figure 8 Physical Appearance Scale - Lettuce

[7] D. Johnson, N. Hipps, and S. Hails, "Helping consumers reduce fruit and vegetable waste: Final report," Waste and Resources Action Programme (WRAP), U.K., Tech. Rep., 2008

According to the physical appearance scale used to code visual observations in **Appendix 7**, Methods 4 (wrapped in paper towels, placed in Snaplock bag) and 5 (in lettuce crisper) were the most successful at protecting the quality of the lettuce with a final rating on the physical appearance scale of 4/5. This was followed by Method 3 (wrapped in a plastic bag) which scored 3/5 and Method 2 (unwrapped in crisper drawer) scoring 2.5/5. Methods 1 and 6 were awarded 0/5 and 1/5 respectively, at the end of the 28 day trial period, as they were completely dry and wilted.

Weight Measurements

Appendix 8 includes the weight measurements taken throughout the trial period for each sample. Larger amounts of weight loss appeared to be detrimental to the texture of the lettuce. Method 1 (unwrapped in fridge) experienced an average weight loss of 81.6g over the trial period and was awarded 0/5 on the visual scale at the end of the trial period.

Smaller amounts of weight loss were associated with the best preserved lettuce e.g. Methods 4 (unwrapped in paper towels, placed in Snaplock bag) and 5 (in a lettuce crisper) experienced 4.5 g weight loss over the trial period. Overall, the least amount of weight lost over the trial period, the better the condition of the lettuce. From this we can conclude that minimising the weight lost by iceberg lettuce i.e. moisture loss during storage, will result in increased shelf life of the lettuce and a higher quality product for a longer period of time.

Conclusion

Wrapping lettuce in paper towels and placing it in a Snaplock bag in the fridge, or storing lettuce in a lettuce crisper, were the most successful methods for preserving the quality of iceberg lettuce. Using these methods resulted in the lettuce remaining an acceptable standard for up to four weeks.

Other effective methods were:

- Storing in a plastic bag in the fridge
- Storing in the crisper drawer

Methods which resulted in the poorest preservation of lettuce were:

- Unwrapped in fridge (control)
- In a perforated bag in the fridge

Figure 9 – Day 1 and Day 28 for the two methods that produced the greatest percentage of acceptable material (Method 4 and 5) and the control (Method 1).

Worst/Control **Best**

Method 1 (unwrapped in fridge) - Day 1

Method 4 (wrapped in paper towel, in Snaplock bag, in fridge) - Day 1

Method 5 (in lettuce saver in fridge) -Day 1

Method 1 (unwrapped in fridge) - Day 28

Method 4 (wrapped in paper towel, in Snaplock bag, in fridge) - Day 28

Method 5 (in lettuce saver, in fridge) - Day 28

Broccoli

Seven storage methods for broccoli were trialled. Storage methods included:

- Unwrapped in fridge (control)
- Unwrapped in crisper
- In a plastic bag in fridge
- In a plastic bag in crisper
- In a perforated bag in fridge
- Broccoli head sprayed with water, wrapped in paper towels and then put in a Snaplock bag in fridge
- Wrapped tightly in cling wrap in fridge

Quality was defined using a scale of 0 to 5 of physical appearance. Physical appearance in this setting refers to visible deterioration and the observable texture of the broccoli as the main determinants of quality. 0 out of 5 was the rating given to products with a completely unacceptable physical appearance, including extensive changes to texture (i.e. wilting, florets loosening and flowering). 5/5 refers to a product that was deemed to be in perfect condition in terms of physical appearance e.g. with tight florets and a firm stalk.

Spraying the broccoli head with water, then wrapping it in a paper towel and placing it in a Snaplock bag in the fridge, was the most successful method to preserve the quality of broccoli and resulted in an acceptable visual appearance for up to four weeks. Storing broccoli in this way could maintain an acceptable quality for up to 2.5 times longer than the control.

