A review of evidence on plastic packaging and fresh produce to inform discussions on providing uncut fresh fruit and vegetables plastic-free/loose; eliminating unnecessary plastic packaging without unintentionally increasing food waste - especially in the home.

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WRAP’s vision is a world in which resources are used sustainably.

Our mission is to accelerate the move to a sustainable resource-efficient economy through re-inventing how we design, produce and sell products; re-thinking how we use and consume products; and re-defining what is possible through re-use and recycling.

Find out more at www.wrap.org.uk
Executive summary

The purpose of this report is to review the available evidence of the effects of plastic packaging in helping to reduce the amount of fresh produce thrown away in the home to inform discussions on providing uncut fresh fruit and vegetables loose/plastic-free in-store. This report has been published for consideration by signatories to the Courtauld Commitment 2025 and the UK Plastics Pact.

The total amount of fresh vegetable and salad waste in the UK is in the region of 1.6 million tonnes, of which approximately 80% (1.3 million tonnes) is food (edible parts). The cost of this food to the citizen is in the region of £2.7 billion. In addition, approximately 940,000 tonnes of fruit waste are produced by UK households, costing the citizen £1.3 billion. Of this, the majority is fresh fruit. Around a third of the waste is food; the remainder inedible parts.

The main reason given for the disposal of all fresh produce is ‘not used in time’ e.g. it has gone rotten, mouldy or is otherwise not fit to eat. This is likely to be linked to the perishability of fresh produce and the large quantities that are often purchased. This could be further exacerbated by being stored in sub-optimal conditions – in general, fresh produce will last for longer in the fridge at <5°C. (Household Food Waste: Restated Data for 2007-2015, WRAP 2018).

For most of the products studied, the evidence shows that:

- Refrigeration in the home is vitally important in maintaining freshness and extending storage-life, commonly for 7 - 14 days longer than at room temperature (22°C); and
- Storing fresh produce in a polyethylene (PE) bag, of the type usually provided in the supermarket, in the fridge can help to retain moisture and freshness, although only two of the 17 fruit and vegetables tested (lemons and peppers) showed a significant improvement (of more than three days) in storage-life for bagged product in the fridge versus un-bagged product in the fridge.

This evidence will inform consideration of whether retailers should offer more fruit and vegetables loose and/or plastic-free. However, further evidence is needed:

- There are gaps in data for many popular fruit and vegetables;
- Plastic packaging serves additional purposes such as product protection and providing citizens with information e.g. on how best to store the product at home. The food waste implications of alternative approaches have not been comprehensively tested, although some innovative films and coatings appear to deliver increases in storage-life;
- The relative environmental impacts of alternative packaging materials need to be fully understood;
- Re-usable airtight containers could offer similar benefits to single-use plastic bags; and
- The relative wastage rates of pre-packaged versus loose fruit and vegetables in-store and at home are yet to be quantified.

Various fruit and vegetables are already provided loose in supermarkets. The common exception is product that is prone to damage, such as grapes and strawberries, for which there are various plastic and alternative packaging options.
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1.0 Introduction

In January 2018 HM Government published the 25 Year Environment Plan (25 YEP) A Green Future: Our 25 Year Plan to Improve the Environment, which sets out what will be done to improve the environment within a generation. The Clean Growth Strategy: Leading the Way to a Low Carbon Future – the sister document to the Environment Plan – sets out how to deliver the clean, green growth needed to combat global warming. Waste reduction commitments in the 25 YEP and Clean Growth Strategy include:

- Making sure that resources are used more efficiently and kept in use for longer to minimise waste and reduce environmental impacts by promoting re-use, re-manufacturing and recycling; and
- Working towards eliminating all avoidable waste by 2050 and working towards no food waste entering landfill by 2030.

The Resources and Waste Strategy, to be published later this year, will establish further policies to act on these commitments.

A Green Future: Our 25 Year Plan to Improve the Environment

“Plastic is an incredibly versatile material that forms a key component of many products we use today. As a packaging material, it is safe, secure, hygienic and cheap. It is tough and long-lasting, which is why it is also a disaster for the environment.

Production of most virgin plastics requires fossil fuels, and when we have finished with them, they are difficult to dispose of in a way that does not harm the natural world.

It is estimated that 8.3 billion tonnes of plastic have been produced since the 1950s1. Without urgent action to cut demand, this is likely to be 34 billion tonnes by 2050, the majority of which will end up in landfill or polluting the world’s continents and oceans.

In the UK alone, during its recent Great British Beach Clean Up the Marine Conservation Society found 718 pieces of litter for every 100m stretch of beach surveyed. Of this, rubbish from food and drink made up at least one fifth. Urgent action to reduce plastic waste in the marine and open environment is needed and is vital for the future of our planet.

To address this issue, we will work to eliminate all avoidable plastic waste over the lifetime of this Plan through a four-point plan taking action at each stage of the product lifecycle – production, consumption, end of use and end of life.

At the consumption stage, we will reduce the amount of plastic in circulation through reducing demand for single-use plastic by working with retailers and WRAP to explore introducing plastic-free supermarket aisles in which all the food is loose.”

The purpose of this report is to review the available evidence on the effects of plastic packaging in helping to reduce the amount of fresh produce thrown away in the home to inform future guidance on providing uncut fresh fruit and vegetables loose and/or plastic-free in-store.

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2.0 Background

Plastic waste is increasingly of concern. If a year’s-worth of the UK’s unrecycled plastic bottles were placed end to end, they would reach around the world 31 times, covering over 780,000 miles.²

Research by Kantar TNS has revealed that excess packaging, especially plastics, is causing widespread concern among the British public. The survey of 1,260 people showed that 63% are concerned about reducing the amount of packaging they buy.³

Populus research commissioned by Higginson PR on behalf of A Plastic Planet⁴, showed that 91% of the UK public supported the idea of having an entire aisle dedicated to the sale of products free of plastic packaging.

Zero Waste Europe and Friends of the Earth reported on the impact of disposable plastic packaging and its links to food waste and set out recommendations for alternatives to disposable packaging. (Schweitzer, Gionfra, Pantzar, & Mottershead, 2018).

Clearly, a step-change is required if we are to make more of plastic, keeping it out of the ocean and in the economy.

2.1 The UK Plastics Pact
WRAP launched The UK Plastics Pact in April 2018, working in partnership with the Ellen MacArthur Foundation (EMF) to create the first national implementation of the vision for a New Plastics Economy.

The UK Plastics Pact is transforming the way that the UK makes, uses and disposes of plastic. We need to move away from a linear plastics economy towards a circular system where we capture the value of plastics material – keeping plastic in the economy and out of the oceans. The UK Plastics Pact brings together governments, businesses, local authorities, citizens and NGOs behind a common vision and commitment to a set of ambitious targets.

The targets for 2025 are⁵:

- Eliminate problematic or unnecessary single-use packaging through redesign, innovation or alternative (re-use) delivery models;
- 100% of plastics packaging to be re-usable, recyclable or compostable – see Plastics Glossary;
- 70% of plastics packaging effectively recycled or composted; and
- 30% recycled content across all plastic packaging.

2.2 The Courtauld Commitment 2025
This voluntary agreement, launched in 2016, brings together organisations from across the UK food system to make food and drink production and consumption more sustainable.

At its heart is a 10-year commitment to identify priorities, develop solutions and implement change to cut the waste and greenhouse gas emissions associated with food and drink by at least one-fifth per person by 2025.

³ https://ciwm-journal.co.uk/new-research-exposes-generation-gap-in-tackling-packaging-waste/
⁴ http://www.populus.co.uk/2017/07/the-plastic-backlash/
⁵ Targets 1, 2 and 4 refer to items or packaging under the control of The UK Plastics Pact members and are collective targets. Target 3 refers to all UK plastic packaging including household, commercial and industrial.
Meeting the Courtauld 2025 target will also help the UK to achieve UN Sustainable Development Goal 12.3:

"By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses."

2.3 The relationship between packaging and food
Plastic is lightweight, easily formed into different shapes and low cost, and it is this versatility that is largely responsible for the huge growth in its use over the past 50 years.

Plastic food packaging is used to support a product on its journey from farm to fork by:

- inhibiting and controlling the ingress/egress of gases and moisture that are the main causes of spoilage, thus reducing deterioration and extending shelf-life;
- preventing access to foreign bodies that would render food inedible;
- protecting it from physical damage during transport and storage;
- and providing product dispensing or collating functions e.g. multi-pack.

2.4 Household food waste in the UK
More than half of the UK’s food and drink waste occurs in the home. Every year UK citizens throw away 7.1 million tonnes of food and drink or 20% of the food and drink we buy, which could be worth up to £810 a year for a typical family.6

More than half of us say we throw away no or hardly any food7, yet the average family with children bins a quarter of a tonne of food each year - the equivalent of more than a meal a day.8

Forty-one per cent of the food and drink we waste (by weight) is thrown away because we do not use it in time. After personal preference (28%), a further 25% is because we prepare, cook or serve too much.

The total amount of fresh vegetable and salad waste in 2012 was in the region of 1.6 million tonnes, of which approximately 80% (1.3 million tonnes) was food. The cost of the wasted food was in the region of £2.7 billion.