Other effective methods were:

- Storing in a plastic bag in the fridge
- Storing in a plastic bag in the crisper drawer
- Unwrapped in the crisper drawer

Methods which resulted in the poorest preservation of broccoli were:

- Unwrapped in fridge (control)
- Wrapping in cling wrap, in fridge
- Storing in a perforated bag, in fridge

Zero waste recommendation to preserve broccoli: wrap the head of broccoli in a damp tea towel and store in a cloth bag in the fridge

Results

Seven storage methods were trialled for broccoli. Each method was trialled three times. The trial period was 28 days.

Table 7 Methods used for broccoli experiments

Method no.	Description of method	Preparation of sample
1	Control – unwrapped in fridge	Place directly in fridge
2	Wrapped in a plastic bag, in fridge	Place the broccoli in a plastic bag, twist end to seal and place in fridge.
3	Wrapped in a plastic bag, in the crisper drawer	Wrapped in a plastic bag, twist end to seal, and placed in the crisper drawer of the fridge.
4	Placed in a perforated bag in the fridge	Place broccoli in perforated bag, twist end to seal and place in fridge.
5	Head sprayed with water, wrapped in paper towels and then placed in a Snaplock bag, in fridge	Run the broccoli under the tap then shake to remove excess water. Take three paper towels, still joined together. Roll the entire broccoli in the length of paper towels, and press around the head. Place this in a Snaplock bag and seal, squeeze out excess air.
6	Wrapped in cling wrap, in fridge	Wrap entire broccoli tightly in cling wrap, completely sealing the vegetable. Place in the fridge.
7	Unwrapped in the crisper drawer	Place directly in the crisper drawer, unwrapped.

All samples were stored in a refrigerator with the temperature set at 4°C. Two measures were used to determine which storage method was most effective; weight and visual assessment of physical quality. Each sample was removed from the fridge every two days, unwrapped and sample 'A' for each method was photographed. All products were weighed using scales to monitor moisture loss or gain. Visual assessment was carried out using the physical appearance scale to assess the physical quality of each sample. Observations were recorded and then entered into Microsoft Excel.

Overall the most successful method of preserving the quality of broccoli was:

- Method 5 – Sprayed with water, wrapped in paper towels, placed in Snaplock bag, in fridge
-

Visual Observations

The physical appearance scale used in the present study was modified from the Waste and Resources Action Programme's (WRAP)[8] scale for visually assessing quality. Their scale awarded an acceptable product 'A' and a not acceptable product 'NA'. In the present study, this scale was adapted to form a 5 point system to define physical acceptability. Using a five-point scale allows for increased detail to be provided.

Point on scale	Characteristics of point on the scale
0	Not acceptable product – Extensive alterations to texture (i.e. buds ope, florets loose and stalk bendy)
1	Not Acceptable product – Advanced alterations to texture apparent
2	Just acceptable product - Alterations to texture, however some chance of salvaging part of the product
3	Acceptable – Changes to texture present- some useable portion of product remaining
4	Acceptable – Product in very good condition. Minor changes to texture. Majority of the product can still be used.
5	Acceptable – Perfect condition, close to original product state. No major alterations to texture.

Figure 10 Physical Appearance Scale – Broccoli

According to the physical appearance scale used to code visual observations in **Appendix 9**, Method 5 (sprayed with water, wrapped in paper towels, placed in Snaplock bag) was the most successful at protecting the quality of the broccoli with a final rating on the physical appearance scale of 4.5/5. This was closely followed by Methods 2 (wrapped in a plastic bag, in fridge) and 3 (wrapped in a plastic bag, in crisper drawer) which both scored 4/5 at the end of the 28-day trial period. Methods 1 (unwrapped in fridge), 4 (in a perforated bag) and 6 (wrapped in cling wrap) were awarded 0/5, 2/5 and 2/5 respectively, at the end of the trial period, as they were bendy and florets were loose.

Weight Measurements

Appendix 10 includes the weight measurements taken throughout the trial period for each sample. Larger amounts of weight loss appeared to be detrimental to the texture of the broccoli. Method 1 (unwrapped in fridge) experienced an average weight loss of 160.4g over the trial period.