Fresh vegetables and salad wasted because they were not used in time cost £1.3 billion, approximately half of the total cost of wasted food from the fresh vegetable and salad category. However, personal preference is also important; it accounts for a little over a third of the cost of wasted food from this category.

Approximately 940,000 tonnes of fruit waste were produced by households in the UK in 2012. Of this, only 20,000 were processed; the majority of fruit waste is fresh fruit. Around a third of the waste was food (edible parts), meaning that the majority comprises inedible parts such as banana peel (270,000 tonnes) and hard peel of other fruit. Apple and berry waste has the highest ratio of wasted food to discarded inedible parts.

The majority of fresh and processed fruit was disposed of because it was not being used in time (e.g. it had gone rotten, mouldy or otherwise inedible). This is likely to be linked to the perishability of fruit and the large quantities that are often purchased. This could be further exacerbated by fruit being stored in sub-optimal conditions – in general, fruit will store for longer in the fridge45.

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6 Household Food Waste: Restated Data for 2007 – 2015 WRAP 2018
7 Food Trends Survey Wave 1 Spring 2018 WRAP (unpublished)
8 Household Food Waste: Restated Data for 2007 – 2015 WRAP 2018
The most wasted fresh produce items\(^9\) are:

<table>
<thead>
<tr>
<th>Product</th>
<th>Wasted food (edible parts)</th>
<th>Not used in time</th>
<th>Prepare, cook, serve too much</th>
<th>Cost £m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>710,000(^{10})</td>
<td>180,000</td>
<td>120,000</td>
<td>555</td>
</tr>
<tr>
<td>Carrot</td>
<td>96,000</td>
<td>43,000</td>
<td>5,000</td>
<td>102</td>
</tr>
<tr>
<td>Apple</td>
<td>63,000</td>
<td>40,000</td>
<td>2,000</td>
<td>130</td>
</tr>
<tr>
<td>Lettuce</td>
<td>57,000</td>
<td>32,000</td>
<td>9,000</td>
<td>402</td>
</tr>
<tr>
<td>Other fresh veg &amp; salad</td>
<td>49,000</td>
<td>30,000</td>
<td>5,000</td>
<td>315</td>
</tr>
<tr>
<td>Banana</td>
<td>47,000</td>
<td>44,000</td>
<td>&lt;1,000</td>
<td>67</td>
</tr>
<tr>
<td>Onion</td>
<td>47,000</td>
<td>39,000</td>
<td>4,000</td>
<td>69</td>
</tr>
<tr>
<td>Tomato</td>
<td>46,000</td>
<td>26,000</td>
<td>2,000</td>
<td>128</td>
</tr>
<tr>
<td>Cabbage</td>
<td>43,000</td>
<td>29,000</td>
<td>5,000</td>
<td>65</td>
</tr>
<tr>
<td>Cucumber</td>
<td>43,000</td>
<td>25,000</td>
<td>3,000</td>
<td>77</td>
</tr>
<tr>
<td>Soft berry fruit</td>
<td>42,000</td>
<td>36,000</td>
<td>&lt;1,000</td>
<td>210</td>
</tr>
<tr>
<td>Stone fruit</td>
<td>37,000</td>
<td>33,000</td>
<td>&lt;1,000</td>
<td>140</td>
</tr>
<tr>
<td>Orange</td>
<td>29,000</td>
<td>27,000</td>
<td>&lt;1,000</td>
<td>56</td>
</tr>
<tr>
<td>Other root veg</td>
<td>29,000</td>
<td>5,000</td>
<td>1,000</td>
<td>57</td>
</tr>
<tr>
<td>Melon</td>
<td>24,000</td>
<td>-</td>
<td>-</td>
<td>59</td>
</tr>
<tr>
<td>Leafy salad</td>
<td>22,000</td>
<td>13,000</td>
<td>&lt;1,000</td>
<td>64</td>
</tr>
<tr>
<td>Other citrus</td>
<td>18,000</td>
<td>17,000</td>
<td>&lt;1,000</td>
<td>52</td>
</tr>
<tr>
<td>Pear</td>
<td>18,000</td>
<td>15,000</td>
<td>&lt;1,000</td>
<td>33</td>
</tr>
<tr>
<td>Other fresh fruit</td>
<td>13,000</td>
<td>6,000</td>
<td>2,000</td>
<td>200</td>
</tr>
<tr>
<td>Pineapple</td>
<td>10,000</td>
<td>-</td>
<td>-</td>
<td>120</td>
</tr>
</tbody>
</table>

\(^9\) Household Food Waste: Restated Data for 2007 – 2015 WRAP 2018

\(^{10}\) 'Edible parts' includes skins/peel, which many people do not eat for reasons of personal preference
3.0  **Summary of WRAP evidence**

3.1  **Helping Consumers Reduce Fruit and Vegetable Waste**

Experimental research found that refrigeration was vitally important in maintaining freshness and extending storage-life for 13 out of 17 fruit and vegetables tested e.g. carrots and oranges last for up to two weeks longer (than stored loose at room temperature) if kept in the fridge.

The study also found: “the dryness in the air within the refrigerator encourages the loss of water (transpiration) and can be a major factor in loss of quality and presumably also in product rejection (waste) by consumers”.

It concluded that storing loose products in perforated polyethylene (PE) bags - of the type available in supermarket fresh produce aisles - was beneficial in conserving water and maintaining freshness in most of the products tested.

Considering the current context on plastic packaging, the evidence from ‘Helping Consumers Reduce Fruit and Vegetable Waste’ was re-visited and reviewed. The findings are summarised in the table that follows.

For only two (lemons and peppers) of the 17 fruit and vegetables tested does there appear to be any significant difference (>3 days) in storage-life between keeping them in the fridge and keeping them in a PE bag in the fridge.

For example:

Lemons retained freshness and quality for at least 7 days longer stored in the fridge (compared to stored loose at room temperature) and retain freshness and quality for at least 14 days longer stored in a bag in the fridge (compared to stored loose at room temperature).

Peppers retained freshness and quality for at least 10 days longer stored in the fridge (compared to stored loose at room temperature) and retain freshness and quality for at least 14 days longer stored in a bag in the fridge (compared to stored loose at room temperature).

Yet, both lemons and peppers are widely provided plastic-free/loose in large supermarkets.

For items that do lose moisture/weight in the fridge e.g. broccoli, carrots, melons, oranges, peppers and tomatoes – keeping them in a re-usable airtight container in the fridge may have the same effect as keeping them in a plastic bag.

The findings for each of the 17 types of fresh produce tested in this study are summarised in the table that follows and presented in more detail in [0 Evidence Review](#).

3.2  **The Role of Plastic Packaging in Prolonging Shelf-life of Fruit and Vegetables – a Literature Review**

WRAP has conducted a review of literature on the role of plastic packaging in prolonging the shelf-life of fruit and vegetables. These findings are also summarised in the table below in the column headed ‘Other evidence’ and presented in more detail in [0 Evidence Review](#).

---

<table>
<thead>
<tr>
<th>Fruit/vegetable</th>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Other evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>None (the variety tested - Granny Smith - was very robust). Current advice for citizens is to store apples in the fridge to keep them fresher for longer.</td>
<td></td>
<td>Paper mould trays and corrugated fibre board (CFB) cartons limited spoilage to 6%. Where there is concern over bruising/damage to fruit at storage/retail stage, this method may be worth investigating. A life cycle impact study by ERM for M&amp;S (2003) found that if transported in re-usable plastic crates, loose apple packaging waste would be less than packaged and overall waste comparable between loose product and four-packs with biodegradable/non-biodegradable foam trays and film.</td>
</tr>
<tr>
<td>Bananas</td>
<td>None (skins blacken)</td>
<td>Use of bag at room temperature retains moisture content and visual quality for longer – up to 3 days</td>
<td>Reducing the number of times bananas are transferred into different containers might help to reduce waste in the supply chain. Selling bananas free-flow in the original packing containers (18kg ready for shelf boxes) could be beneficial compared to packaged bananas (WRAP, 2011). Morrison’s sells packaged and free-flow bananas, presenting single loose fruits in a box so customers can buy single/small quantities. Tesco and Morrisons offer free fruit for kids whilst their parent/guardian shops in-store, which could be an effective way of using single loose bananas.</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Retained freshness and quality for at least 5 days longer</td>
<td>Retains freshness and quality for at least 5 days longer and reduces water loss (observable difference in turgidity)</td>
<td>Refrigerating broccoli at 4°C maintained shelf-life for 10 days, regardless of whether the heads were stored in Modified Atmosphere Packaging (MAP) or open boxes.</td>
</tr>
</tbody>
</table>