Smaller amounts of weight loss were associated with the best preserved broccoli e.g. Method 5 (head sprayed with water, wrapped in paper towels and then placed in a Snaplock bag, in fridge) experienced 0.2g weight loss over the trial period. Methods 2 (in a plastic bag, in fridge) and 3 (in a plastic bag, in the crisper drawer) experienced 10.5g and 3.2g weight loss respectively. Overall, the least amount of weight lost over the trial period, the better the condition of the broccoli. From this we can conclude that minimising the weight lost (i.e.

[8] D. Johnson, N. Hipps, and S. Hails, "Helping consumers reduce fruit and vegetable waste: Final report," Waste and Resources Action Programme (WRAP), U.K., Tech. Rep., 2008

moisture loss) of broccoli during storage will result in increased shelf life of the broccoli and a higher quality product for a longer period of time.

Conclusion

Spraying the broccoli head with water, then wrapping it in paper towels and placing it in a Snaplock bag in the fridge was the most successful method for preserving the quality of broccoli. Using this method resulted in the broccoli remaining at an acceptable standard for up to four weeks.

Other effective methods were:

- Storing in a plastic bag in the fridge
- Storing in a plastic bag in the crisper drawer
- Unwrapped in the crisper drawer

Methods which resulted in the poorest preservation of broccoli were:

- Unwrapped in fridge (control)
- Wrapping in cling wrap, in fridge
- Storing in a perforated bag, in fridge

Zero waste recommendation to preserve broccoli: wrap the head of broccoli in a damp tea towel and store in a cloth bag in the fridge.

Figure 11 – Day 1 and Day 28, comparing the best method (Method 5) to the control (Method 1). Note: The photo of the broccoli head for Method 1 is taken at the same angle in the Day 1 photo and the Day 28 photo. The florets have become limp and wilted meaning the stalk is now visible.

Worst/Control **Best**

Method 1 (unwrapped in fridge) - Day 1- Head

Method 1 (unwrapped in fridge) - Day 1- Stalk

Method 5 (wrapped in paper towel, in Snaplock bag, in fridge) - Day 1- Head

Method 5 (wrapped in paper towel, in Snaplock bag, in fridge) - Day 1- Stalk

Method 1 (unwrapped in fridge) - Day 28- Head

Method 1 (unwrapped in fridge) - Day 28 - Stalk

Method 5 (wrapped in paper towel, in Snaplock bag, in fridge) - Day 28- Head

Method 5 (wrapped in paper towel, in Snaplock bag, in fridge) - Day 28- Stalk

Pumpkin

Six storage methods for cut pumpkin were trialled, each method was trialled with the seeds in and the seeds removed. Storage methods included:

- Wrapped in cling wrap
- In a plastic bags
- Wrapped in a Honeywrap
- Wrapped using Glad Press'n Seal [9]

Quality was defined using a scale of 0 to 5 of physical appearance. Physical appearance in this setting refers to visible mould development and observable texture of the flesh as the main determinants of quality. 0 out of 5 was the rating given to products with a completely unacceptable physical appearance, including extensive mould development, changes to texture (i.e. very dry, very slimy). 4/5 refers to a product that was deemed to be in acceptable condition - minor changes to texture and minor appearance of white mould on cut surfaces.[10] Majority of the product can still be used. 5/5 refers to a product that was deemed to be in perfect condition in terms of physical appearance: dewy orange appearance, not dry or slimy and no presence of mould.

Wrapping pumpkin in cling wrap was the most successful method to preserve the quality of a piece of cut pumpkin. This method resulted in a perfect visual appearance for up to nine days and for up to 7 days longer than the control. After this, it developed a thin film of white mould. Mould can be cut away if the surface of the pumpkin remains firm and dry, by removing a clean margin of 1cm from around the mould leaving the remaining pumpkin safe to eat. Wrapping pumpkin in cling wrap significantly slowed the growth of mould compared to all other storage methods tested.

For cling wrap there was no difference in quality between whether the seeds were left in or removed. However, for samples wrapped in plastic bags (Methods 9 and 10) and samples wrapped in Honeywraps (Methods 11 and 12) there were significant differences in quality between samples with seeds left in and seeds removed. In both cases, methods with seeds removed (Method 10 and 12) resulted in 6 days of increased shelf life compared to methods 9 and 11 where seeds were left in.

Methods which resulted in the poorest preservation of cut pumpkin were:

- Left unwrapped in the fridge, with and without seeds (control)
- Sprinkled with black pepper and placed in fridge, with and without seeds
- Placed in a plastic bag, with seeds
- Wrapped in a Honeywrap, with seeds

[9] While other cling wraps cling to the product Glad, Press'n Seal actually seals to the surface

[10] White mould on pumpkin can be safely cut away if the surface of the pumpkin is still firm and dry, leaving the rest of the pumpkin safe to eat.

Zero waste recommendation to preserve pumpkin: Honeywraps can be used to preserve the quality of cut pumpkin. Remove the seeds before wrapping in a large Honeywrap. However, the pumpkin will dry out more quickly using this method compared to cling wrap. Softening of the areas affected by mould also occurred more quickly when using this method compared to cling wrap.

Results

Twelve storage methods were trialled for cut pumpkin. Each method was trialled three times. The trial period was 20 days.

Table 8 Methods for pumpkin experiments

Method no.	Description of method	Preparation of sample
1	Control – unwrapped in fridge (seeds in)	Place piece of pumpkin directly in fridge without removing seeds.
2	Unwrapped in fridge (seeds out)	Remove seeds and place in fridge.
3	Wrapped in cling wrap (seeds in)	Wrap pumpkin tightly in cling wrap to cover entire fleshy surface. Leave seeds in. Place in fridge.
4	Wrapped in cling wrap (seeds out)	Remove seeds. Wrap pumpkin tightly in cling wrap to cover entire fleshy surface. Place in fridge.
5	Sprinkled with black pepper (seeds in)	Sprinkle cracked black pepper onto the fleshy surface of the pumpkin with seeds left in. Place in fridge.
6	Sprinkled with black pepper (seeds out)	Remove seeds, sprinkle cracked black pepper onto the fleshy surface of the pumpkin. Place in fridge.
7	Wrapped in Press and Seal – (seeds in)	Leave seeds in. Wrap pumpkin tightly with Press and Seal, place in fridge.
8	Wrapped in Press and Seal – (seeds out)	Remove seeds. Wrap pumpkin tightly with Press and Seal, place in fridge.
9	Wrapped in plastic bag (seeds in)	Leave seeds in, wrap in plastic bag, fold end of bag under pumpkin, and place in the fridge.
10	Wrapped in plastic bag (seeds out)	Remove seeds, wrap in plastic bag, fold end of bag under pumpkin, and place in the fridge.
11	Wrapped in a Honeywrap (seeds in)	Leave seeds in, wrap tightly in a large Honeywrap and place in the fridge.
12	Wrapped in a Honeywrap (seeds out)	Remove seeds in, wrap tightly in a large Honeywrap and place in the fridge.

All samples were stored in a refrigerator with the temperature set at 4°C. Two measures were used to determine which storage method was most effective; weight and visual assessment of physical quality. Each sample was removed from the fridge every three days, unwrapped and sample 'A' for each method was photographed. All products were weighed using scales to

monitor moisture loss or gain. Visual assessment was carried out using the physical appearance scale to assess the physical quality of each sample. Observations were recorded and then entered into Microsoft Excel.

Overall the two most successful methods of preserving the quality of cut pumpkin were:

- Method 3 – Cling wrap with seeds in
- Method 4 – Cling wrap with seeds removed

Mould

Many types of mould can appear on pumpkin, ranging in colour from white, to blue/green, to black. Consumption of any mould on pumpkin should be avoided. If the pumpkin is still firm the mould can be cut off, removing a clean margin of 1 cm and the remainder of the pumpkin consumed. If the area around the mould is soft or wet this indicates that the mould may have penetrated into the flesh of the pumpkin. It is not safe to consume the pumpkin, regardless of whether the mould has been removed or not.

Visual Observations

The physical appearance scale used in the present study was modified from the Waste and Resources Action Programme's (WRAP)[11] scale for visually assessing quality. Their scale awarded an acceptable product 'A' and a not acceptable product 'NA'. In the present study, this scale was adapted to form a 5 point system to define physical acceptability. Using a five-point scale allows for increased detail to be provided.