12 Effect of pre-cooling, fruit coating and packaging on postharvest quality of apple
13 Effect of post-harvest and packaging treatments on glucoraphanin concentration In broccoli (brassica oleracea var. italica)
<table>
<thead>
<tr>
<th>Produce</th>
<th>Retained freshness and quality for at least</th>
<th>Retains freshness and quality for at least</th>
<th>MAP recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrots</td>
<td>14 days longer</td>
<td>17 days longer</td>
<td>MAP is not recommended for carrots, as it reduces the sensory quality.(^\text{14})</td>
</tr>
<tr>
<td>Grapes</td>
<td>7 days longer</td>
<td>Pre-packed produce used in trials</td>
<td>Cardboard boxes could replace plastic punnets.(^\text{15}) NVT-100 films could replace NP films as a biodegradable alternative.(^\text{16})</td>
</tr>
<tr>
<td>Lemons</td>
<td>Retained freshness and quality for at least 7 days longer</td>
<td>Retains freshness and quality for at least 14 days longer</td>
<td></td>
</tr>
<tr>
<td>Kiwi fruit</td>
<td>Kiwi fruit retained freshness and quality for at least 4 days longer</td>
<td>Retains freshness and quality for at least 4 days longer and reduces weight loss slightly</td>
<td></td>
</tr>
<tr>
<td>Melons</td>
<td>Retained freshness and quality for at least 10 days longer</td>
<td>Retains freshness and quality for at least 10 days longer and reduces weight loss</td>
<td></td>
</tr>
<tr>
<td>Mushrooms</td>
<td>Retained quality (reduced browning) for at least 9 days longer, BUT ideally use paper bag</td>
<td>Retains quality (reduced browning) for at least 2 days longer, BUT ideally use paper bag</td>
<td></td>
</tr>
<tr>
<td>Oranges</td>
<td>Retained freshness and quality for at least 14 days longer</td>
<td>Retains freshness and quality for at least 14 days longer and reduces weight loss</td>
<td>Edible coatings of pea starch, guar gum, shellac and oleic acid can extend orange shelf-life for up to 4 weeks at 5°C and 1 week at 20°C.(^\text{17})</td>
</tr>
<tr>
<td>Pears</td>
<td>Retained freshness and quality for at least 14 days longer</td>
<td>Reduces weight loss of pears stored at 22°C</td>
<td>PP non-perforated was the most suitable packaging material for extending the shelf-life of pears up to 15 days in ambient conditions.(^\text{18})</td>
</tr>
</tbody>
</table>

\(^\text{14}\) Quality of carrots as affected by pre- and postharvest factors and processing
\(^\text{15}\) Unique techniques developed in Israel for short- and long-term storage of table grapes
\(^\text{16}\) A study on quality loss of minimally processed grapes as affected by film packaging
\(^\text{17}\) Application of bio composite edible coatings based on pea starch and guar gum on quality, storability and shelf life of ‘Valencia’ oranges
\(^\text{18}\) Extension of shelf life of pear fruits using different packaging materials
<table>
<thead>
<tr>
<th>Produce</th>
<th>Retained freshness and quality for at least X days longer</th>
<th>Retained freshness and quality for at least Y days longer</th>
<th>Conflicting reports on shelf-life of both wrapped and unwrapped peppers. Overall, MAP and LDPE packaging extend shelf-life. Chitosan films have been tested as an alternative to plastic.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peppers</td>
<td>Retain freshness and quality for at least 10 days longer</td>
<td>Retains freshness and quality for at least 14 days longer</td>
<td>None without the use of a bag. Faster loss of moisture in fridge loose versus loose at 15°C. Current FSA potato storage advice is that raw potatoes should NOT be stored in the fridge if intending to cook them at high temperatures, such as by roasting or frying. Use of bag, either at room temperature or in the fridge* retained freshness and quality for at least 10 days longer. Some good practice to extend life in depots/store by covering products to exclude light e.g. when stores are closed to prevent greening and sprouting. At home, storage in a cloth bag can prevent greening and sprouting better than PE packaging.</td>
</tr>
<tr>
<td>Potatoes</td>
<td>None without the use of a bag. Faster loss of moisture in fridge loose versus loose at 15°C</td>
<td>Use of bag, either at room temperature or in the fridge* retained freshness and quality for at least 10 days longer</td>
<td>Use of bag, either at room temperature or in the fridge* retained freshness and quality for at least 10 days longer. Some good practice to extend life in depots/store by covering products to exclude light e.g. when stores are closed to prevent greening and sprouting. At home, storage in a cloth bag can prevent greening and sprouting better than PE packaging.</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>Retain freshness and quality for at least 7 days longer</td>
<td>Retains freshness and quality for at least 10 days longer and reduces weight loss</td>
<td>Waxes and edible coatings can reduce weight loss and extend shelf-life to up to 18 days. Cardboard punnets have been trialled as alternative to plastic trays. Intact bitter cassava-based film could present an alternative to conventional OPP wrap.</td>
</tr>
<tr>
<td>Strawberries</td>
<td>Strawberries retained freshness and quality for at least 7 days longer</td>
<td>Pre-packed produce used in trials</td>
<td>Packaging composed of yam starch or glycerol could replace traditional PVC wrap.</td>
</tr>
</tbody>
</table>

19 A comparative study on the effect of packaging material and storage environment on shelf life of fresh bell-pepper
20 Storage studies of tomato and bell pepper using eco-friendly films
21 Reducing supply chain and consumer potato waste
22 Mango kernel starch as a novel edible coating for enhancing shelf-life of tomato (Solanum lycopersicum) fruit
23 New packaging with a tomato source
24 Evaluation of novel bitter cassava film for equilibrium modified atmosphere packaging of cherry tomatoes
25 New packaging with a tomato source
26 Evaluation of novel bitter cassava film for equilibrium modified atmosphere packaging of cherry tomatoes
27 Effects of yam starch films on storability and quality of fresh strawberries (Fragaria ananassa)
3.3 Consumer Attitudes to Food Waste and Food Packaging

Produced by WRAP in partnership with INCPEN, The Packaging Federation, the Food and Drink Federation, Kent Waste Partnership and the British Retail Consortium, this report revealed that citizens did not realise the important role packaging plays in helping to reduce food waste at home.

The research also found that when shopping in-store, packaging was a low priority for citizens - quality, freshness and the look/smell of the product were the most important. However, once set within a framework of environmental concern, attitudes towards packaging became negative.

Furthermore, attitudes to packaging were linked to the ability to recycle. The research noted a strong correlation between concerns about packaging materials and how easy it was to recycle them at home. The more difficult it was to recycle an item the more concern was expressed about it.

### The role of packaging in specific product choices – leeks

- 47% of citizens chose the pre-packed option compared to 49% who chose the product loose
- Younger citizens aged 18 - 34 were more likely to choose pre-packed (56% vs. 43% of those aged 65+) as were those who thought that packaging helps to keep food fresher for longer (57%)
- Of those who chose to buy loose, 30% said this was specifically because it had no packaging and 23% because they could choose their own

Of those who chose to buy pre-packed, 14% said it was because it was packed and a further 50% gave reasons that were related to it being packaged e.g. 29% said it was easier to prepare/already prepared/ready to cook; 11% said it meant there was less waste; 10% said the appearance was better.

3.4 Review of Literature about Freezing Food at Home

The potential annual UK waste savings resulting both from lowering fridge temperature to <5°C and refrigerating foods, which are incorrectly stored at ambient temperatures, is c.£200 million and a net reduction of around 210,000 tonnes CO₂e (factoring in additional energy use).

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28 Consumer Attitudes to Food Waste and Food Packaging WRAP 2013
29 Review of Literature About Freezing Food at Home WRAP 2012
### 4.0 Evidence review

This chapter presents, in alphabetical order, more detailed findings on the 17 fresh produce items tested in ‘Helping Consumers Reduce Fruit and Vegetable Waste’ and the evidence on commonly-waste fruit and vegetables identified by the Literature Review. For some items there is evidence from both sources; for others there is evidence either from ‘Helping Consumers Reduce Fruit and Vegetable Waste’ or the Literature Review.

#### 4.1 Apples

<table>
<thead>
<tr>
<th>Helping Consumers Reduce Fruit and Vegetable Waste</th>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>None shown in this trial – BUT variety used (Granny Smith) was very robust! Expert opinion used to develop advice.</td>
<td>None shown in this trial – BUT variety used (Granny Smith) was very robust! Expert opinion used to develop advice.</td>
<td>None</td>
<td>Although apples kept at 22°C lost more weight than those kept in the fridge, this was insufficient to affect visual quality. Similarly, polyethylene bags reduced weight loss of apples kept at 22°C but did not affect visual quality. There were no significant effects of storage temperature or bags on shore values. Although advice provided by retailers to store apples under refrigeration seemed inappropriate for this consignment of apples, in general this course of action would extend storage life of apples in the home. The use of bags would also be generally advised since apple cultivars more prone to weight loss are likely to benefit from their use.</td>
<td></td>
</tr>
</tbody>
</table>

Fresh apples are currently available both in packaging and loose in most UK supermarkets. The shelf-life of apples varies according to the cultivar and ripeness at the time of harvesting, however apples broadly have a storage life of up to 12 months and a shelf-life of 3 - 4 weeks (WRAP, 2008) (WRAP, 2011) (Wijewardane, 2013).

A variety of packaging types has been tested for extending the shelf-life of apples. At present, apples are generally sold in 'flow wrap' (polyethylene or polypropylene), polyethylene (PE) bags or in a plastic/polystyrene tray with flow wrap covering or loose. Modified atmosphere packaging has the potential to extend shelf-life, however according to research conducted into suppliers and retailers by WRAP Cymru (2011), the cost is rarely outweighed by the benefits (WRAP, 2011).