Point on scale	Characteristics of point on the scale
0	Not acceptable product –Extensive mould development or alterations to texture (sliminess, wetness, softness or excessive dryness)
1	Not acceptable product – Substantial mould development or alterations to texture apparent (sliminess, wetness, softness or excessive dryness)
2	Just acceptable product – Moderate mould development or alterations to texture.
3	Acceptable – Minor changes to texture, product not wet or soft. Appearance of thin film of white mould on cut surfaces, safe to remove.
4	Acceptable – Product in very good condition. Minor changes to texture and very minor appearance of white mould on cut surfaces. Majority of the product can still be used.
5	Acceptable – Perfect condition, close to original product state. Dewey, orange appearance still prominent and no major alterations to texture

Figure 12 Physical Appearance Scale - Pumpkin

According to the physical appearance scale used to code visual observations in **Appendix 11**, Methods 3 (cling wrap, seeds in) and 4 (cling wrap, seeds out) were the most successful at protecting the quality of the pumpkin with a final rating on the physical appearance scale of 3/5. All other methods were given a final score of 0/5 at the end of the 20 day trial period.

[11] D. Johnson, N. Hipps, and S. Hails, "Helping consumers reduce fruit and vegetable waste: Final report," Waste and Resources Action Programme (WRAP), U.K., Tech. Rep., 2008

Weight Measurements

Appendix 12 includes the weight measurements taken throughout the trial period for each sample. Larger amounts of weight loss appeared to be detrimental to the physical appearance of the pumpkin. Methods 1 (unwrapped, seeds in), 2 (unwrapped, seeds out), 5 (black pepper, seeds in) and 6 (black pepper, seeds out) experienced the largest amounts of weight loss over the trial period. These samples were awarded 0/5 on the visual scale at the end of the trial period as they appeared dry and shrivelled. However, no mould growth occurred.

Those that experienced the smallest amount of weight loss were associated with mould growth. Methods 7, 8, 9, 10, 11 and 12 all experienced extensive mould growth by the end of the trial period. Method 3 (wrapped in cling wrap with seeds) and 4 (wrapped in cling wrap without seeds) experienced the least extensive mould growth and no softening or wetness of flesh. These methods experienced some of the lower amounts of weight loss over the trial period.

Conclusion

Wrapping pumpkin in cling wrap was the most successful method to preserve a cut pumpkin, whether the seeds were removed or not. If wrapped, pumpkin could stay edible for up to 20 days. Provided the texture is still firm, not wet, and mould growth was minor, the mould can be cut off by removing a clean margin of 1cm around mould. A perfect visual appearance was maintained using this method for up to 9 days i.e. no mould what so ever.

Other effective methods were:

- Wrapped in a plastic bag with seeds removed
- Wrapped in a Honeywrap with seeds removed

Methods which resulted in the poorest preservation of cut pumpkin were:

In terms of dryness:

- Left unwrapped in the fridge, with and without seeds (control)
- Sprinkled with black pepper and placed in fridge, with and without seeds

In terms of mould:

- Placed in a plastic bag, with seeds
- Wrapped in a Honeywrap with seeds
- Glad Press and Seal, with and without seeds

For zero waste advocates a Honeywrap can be used to preserve the quality of cut pumpkin. Remove the seeds before wrapping in a large Honeywrap. This will keep the pumpkin at acceptable quality for up to 9 days.

Figure 13 – Day 1 and Day 20 for the control (Method 1), the least effective method (Method 9), and the two methods (Method 3 and 4), with the least white mould growth.

Control **Worst** **Best**

Method 1 (unwrapped, in fridge, seeds in) – Day 1

Method 9 (wrapped in plastic bag, in fridge, seeds in) – Day 1

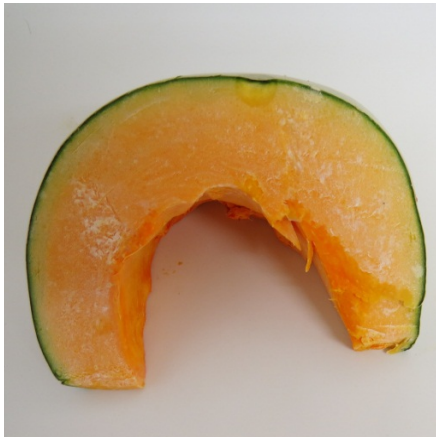
Method 3 (wrapped in cling wrap, in fridge, seeds in) – Day 1

Method 4 (wrapped in cling wrap, in fridge, seeds out) – Day 1

Method 1 (unwrapped in fridge, seeds in) – Day 20

Method 9 (wrapped in plastic bag, in fridge, seeds in) – Day 20

Method 3 (wrapped in cling wrap, in fridge, seeds in) – Day 20



Method 4 (wrapped in cling wrap, in fridge, seeds out) – Day 20

Bagged lettuce

Seven storage methods for bagged lettuce were trialled. Storage methods included:

- In open bag in fridge (control)
- In open bag in crisper
- In a Snaplock bag in the fridge
- In an airtight container in the fridge
- In bag with Fenugreen edible paper[12] in the fridge

Quality was defined using a scale of 0 to 5 of physical appearance. Physical appearance in this setting refers to visible deterioration and the observable texture of the bagged lettuce, as the main determinants of quality. 0 out of 5 is a rating given to products with a completely unacceptable physical appearance, including extensive changes to texture (i.e. wilting, disintegration of leaves, appearance of slime). 5/5 refers to a product that is deemed to be in perfect condition in terms of physical appearance: not wilted, disintegrated or slimy.

Placing bagged lettuce in an airtight container was the most successful preservation method and resulted in an acceptable visual appearance for up to 2 weeks. Storing bagged lettuce in this way could maintain an acceptable quality for up to 2 days longer than the control (leaving it open in its original packaging).

Other effective methods were:

- In an airtight container with Fenugreen paper in the fridge
- In a Snaplock bag in the fridge
- In a Snaplock bag with a paper towel in the fridge

Methods which resulted in the poorest preservation of bagged lettuce were:

- Open in fridge
- Open in crisper drawer
- Open with Fenugreen paper in the fridge

For zero waste advocates storing bagged lettuce in an airtight container would be the most effective storage method.

[12] The five-inch square paper is comprised of edible organic botanical extracts, and is simply placed into refrigerator drawers, cartons, bags and containers with produce to extend shelf life

Results

Seven storage methods were trialled for bagged lettuce. Each method was trialled three times. The trial period was 13 days.

Table 9 - methods trialled for bagged lettuce

Method no.	Description of method	Preparation of sample
1	Control – open bag in fridge	Bag opened and placed directly in fridge.
2	Open bag in crisper drawer	Bag opened and placed directly in crisper drawer.
3	In a sealed Snaplock bag in fridge	Place lettuce leaves into a Snaplock bag, squeeze air out, seal bag.
4	In an airtight container lined with Fenugreen paper in the fridge.	Line a container with Fenugreen paper, place lettuce leaves in container, seal and place in fridge.
5	Open bag with Fenugreen paper in fridge	Open bag, slide in a piece of Fenugreen paper, and place directly in fridge.
6	In a sealed Snaplock bag in fridge, with a paper towel	Place a paper towel inside a Snaplock bag, tip lettuce leaves in and squeeze out air. Seal and place in the fridge.
7	In an airtight container in fridge	Place in an airtight container in the fridge

All samples were stored in a refrigerator with the temperature set at 4°C. Two measures were used to determine which storage method was most effective; weight and visual assessment of physical quality. Each sample was removed from the fridge every four days, unwrapped and sample 'A' for each method was photographed. All products were weighed using scales to monitor moisture loss or gain. Visual assessment was carried out using the physical appearance scale to assess physical quality of each sample. Observations were recorded and then entered into Microsoft Excel.