Research published in the Journal of Food Science and Technology found that shrink-wrapping apples could extend their shelf-life by up to two weeks. Cryovac shrink-wrap reduced weight loss from 10.7% to 2.3% during storage at ambient temperature, however, 30 Shore hardness is measured with an apparatus known as a Durometer and consequently is also known as 'Durometer hardness'. The hardness value is determined by the penetration of the Durometer indenter foot into the sample.

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**WRAP - Evidence Review: Plastic Packaging and Fresh Produce 12**
this method was also linked to a loss of firmness (possibly due to water retention) and an increasingly mealy texture in the fruit (Sharma, 2013).

Another 2013 study found that shrink-wrapped, in-tray packaging and Low-Density Polyethylene (LDPE) liner and corrugated fibre board (CFB) cartons were the most effective means of extending shelf-life. The apples were stored over a 45-day period at room temperature (18 - 25°C) and the packaging limited spoilage to 5.9% of the tested fruits. However, although an improvement, apples stored in a paper mould tray and CFB carton experienced only 6% spoilage. Where there is concern over bruising/damage to fruit at retail/storage stage, such a packaging method may be worth investigating further as an alternative to plastic (Wijewardane, 2013).

Some research has been conducted into new, biodegradable films which might help to prolong shelf-life and act as a substitute for conventional plastic packaging.

The potential utility of chitosan-based films is being investigated across the food packaging industry. Chitosan is derived from chitin and ‘sourced from waste products of the shellfish industry’ (Moreira, Antimicrobial Effectiveness of Bioactive Packaging Materials from Edible Chitosan and Casein Polymers: Assessment on Carrot, Cheese, and Salami, 2010). Binary-coated chitosan was trialled in India as a potential wrapping for apples and guavas. The study found that the shelf-life of apples wrapped in chitosan film was extended by 6 days compared to unwrapped fruit, even when stored in abusive conditions (stored at temperatures of 40 - 45°C). The sample size in this study was small and storage temperatures artificially high in the context of UK retailers and households, however the technology may warrant further investigation.

Given the relatively long shelf-life of apples even without packaging, it is possible to sell these items loose. Current recommendations from WRAP and suppliers advise storing apples in the fridge at home (below 5°C) (WRAP, 2008) (Thompson, 1996).

4.2 Retailer evidence: M&S (apples)

In 2003, M&S commissioned a report into the product and packaging waste associated with their apple sales (Environmental Resources Management, 2003). The study looked at the life cycle impact of loose product; non-biodegradable ‘four packs’ (with foam tray and film); and biodegradable ‘four packs’ (biodegradable foam and film), considering the energy consumption, biodegradable and total waste caused by each method.

This research found that loose apples were associated with the most packaging waste and waste overall. This was due primarily to the single-use cardboard euro-crates used in distribution. Loose apples were also found to be more prone to damage during the retail stage and in transit to citizens’ homes. 132kg of loose apples were wasted per tonne compared to 106kg per tonne of packaged apples (in both biodegradable and non-biodegradable packaging).* Loose apples are therefore associated with a 26kg increase in food waste per tonne.

The overall waste associated with packaged apples was 135kg per tonne, compared to 185kg for loose apples. However, the total non-biodegradable waste from the life-cycle of loose apples was just 5.7kg, compared to 26.7kg for non-biodegradable packaging and 13.5kg for biodegradable. The study concluded that four packs resulted in less food waste, but that if loose apples were transported in re-usable plastic crates instead of cardboard, loose apple packaging waste would be less than packaged. Overall waste would, at that point, become comparable between the two systems.
The total energy consumption for non-biodegradable-packaged apples was 3104MJ, the highest of all three systems, due to the production of the foam packaging. The second highest was loose apples, at 2818MJ. The main contributor to this was the production of cardboard crates (partially offset by recycling). The least energy exhaustive system was the biodegradable packaging, at 2419MJ. Again, if loose apples were transported in re-usable plastic crates this would significantly reduce energy consumption.

*The effectiveness of the different packaging types was assumed to be the same in the study.

4.3 Avocado
Avocados have an average postharvest life of 3 - 5 weeks and a shelf-life of 2 - 4 days (Tesfay, 2017) (WRAP, 2011). In the UK, pre-climacteric avocados are generally sold loose and climacteric (ripe) avocados are sold in plastic-wrapped trays (WRAP, 2011). Packaging in this case is generally used to limit damage/bruising to the fruits in their softened, ripened state. This report has been unable to uncover any research into alternatives for protective packaging. However, two 2017 studies investigated bio-coatings which retarded ripening and extended shelf-life when avocados were kept at room temperature.

A bioactive and biodegradable coating of candelilla wax and purified polyphenols from *Larrea tridentata* (creosote bush) was successfully developed that reduced fruit weight loss by 58% and inhibited the development of internal grey pulp by 100% as compared to the uncoated control (Aguirre-Joya, 2017). This may be a useful means of extending shelf-life at the retail stage and within households. There is also potential that this coating could be developed into a film, which might warrant further research as an alternative to fossil-based plastics.

In terms of home storage and packaging, research conducted at the University of Otago, New Zealand, found that the best ways to store cut avocados were refrigerated and:

- Wrapped in cling wrap;
- In an airtight container with a piece of cut onion; and
- In an airtight container.

Wrapping avocados in cling wrap with the stone left in maintained shelf-life for up to 8 days, as compared to unwrapped in the fridge or – the worst storage method – rubbed with olive oil or lemon juice. This is useful information for climacteric fruits kept at home, however further research is needed into packaging alternatives for climacteric fruits at the retail stage.

4.4 Bananas

<table>
<thead>
<tr>
<th>Helping Consumers Reduce Fruit and Vegetable Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit of refrigeration vs loose at 22°C</td>
</tr>
<tr>
<td>None (skins will blacken)</td>
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</tbody>
</table>
more weight at the higher storage temperature and the use of bags reduced weight loss, although due to limited replication the effect just failed to reach significance at the 5% level of probability. Visual quality was maintained longer where the fruit was kept in polyethylene bags. It is not appropriate to store bananas in the fridge as they are chilling-sensitive, and their skins become blackened, but the coolest place in the home is the best storage location and the fruit should be kept in bags.

Bananas sold in the UK are mostly sourced from Central and South America. They are harvested while still in a pre-climacteric (green) condition and shipped to the UK where ripening is triggered using ethylene gas and heightened temperatures. Transit and storage generally takes up to 4 weeks, and once ripening has been triggered, the shelf-life is about 2-5 days.

According to a WRAP Cymru report, retailers generally have a 2-day retail shelf-life for bananas sold loose and 3 days for those sold packed (WRAP, 2011). Extensive research has been conducted into banana preservation during transit (Kudachikar, 2011), however information on post-ripening shelf-life and household storage is limited.

The most extensive research on home storage was conducted by East Malling Research on behalf of WRAP UK (2008) – see above.

MAP has been shown to extend storage life of pre-climacteric bananas to up to 7 weeks, however it is rarely used at the retail stage. This is because although MAP inhibits skin discolouration, it does not consistently slow the ripening of the pulp (Kudachikar, 2011) (WRAP, 2011).

More research into potential means of prolonging shelf-life without packaging is needed. In recent years, studies have found that edible coatings and bio-based films can have a positive impact on shelf-life, which could present a viable alternative to conventional plastic packaging (Sanwal & Payasi, 2007).

In 2017, research conducted at Silpakorn University, Thailand, found that an edible film of pork gelatine and shellac could keep bananas fresh for up to 4 weeks, even when stored at 25°C (Soradech, 2017). However, in 2018 initial reactions from the UK Vegetarian and Vegan Societies were negative when it was proposed that animal gelatine could be used in the lids of milk bottles (Richards, 2018). It is questionable, therefore, how well a gelatine coating directly placed on food would be received by UK citizens. Vegan alternatives to gelatine may be as effective.

A 2016 study found that dipping ethylene-gassed (i.e. ripening) bananas in a phospholipid (Lysophosphatidylethanolamine (LPE)) and soy lecithin mix for 30 minutes could prolong shelf-life at room temperature for up to 3 days. This is a comparable shelf-life to bananas

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31 Bio-based plastic - Made using polymers derived from plant-based sources e.g. starch, cellulose, oils, lignin etc. Bio-based plastic is the term used for any plastic made from bio-based polymers, and refers to the source from which the plastic is made, not how the material will function.
stored in PE bags, and could, after further research, act as an alternative to conventional plastic (Ahmed, 2016).

Speed of ripening aside, a further benefit of packaging is to protect bananas from bruising and excessive handling by citizens. Retailers have reported that damage is caused by citizens breaking bunches of loose bananas while selecting the appropriate number of fruits and their preferred level of ripeness (WRAP, 2011). The damage to loose fruits at this stage, however, is potentially offset by the bruising caused to packaged bananas as they are transferred from their secondary (storage) packaging to primary (retail) packaging. Reducing the number of times bananas must be transferred to different forms of container might help to reduce food loss in supply lines. Selling bananas free-flow in the original packing containers (18kg, ready for shelf boxes) could, therefore, be beneficial compared to packaged bananas (WRAP, 2011).

4.5 Retailer evidence: Morrisons, Tesco (bananas)

The UK supermarket, Morrisons, sells bananas both pre-packaged and free flow in bunches. Single loose bananas are grouped in boxes beside the bunches, allowing citizens to buy as few as they need.

Tesco’s Free Fruit for Kids scheme, launched in 2016, is an effective way of using loose bananas and other fruits which might otherwise go to waste. The scheme allows children to take one piece of fruit to eat from the crates provided while their parent/guardian shops in store. In the first 10 months of the scheme, Tesco gave away 8 million bananas, 6.5 million apples, and 5.5 million oranges (Tesco PLC, 2017).

4.6 Broccoli and cauliflower

<table>
<thead>
<tr>
<th>Benefit of Consumers Reduce Fruit and Vegetable Waste</th>
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</thead>
<tbody>
<tr>
<td>Benefit of refrigeration vs loose at 22°C</td>
</tr>
<tr>
<td>Retains freshness and quality for at least 5 days longer</td>
</tr>
</tbody>
</table>
The post-harvest life of broccoli ranges from 3 - 21 days depending on storage conditions. The recommended storage of broccoli and cauliflower is in plastic bags and refrigerated at 4°C.

A 2010 study tested different forms of packaging for cauliflower and found that High-Density Polyethylene (HDPE) bags with perforation preserved curds the longest. HDPE perforated bags, combined with storage at 0°C, maintained cauliflower quality at ‘excellent’ for 14 days and ‘very good’ after 21 days. This compares to unwrapped cauliflower stored at the same temperature that was rated ‘fair’ after 14 days and ‘poor’ after 21 days. The same study found that cling wrap, though beneficial in reducing weight loss in cauliflower curds, also prompted more spoilage overall. Cling wrap is therefore not recommended for cauliflower (Dhall R. K., Effect of Packaging on Storage Life and Quality of Cauliflower Stored at Low Temperature, 2010).

Research conducted in 2002 found that refrigerating broccoli at 4°C maintained its shelf-life for 10 days, regardless of whether the heads were stored in MAP or open boxes. When stored at 20°C, plastic bags extended shelf-life by up to 4 days as compared to the unwrapped vegetables (7-day overall shelf-life and 3 days, respectively). After 3 days’ storage in plastic bags, however, the oxygen in bags stored at 20°C had declined to zero, which triggered anaerobic respiration and a subsequent, rapid decline in quality (Rangkadilok, 2002).

With regards to home storage, a New Zealand study found that the most effective means of storing broccoli was to spray the head with water, wrap it in a paper towel and store it in a re-usable ‘snap-lock’ bag in the fridge. This kept the heads in ‘acceptable/almost perfect’ condition for 4 weeks. Other effective methods included wrapping the broccoli in a plastic bag and keeping it in the crisper drawer. The least effective methods were keeping the broccoli unwrapped in the fridge and covered in cling wrap. The effect of keeping broccoli unwrapped in the crisper drawer or wrapped solely in paper towel, were not tested (Goodman-Smith, 2017).

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32 The state of being turgid or swollen, especially due to high fluid content. Turgidity is essential in plant cells to make them keep standing upright. Plant cells that lose much water have less turgor pressure and tend to become flaccid.

33 The head or edible white flesh, sometimes called “curd” (with a similar appearance to cheese curd).
Broccoli and cauliflower are already available to buy loose in the UK. In 2009, it was reported that retailers were researching ways to extend broccoli and cauliflower shelf-life without primary packaging, including using a MAP liner in distribution. Storing broccoli in a paper towel and re-usable plastic bag may be an effective means of preserving product bought free flow and is likely to enjoy a longer shelf-life than shrink-wrapped alternatives (Goodman-Smith, 2017).

4.7 Carrots

| Helping Consumers Reduce Fruit and Vegetable Waste |
|---------------------------------------------------|-----------------------------------------------|
| Benefit of refrigeration vs loose at 22°C         | Benefit of refrigeration in bag vs loose at 22°C | Difference (days) | Details |
| Retains freshness and quality for at least 14 days longer | Retains freshness and quality for at least 17 days longer | 3 | Carrots stored at 22°C for 4 days were inedible due to the presence of soft rots (when stored in bags) or dehydration and skin necrosis (when stored without bags). Carrots stored well in the fridge for 21 days. The use of the polyethylene tied bags was beneficial in reducing weight loss and maintaining the turgidity of carrots although this did not affect the firmness of the roots. These results confirm the advice provided by retailers that carrots should be stored under refrigeration. It is advised that carrots should be stored in bags to minimise dehydration and preserve the turgidity that citizens associate with freshness and to reduce the likelihood of wastage. |

Carrots are the second most wasted vegetable in the UK with 73,000 tonnes thrown away by UK households every year. 58,000 tonnes of this waste are caused by carrots not being used in time (WRAP, 2014). Maintaining a longer shelf-life for carrots may therefore be beneficial to reducing waste.

A 2013 study found that maintaining a high relative humidity is important for prolonging carrot shelf-life. Unpacked carrots or carrots packed in paper bags, which does not provide a high-humidity environment, experience 'rapid losses of nutrients during marketing’ (Seljasen, 2013). However, the study found that MAP and controlled atmosphere packaging can also be detrimental to carrots, as O₂ permeability is necessary to maintain a healthy environment. By contrast, storing carrots at 4°C with a relative humidity (RH) of 90% was found to keep carrots fresh for up to 2 months (Zhang, 2005). This storage was effective in cartons with or without plastic liners. However, carrots were found to brown faster at room temperature the longer they were kept in cold storage. Maintaining shelf-life at the marketing stage therefore relies on keeping carrots at low temperatures throughout the supply chain.

Research from New Zealand broadly cohered to these findings, though with different timescales - the unwrapped, refrigerated carrots were dry, bendy and starting to brown within four days of storage. Carrots wrapped in a bag in the fridge remained of good sensory quality (slightly dry, but still rigid) after 29 days. The study also found that bags were not as effective for maintaining quality as re-usable containers: wrapping carrots in paper towel, placing in an airtight container and storing in the fridge kept carrots in ‘perfect’ condition for
up to 4 weeks. This was 10 times longer than the unwrapped, refrigerated carrots (Goodman-Smith, 2017).

Developments in edible films and bioactive packaging have presented possible new ways of extending carrot shelf-life. A report in the *Journal of Food Science* found that an ‘edible’ film composed of chitosan and casein (whey) polymers may be potentially beneficial as antimicrobial packaging for carrots (Moreira, Antimicrobial Effectiveness of Bioactive Packaging Materials from Edible Chitosan and Casein Polymers: Assessment on Carrot, Cheese, and Salami, 2010).

A plasticised blend of wool keratin, citric acid and water has also been tested on carrots as a biocidal film. Cut carrot pieces were preserved for up to 51 days when wrapped in the film and stored at 20°C. This compared to 11 days for carrot pieces wrapped in PET film and unwrapped samples (Diego, 2017). The sample size in this study was very small and the carrots were cut rather than whole, however the results suggest that further investigation into such biocidal films might benefit the shelf-life of carrots, and act as an alternative to fossil-based plastic.

Carrots are already sold loose in most UK supermarkets, as well as in HDPE/LDPE bags. A shelf-life of several weeks is achievable during home storage without plastic, however for this to happen without an increase in food waste, removal of packaging would need to be combined with alternative storage advice.

4.8 Cucumbers
Cucumbers are largely sold either free-flow or shrink-wrapped in the UK. Storage advice varies across retailers, recommending either storing in the fridge or at ambient temperatures. In supermarkets, cucumbers tend to be stored at 10 - 12°C (WRAP, 2008).

One study found that cucumbers fare significantly better when stored at 12°C compared to a high ambient temperature (31°C), with unwrapped samples maintaining their shelf-life for 9 days and 2 days respectively (Dhall, Sharma, & Mahajan, 2012). When shrink-wrapped as well, cucumbers could last for up to 15 days at 12°C and 6 days at 31°C. Shrink-wrapping has also been shown to reduce spoilage caused by chilling when cucumbers are stored in the fridge and a 2014 study found that cucumbers stored in perforated MAP could last for 12 days at 1°C (Manjunatha & Anurag, 2014).

Potential alternatives to shrink-wrapping which offer the same benefits to shelf-life have not, as far as this review can discover, been investigated. Further research is needed.

4.9 Retailer evidence: Co-op (cucumbers)
A live trial was carried out comparing wastage rates on wrapped and unwrapped cucumbers with 40% of production being wrapped. This was a large-scale trial making the results statistically valid. The waste on wrapped over the 4 weeks averaged 1.33% and unwrapped 4.77%.

Sales data from Newhouse (wrapped) and Lea Green Depots (unwrapped) was used to assess the relative impact on sales comparing the 4 weeks before the change to the 4-week trial period. Both showed an uplift in sales with Newhouse showing +21.28% and Lea Green +20.56%. This supports the view that customers had no strong preference between wrapped and unwrapped.