Overall the most successful method of preserving the quality of bagged lettuce was:

- Method 7– In an airtight container in the fridge

Table 10 - Methods which maintained the greatest percentage of acceptable product at end of the 13-day trial period, compared to the control (1) and the worst method (2)

Top 5 methods	% acceptable product
(7) In an airtight container	95.3
(4) Airtight container lined with Fenugreen paper	90.1
(6) In a Snaplock bag with a paper towel inside	87.4
(3) In a Snaplock bag – no paper towel	73.1
(5) Open bag with Fenugreen paper in fridge	52.7
(1) Open bag in fridge	50.1
(2) Open bag in crisper drawer	44.3

At the end of the trial the spoiled leaves were separated from good quality leaves and the amount of acceptable product remaining was weighed. This was then taken as a percentage of the weight of the product. After 13 days of storage, Method 7 had the greatest percentage of acceptable product remaining.

Visual Observations

The physical appearance scale used in the present study was modified from the Waste and Resources Action Programme's (WRAP)[13] scale for visually assessing quality. Their scale awarded an acceptable product 'A' and a not acceptable product 'NA'. In the present study, this scale was adapted to form a 5 point system to define physical acceptability. Using a five-point scale allows for increased detail to be provided.

Point on scale	Characteristics of point on the scale
0	Not acceptable product – Extensive alterations to texture (i.e. slimy, leaves disintegrated and wilted)
1	Not acceptable product – Advanced alterations to texture apparent
2	Just acceptable product - Alterations to texture, however some chance of salvaging part of the product
3	Acceptable – Changes to texture present - some useable portion of product remaining
4	Acceptable – Product in very good condition. Minor changes to texture. Majority of the product can still be used.
5	Acceptable – Perfect condition, close to original product state. No major alterations to texture.

Figure 14 Physical Appearance Scale

According to the physical appearance scale used to code visual observations in **Appendix 13**, Method 7 (stored in an airtight container in the fridge) was the most successful at protecting the quality of the bagged lettuce with a final rating on the physical appearance scale of 4.5/5.

[13] D. Johnson, N. Hipps, and S. Hails, "Helping consumers reduce fruit and vegetable waste: Final report," Waste and Resources Action Programme (WRAP), U.K., Tech. Rep., 2008

This was followed by Method 4 (stored in an airtight container, lined with Fenugreen paper, in the fridge) which scored 4/5 at the end of the 13 day trial period. Method 1 (open bag in fridge), 2 (open bag in crisper drawer) and 5 (open bag with Fenugreen paper in fridge) were awarded 0/5 at the end of the trial period, as they had more disintegrated leaves than good quality leaves.

Weight Measurements

Appendix 14 includes the weight measurements taken throughout the trial period for each sample. Larger amounts of weight loss appeared to be detrimental to the texture of the bagged lettuce. Methods 1 (open bag in fridge) and 5 (open bag with Fenugreen paper in fridge) experienced the greatest average weight loss over the 13-day trial period, of 3g and 4g respectively. These methods also performed poorly in visual assessment.

Smaller amounts of weight loss were associated with the best preserved bagged lettuce e.g. method 7 (in an airtight container in the fridge) experienced 1.1g weight loss over the trial period. Overall, the least amount of weight lost over the trial period, the better the condition of the bagged lettuce. However, it is interesting to note that method 2 (open bag stored in the crisper drawer) which performed poorly in visual assessment only experienced 1.7g of weight loss over the trial period. From this it is hard to draw conclusions about weight loss and quality of bagged lettuce. Visual appearance is therefore deemed to be a better method for assessing quality of bagged lettuce.

Conclusion

Storing bagged lettuce in an airtight container in the fridge was the most successful method for preserving the quality. Using this method resulted in the bagged lettuce remaining an acceptable standard for up to 13 days.

Other effective methods were:

- In an airtight container with Fenugreen paper
- In a Snaplock bag
- In a Snaplock bag with a paper towel

Methods which resulted in the poorest preservation of bagged lettuce were:

- Open in fridge
- Open in crisper drawer
- Open with Fenugreen paper

For zero waste advocates storing bagged lettuce in an airtight container would be the most effective.

Figure 13 – Day 1 and Day 13 for the control (Method 1), the most effective method (Method 7)

Method 1 (open bag in fridge) - Day 1

Method 7 (airtight container in fridge) - Day 1

Method 1 (open bag in fridge) - Day 13

acceptable leaves on left, inedible leaves on right

Method 7 (airtight container in fridge) - Day 13

acceptable leaves on left, inedible leaves on right