The carbon impact was also calculated using WRAP data.
### Helping Consumers Reduce Fruit and Vegetable Waste

<table>
<thead>
<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retains freshness and quality for at least 7 days longer</td>
<td>Pre-packed produce used in the trials</td>
<td>n/a</td>
<td>Where grapes were stored in ambient temperatures or fridges with bagged produce comparable weight losses occurred in fruit kept at 22°C for 4 days (3.2%) and in the fridge for 11 days (3.1%); an extension in storage life of 7 days. A similar extension in storage life was indicated by comparing weight loss data for grapes stored with produce without bags. Weight loss in grapes stored for 4 days at 22°C (1.9%) was like that after 14 days in the refrigerators (1.6%). Clearly, the advice supplied by retailers to refrigerate needs to be observed for maximising freshness and storage life. Although all grapes were stored in their original plastic pouches, the weight loss was higher when they were stored with other bagged products. As expected, the relative humidity of the air in fridges containing bagged product was lower than where un-bagged product was stored. This would have accelerated the loss of weight from within the bags of grapes. The same effect was likely in the trays of product at ambient (22°C) temperature.</td>
</tr>
</tbody>
</table>

Very little research has been conducted into how grapes might be stored without plastic packaging. With their soft outer skin and high-water content, grapes are delicate and prone to being squashed or otherwise damaged during transit and storage. WRAP research and retailer storage advice both recommend keeping grapes in the fridge, where their shelf-life can generally be extended by up to 8 days compared to room temperature (WRAP, 2008). This research kept the samples in their original (bagged) packaging, so it is unknown how grapes would fare in an un-bagged state. However, grapes fare better when stored at high relative humidity. More research into what might take the place of plastic in delivering this function is needed.

Some research from Israel has proposed using cardboard boxes without liners, wrapped in LDPE, for short-term storage and shipping (Lichter, 2016). Cardboard boxes could replace current use of plastic trays at the retail stage. This would maintain the protective benefits of packaging for grapes. Other plastic substitutes suggested are NVT-100 and a film developed...
from gelatine and corn starch. NVT-100 is a biodegradable, polyester-based, monolayer film which was found in a 2009 experiment to be as effective as nylon and polyolefin (NP) in the preservation of grapes (Nobile, 2009). Meanwhile, an ‘edible’ film composed of gelatine, corn starch and sorbitol was effective in preserving the shelf-life of cv. ‘red crimson’ grapes. The study suggested that this new film could act as a viable alternative to petrochemical plastics. Citizen responses to gelatine-based packaging were not investigated (Fakhouri, 2015).

More research is needed both into grape shelf-life under different storage conditions, and potential packaging alternatives to conventional plastic bags and trays.

4.11 Lettuce (and salad leaves)

44,000 tonnes of lettuce and 21,000 tonnes of leafy salad are thrown away by UK households every year. Most of this disposal was prompted by the lettuce having an off-looking or slimy appearance (WRAP, 2008).

Research into salad shelf-life has largely focused on pre-cut/pre-prepared leaves, rather than unprocessed/whole lettuces. Pre-cut and minimally processed salad is a convenience food and would be impractical for most retailers to sell loose; thus, research in this area has focused on MAP and extending shelf-life through packaging. Waitrose did take steps to reduce packaging on their pre-prepared salads by thinning its salad bags, though more information on the impact of this (both on salad preservation and reduction in plastic waste) is needed (Meier, 2018).

In terms of whole lettuces, only research from the University of Otago, New Zealand, has been found which explores storage methods in the home. Of the storage methods tested, the most effective were:

- Wrapping lettuce in a (dry) paper towel, placing in a Snaplock bag in the fridge; and
- Using a lettuce crisper (a covered bowl with a raised grid at the base to allow air flow).

Both these methods kept lettuce fresh for up to 4 weeks – 4.5 times longer than storing lettuce unwrapped in the fridge. Other effective methods included storing lettuce in a plastic bag or unwrapped in the crisper drawer. Interestingly, keeping the lettuce in the crisper drawer of the fridge was as effective as storing in a twist-closed plastic bag (after 28 days, 69% of both lettuces were still edible) (Goodman-Smith, 2017). Lettuces tend to be sold wrapped in film or PE bags in the UK. Potential alternatives could include refrigerated storage during the retail stage and storage in the fridge crisper drawer at home. An alternative to plastic packaging while in transit would need to be investigated.

4.12 Kiwi fruit

<table>
<thead>
<tr>
<th>Helping Consumers Reduce Fruit and Vegetable Waste</th>
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<tbody>
<tr>
<td>Benefit of refrigeration vs loose at 22°C</td>
</tr>
<tr>
<td>Retains freshness and quality for at least 4 days longer</td>
</tr>
</tbody>
</table>
softening by 4 days (shore readings after 7 days at 22°C (59.1) and 11 days in the refrigerators (58.4) were similar). It is reasonable to equate loss of firmness with storage life and to suggest that refrigeration will extend storage life by 4 days either with or without the use of the polyethylene bags. Fruit stored in bags at 22°C was particularly soft possibly because of ethylene accumulation. However, there was no effect of the bags on firmness of the fruit stored under refrigeration. The advice supplied by retailers to refrigerate kiwi fruit was supported by these results. The use of bags reduced weight loss of kiwi fruit stored in the fridge but even in un-bagged product, the weight loss was less than 2% of the original weight after 21 days and did not affect the quality of the product. Since there was no adverse effect of bags where the fruit was stored in the fridge, it would appear convenient to purchase and store kiwi fruit in the tied polyethylene bags provided by the retailer.

4.13 Lemons

<table>
<thead>
<tr>
<th>Helping Consumers Reduce Fruit and Vegetable Waste</th>
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</thead>
<tbody>
<tr>
<td>Benefit of refrigeration vs loose at 22°C</td>
</tr>
<tr>
<td>Retains freshness and quality for at least 7 days longer</td>
</tr>
</tbody>
</table>
### 4.14 Melons

<table>
<thead>
<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retains freshness and quality for at least 10 days longer</td>
<td>Retains freshness and quality for at least 10 days longer, and reduces weight loss</td>
<td>None</td>
<td>In view of the lack of any beneficial effects of bags on fruit quality and the development of ‘musty’ smells in melons not kept under refrigeration, the use of bags for melons may be inappropriate.</td>
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</tbody>
</table>

### 4.15 Mushrooms

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<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retains quality (reduced browning) for at least 9 days longer, BUT ideally use paper bag</td>
<td>Retains quality (reduced browning) for at least 2 days longer, BUT ideally use paper bag</td>
<td>-7</td>
<td>Mushrooms are highly perishable, being subject to rapid dehydration and oxidative browning. In the absence of purpose-designed paper bags, mushrooms were stored in polyethylene tied bags, which was unlikely to be ideal for storage in the home. After 4 days at 22°C the mushrooms were discarded. Although the bags almost completely prevented weight loss there was condensation of water in the bags and the mushrooms were brown and affected by rot lesions. Although mushrooms stored at 22°C without bags were not rotten they were brown and desiccated and unfit for use. Storing mushrooms under refrigeration delayed browning and opening of the caps and extended the storage life to 4 days (with bags) or 11 days (without bags). Although the polyethylene tied bags prevented some weight loss, the build-up of condensation in the bags resulted in the mushrooms being wet and encouraged the development of rots and off-odours. Mushrooms stored in the fridge without bags for 11 days were considered edible despite their dry, brown appearance. Clearly, the advice supplied by retailers to refrigerate mushrooms was fully endorsed.</td>
</tr>
</tbody>
</table>
Polyethylene tied bags are unsuitable for storing mushrooms and that paper bags designed specifically for mushrooms and normally available in retail shops are likely to be most appropriate for storage.

4.16 Onions

<table>
<thead>
<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>None</td>
<td>N/a</td>
<td>Onions stored well over the 21 days of the experiment regardless of temperature, light and irrespective of the use of polyethylene bags. Although weight loss increased with higher storage temperatures the weight loss at 22°C over a 21-day period was less than 2% of the original weight. Some slight rooting was noted on onions stored in the crisper compartment of the fridge (with and without bags). Although this had no effect on the quality of this sample the effect may be more significant for other consignments with an enhanced capacity for root development. The presence of condensation in the crisper and in the bags would not be considered ideal for onions which are normally stored in a relative humidity of 65 - 70%. It appears unnecessary to store onions under refrigeration or to use polyethylene tied bags. The advice provided to citizens by retailers to store onions in a cool place that is preferably dry and dark would seem to be appropriate.</td>
</tr>
</tbody>
</table>

Onions are sold loose, in PE bags and net bags (generally in lines of three) in UK supermarkets (WRAP, 2011). The post-harvest life of onions is relatively long depending on storage conditions. Research on behalf of WRAP found that onions benefit from cool (15°C) storage in the home, where they fare better than either warm (22°C) or refrigerated conditions. The most crucial factor was limiting light exposure, which encouraged sprouting (WRAP, 2008) – see above.

Post-harvest life of onions can range from 21 - 300 days with a mean storage life of 120 - 160 days. Shelf-life ranges from 5 days (at the end of the growing season) to 10 days (WRAP, 2011).
Very little research into the packaging and preservation of whole onions has been conducted in the last two decades. This may be because, post-harvest and after commercial storage, onions keep relatively well in most conditions. WRAP research found that PE bags made very little difference to storage-life at home and that onions remained usable after 21 days whether stored at 22°C, 15°C or in the fridge, with or without PE bags (WRAP, 2008). There is some debate as to whether plastic bags are detrimental to onions in comparison to net packaging, given the restricted air flow. Vertical form-fill bags can result in increased waste at the packing stage, as the product is subject to bruising. Further research into onion storage may be beneficial, however there does not seem to be any significant negative impact from storing and selling onions loose.

4.17 Oranges

<table>
<thead>
<tr>
<th>Helping Consumers Reduce Fruit and Vegetable Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit of refrigeration vs loose at 22°C</td>
</tr>
<tr>
<td>Retains freshness and quality for at least 14 days longer</td>
</tr>
</tbody>
</table>

Citrus fruits are relatively robust due to their thick outer skin and low respiration rates, though soft citrus (easy peelers, satsumas etc) are more susceptible to bruising and other damage. Shelf-life for citrus tends to be 7 - 9 days (WRAP, 2011).

Suppliers have noted that films and nets do not protect fruit any better than when stored loose (WRAP, 2011). Storing oranges at 5°C prolongs their shelf-life by up to 14 days, with or without packaging (WRAP, 2008). The main benefit of packaging in this case, therefore, is convenience for the citizen and reduced risk of damage while in transit. However, when oranges are stored at room temperature (22°C), PE bags can reduce weight loss through respiration (WRAP, 2008).

To reduce respiration and prolong shelf-life, researchers in Australia and Scotland have tested a bio-composite, edible coating for cv. Valencia oranges. A pea starch, guar gum, shellac and oleic acid composite was found to preserve the fruit’s shelf-life for up to 4 weeks when stored at 5°C, and one week at 20°C. This might constitute an alternative to plastic packaging in some cases (Saberi, 2018).
### 4.18 Pears

<table>
<thead>
<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retains freshness and quality for at least 14 days longer</td>
<td>Reduced weight loss of pears stored at 22°C</td>
<td>None</td>
<td>To prevent ripening of pears in commercial storage, it is necessary to maintain storage temperatures below 0°C. Pears removed from store and placed in ambient temperatures of 20°C will normally ripen in 5 - 7 days. Consistent with this pattern of effects, the pears used in this experiment were judged to be fully ripe after 7 days at 22°C and no further examinations were made. Storing the pears in the fridge markedly slowed their ripening. The use of bags reduced weight loss of pears stored at 22°C but not of fruit stored in the fridge where weight loss over a 21-day period was only 1% or less of their original weight. The advice provided by retailers to store in the fridge or under cool conditions is therefore endorsed by these results. Storage in the fridge will extend the storage life in the home.</td>
</tr>
</tbody>
</table>

### 4.19 Peppers

<table>
<thead>
<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retains freshness and quality for at least 10 days longer</td>
<td>Retains freshness and quality for at least 14 days longer</td>
<td>4</td>
<td>The major problem with the storage of sweet peppers was dehydration and associated loss of turgidity and eventual shrivelled appearance of the product, which is likely to result in rejection by the citizen. Storage at 22°C resulted in a higher weight loss compared with storage under refrigeration. The use of polyethylene tied bags was highly effective in reducing weight loss both in ambient conditions (22°C) and in the fridge. Peppers kept at 22°C without protection from bags were discarded after 11 days when they had lost 12.8% of their original weight and were considered too shrivelled to be acceptable. Peppers kept in the fridge without protection from bags were</td>
</tr>
</tbody>
</table>
discarded after 21 days when they had lost 9.6% of their original weight and again were considered too shrivelled to be acceptable. These results confirm the advice provided by retailers that peppers should be stored under refrigeration. It is advised that peppers should be stored in bags to minimise dehydration and preserve the turgidity that citizens associate with freshness and to reduce the likelihood of wastage.

The main cause of perishability in peppers is weight loss and shrivelling due to high levels of respiration (WRAP, 2008) – see above.

Research conducted in India in 2014 tested different forms of plastic packaging for bell peppers at both refrigerated and ambient temperatures (Sahoo, 2014). The study found that keeping bell peppers refrigerated at 4°C in polypropylene (PP) wrap was the most effective form of packaging, keeping the product at marketable quality for 20 days. Perforated LDPE maintained a similar shelf-life. This compared to just 4 days for peppers kept unwrapped in the fridge (Sahoo, 2014). This contrasts with WRAP research, which found that unwrapped sweet (bell) peppers could last up to 21 days in the fridge (WRAP, 2008).

A further study from India found that peppers might be preserved for up to 7 weeks when refrigerated and kept in MAP with silica sachets. MAP and refrigeration alone maintained peppers’ quality for 6 weeks, compared to 2 weeks for unwrapped peppers stored at ambient temperature and 3 weeks for unwrapped, refrigerated peppers (Singh, 2014). These results broadly cohere, in that they all found that packaging and refrigeration were beneficial for product shelf-life. However, further research is needed to understand the discrepancy in results regarding the lifespan of unwrapped peppers.

Sweet peppers are generally sold in the UK in PE bags, flow wrap or loose. There has been some research into alternatives to plastic packaging for peppers, though again the field would benefit from further investigation. Chitosan-based film was tested as a substitute for LDPE packaging in 2006 (Srinivasa, 2006). The film was shown to reduce weight loss by up to 4% compared to unpackaged product, however was not as effective as LDPE (10 - 11% weight loss in chitosan packaging, compared to 2 - 2.5% WL in LDPE). However, with recent developments in composite bio-films, more effective alternatives to conventional plastics may now be available.

4.20 Pineapples

<table>
<thead>
<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>None</td>
<td>N/a</td>
<td>As expected, the storage life of pineapples at 15 - 22°C was short (4 - 7 days). It was difficult to judge when pineapples were no longer acceptable, but generally after 4 - 7 days the areas that comprise the leaf base and the base of the fruit were soft and</td>
</tr>
</tbody>
</table>
brown. Storage in bags promoted mould growth on the leaves and imparted a general ‘musty’ smell. The colour of un-bagged fruit was a brighter orange than bagged fruit. Bags tended to reduce weight loss although due to limited replication the effect just failed to reach significance at the 5% level of probability. The most successful storage treatment was the cooler temperature (15°C) with no bags. However, with only one pineapple represented per treatment it is only marginally appropriate to apply statistical tests and results should be treated with caution. Citizens need to be aware of the perishable nature of pineapples and maintain cool temperatures prior to consumption. The use of bags is not advised.

### 4.21 Potatoes

#### Helping Consumers Reduce Fruit and Vegetable Waste

<table>
<thead>
<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>None without the use of a bag. Faster loss of moisture in fridge loose versus loose at 15°C</td>
<td>Use of bag, either at room temperature or in the fridge retained freshness and quality for at least 10 days longer. CURRENT FSA ADVICE ON POTATO STORAGE IS THAT THEY ARE NOT STORED IN THE FRIDGE IF INTENDING TO COOK THEM AT HIGH TEMPERATURES, SUCH AS BY ROASTING OR FRYING</td>
<td>N/a</td>
<td>After only 4 days of storage in the light at 15°C and 22°C potatoes had developed significant greening. It is anticipated that with the normal cycling of day and night the potatoes would have taken longer to green than under the conditions of the experiment where light was applied continuously. Where potatoes were kept in the dark, no greening developed over a 21-day period irrespective of storage temperature. The advice provided to citizens by retailers to store potatoes in a dark place was supported by these results. Potatoes stored without polyethylene bags lost water readily and eventually the texture of the tubers was described as spongy or rubbery. Potatoes stored at 22°C for 21 days without bags were considered too rubbery for baking purposes. At this point the potatoes had lost</td>
</tr>
</tbody>
</table>
12.7% of their original weight. The lowest weight loss occurred at 15°C, which endorses the advice provided to citizens by retailers to store potatoes in a cool place. There was no effect of light on weight loss. It is clear that potatoes should be stored in the dark and the use of polyethylene tied bags is essential to prevent excessive moisture loss, which could lead to wastage. Although refrigeration is not essential, the quality of the potatoes from the fridge was slightly superior to those kept at higher temperatures, where slight sprouting was evident, particularly where bags were used.

The two critical environmental factors involved in properly storing potatoes are temperature and humidity. Adequate and unrestricted air movement is also necessary to maintain constant temperature and humidity throughout the storage pile, and to prevent excessive shrinkage from moisture loss and decay. (R. E. Voss & K. G. Baghott).

Research commissioned by the British Potato Council examined shopper attitudes and perceptions of potato packaging including likes and dislikes, environmental concerns, priorities, on pack messages and differences by life stage. (The Oxford Partnership, 2007).

The research revealed:

- Customers want to see and feel the potatoes;
- Plastic is increasingly anachronistic to today’s citizen;
- Packaging should be as natural as possible; and
- It must be recyclable or compostable – and “say it loud” on pack.

Spontaneous suggestions from respondents on smaller pack sizes indicated loose potatoes are not necessarily a substitute for small packs - many will go without rather than buy loose out of convenience and do not understand why they cannot get small packs.

This study concluded that citizens’ favourite packaging option was a netting bag, but it would have to be ‘recyclable or compostable probably with paper or card rather than plastic’.

Tesco supplier Branston used ‘storage boosting packaging’ (Perfotec.com, 2016) for its bags of salad potatoes for a year prior to rolling out to King Edwards and four-packs of jacket potatoes during 2016. (The latter variety produces one of the highest levels of in-store potato wastage.) The packaging works by slowing down the natural respiration rate of the crop, putting the potatoes ‘back to sleep’ and extending storage life by two days.

WRAP and FSA have been discussing whether the guidance relating to potatoes could be updated. WRAP and FSA have been discussing whether the guidance for home storage of
potatoes could be updated. To help the FSA consider this further, WRAP is co-ordinating an industry research project to provide the necessary evidence. This is due to complete autumn 2019.

Current advice to citizens is not to store raw potatoes in the fridge if intending to cook them at high temperatures, such as by roasting or frying. This is because keeping raw potatoes in the fridge can lead to the formation of more free sugars in the potatoes. This process is sometimes called ‘cold sweetening’.

Cold sweetening can increase overall acrylamide levels, especially if the potatoes are then fried, roasted or baked. Therefore, raw potatoes should be stored in a dark, cool place at temperatures above 6°C.

For further information, visit https://www.food.gov.uk/safety-hygiene/acrylamide

4.22 Spinach

Due to the delicate and disaggregated nature of spinach and other leafy greens, little to no research has been conducted into how they might be sold loose. There are a number of studies into how the shelf-life of fresh greens might be extended through MAP, irradiation and different forms of plastic packaging, but all struggle to extend shelf-life beyond 8 days (Gomes, 2008) (Piagentini, 2002) (Kobori, 2011).

A potential alternative to conventional plastic bags has been investigated, in the form of a film composed of sweet potato starch (SPS), montmorillonite (MMT) nanoclays and thyme essential oil (TEO). The combined antimicrobial and plasticizing effect of TEO and nanoclays kept the packaging durable and the spinach fresh for 8 days (Issa, 2017). Further investigation is needed, but this packaging was found to be as effective as separate studies on LDPE.

4.23 Strawberries

<table>
<thead>
<tr>
<th>Helping Consumers Reduce Fruit and Vegetable Waste</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit of refrigeration vs loose at 22°C</td>
<td>Pre-packed produce used in trials</td>
</tr>
<tr>
<td>Benefit of refrigeration in bag vs loose at 22°C</td>
<td>N/a</td>
</tr>
<tr>
<td>Difference (days)</td>
<td>Strawberries are highly perishable and storage under refrigeration is advised by retailers. After 4 days at 22°C the fruit was inedible due to the presence of fungal rots. Strawberries stored in fridges with bagged products lost more weight than those stored with un-bagged products and remained in an acceptable condition for 11 days compared with 14 days when stored with un-bagged product. Effects of storing packaged strawberries in fridges along with bagged or un-bagged products were like those described for grapes. Although all</td>
</tr>
</tbody>
</table>

34 Two of the fridges [in the trial] contained bagged product and the remaining two contained un-bagged product except for strawberries and grapes, which were stored in their original packaging in all four fridges. The fridges were also 'loaded' with 
strawberries were stored in their original plastic containers, the weight loss was higher when they were stored with other bagged products. As expected, the relative humidity of the air in fridges containing bagged product was lower than where un-bagged product was stored. This would have accelerated the loss of weight from within the containers of strawberries. Clearly, the advice supplied by retailers to refrigerate needs to be observed for maximising freshness and storage life.

<table>
<thead>
<tr>
<th>Benefit of refrigeration vs loose at 22°C</th>
<th>Benefit of refrigeration in bag vs loose at 22°C</th>
<th>Difference (days)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retains freshness and quality for at least 10 days longer, and</td>
<td>Retains freshness and quality for at least 10 days longer, and</td>
<td>3</td>
<td>Refrigeration extended the storage life of tomatoes by slowing the colour change from orange to red and maintaining the firmness of the fruit.</td>
</tr>
</tbody>
</table>

The USDA recommends that strawberries are kept at 0°C and 95% relative humidity, which can maintain shelf-life for up to two weeks (USDA, 2016). The fragility of strawberries and other berry fruits (raspberries, currants etc.) again means that little to no research has been conducted on whether product might be unpackaged. The ‘one punnet’ system is favoured by suppliers and retailers in the UK, which allows for strawberries to be harvested and packaged in ‘ready for shelf’ containers. This reduces the level of handling and thus potential for bruising/other damage (WRAP, 2011). Few innovations in strawberry packaging have been made in the last few years, although heat-sealed film lids (as opposed to conventionally moulded lids) have helped to reduce packaging weight while maintaining shelf-life (WRAP, 2011).

Some strawberries are stored in MAP in the UK, which can have a positive impact on shelf-life by inhibiting development of mould and rot. This benefit is only achieved where temperatures are constant, otherwise MAP can have a negative impact on the fruits (WRAP, 2011). A negative side of punnet packaging is that, during the supply and retail stage, entire punnets are disposed of when only some fruits are past marketable quality. This causes both packaging waste and unnecessary food waste.

No recommendations have thus far been made that support the removal of packaging for strawberries and other berry fruits. However, it has been suggested that bio-plastics could replace traditional PVC wrapping. A 2003 experiment found that films composed of yam starch and glycerol were as effective as PVC wrappings in prolonging shelf-life, with both forms of packaging keeping strawberries fresh for 21 days (Grossman & Mali, 2003). The study used PP trays to hold both samples, however, so further research is needed before conventional plastic packaging can be entirely removed from the product.

4.24 Tomatoes

fats (lard and butter) and products in bottles, jars or cartons. The freezer compartments were loaded with bread (eight loaves per freezer) which was pre-frozen prior to loading.
The firmness benefit was generally more evident from squeezing the fruit than from the objective tests for firmness. Weight loss increased at higher storage temperatures and was reduced significantly using polyethylene tied bags. However, the use of bags did not affect the firmness of the fruit or the visual assessment of quality. The storage of tomatoes in the fridge is considered to impair flavour because of chilling injury. Where the citizen preference is for maximum flavour, it might be pertinent to store under cool conditions rather than in the fridge. However, where the intention is to slow ripening and maximise firmness retention the fridge would be the preferred option. Given the general lack of cool space in most homes, it may be more appropriate to store in the fridge to avoid wasting tomatoes but allowing fruit to warm to room temperature prior to consumption to maximise flavour.

Tomatoes in the UK are currently sold both ‘free flow’ and pre-packed (WRAP, 2011). Free flow tomatoes are associated with higher waste at the retail stage due to the damage caused by citizen handling. The shelf-life of tomatoes is up to 14 days from harvest to end of display and at-home storage life can be up to 11 days at room temperature (WRAP, 2008). WRAP research has found that refrigeration can extend shelf-life by up to 7 days and when stored in the fridge in PE bags tomato shelf-life can be extended to 10 days – see above. This research is broadly supported by an earlier study, where unwrapped tomatoes stored at room temperature lasted for 21 days compared to LDPE-wrapped samples which lasted for 30 (Srinivasa, 2006).

Beyond mishandling, weight loss caused by respiration and development of mould are the two major causes of tomato spoilage. A significant amount of research has been dedicated to reducing these factors, some of which may be beneficial as a substitute to plastic packaging.

Starch and wax-based edible coatings have been shown to reduce weight loss through respiration and thus increase shelf-life. One edible coating, composed of mango kernel starch and sorbitol, kept tomatoes fungus-free at room temperature (25°C and 60% RH) for 18 days (Nawab, 2017). Another experiment found that a surface coating of shellac; aloe vera gel; or a composite of the two can enjoy a shelf-life of 10 days, 8 days, and 12 days respectively (Chauhan, 2015). In this study, the tomatoes were kept in cardboard boxes at 28°C. This is both a high storage temperature and non-plastic packaging, suggesting that such a coating and packaging may pose a viable alternative to plastic. Finally, a carnauba wax coating applied to tomatoes (green at harvesting) helped to reduce weight loss. Waxed tomatoes had a marketable shelf-life that was 6 days longer than unwaxed samples and were less likely to succumb to chilling injury at 5°C (Mejia-Torres, 2009).
In terms of reducing damage through citizen handling and while in transit, some bio-plastics and alternative packaging solutions have been proposed. In October 2017, Waitrose began trialling punnets made of tomato leaf and recycled paper pulp to replace plastic trays in their 'Duchy Organic' cherry tomatoes (Waitrose, 2017). In a 2013 study, micro-corrugated cardboard punnets sprayed with bio-based polylactic acid (PLA) were found to be more effective than conventional plastic trays (García-García, 2013). Both this experiment and the Waitrose punnets are still wrapped in LDPE, however. Alternatives to this film might appear in the form of a film made from intact bitter cassava (IBC). IBC film was tested as a wrapping combined with PP trays for cherry tomatoes. Samples were stored at 10°C and 20°C for 19 and 15 days respectively. Though not as effective as OPP-based film, the IBC-based film nevertheless functioned well as MAP and kept tomatoes at an acceptable colour and weight during the experiment. The tomatoes in IBC MAP achieved atmospheric equilibrium faster than the OPP – within 8 days as compared to 12 (Tumwesigye, 2017).

5.0 Discussion

Any recommendations on which fruit and vegetables are suitable for providing plastic-free/loose will need to be balanced against a potential increase in household food waste therefore, retailers will also need to maximise the opportunities to encourage citizen food waste prevention.

For example: buying loose fresh produce requires customers to decide how much they need to buy, so there is an opportunity for retailers to offer advice to customers on appropriate quantities of loose fresh produce at-fixtures.

WRAP evidence\textsuperscript{35} indicates that the ability to purchase fresh produce loose could be of significant benefit to single-person households, who waste, on average 40% more per capita than other households. This is because they don’t use what they buy in time (and for fresh produce this is mainly due to the food going off before it can be eaten).

Single-person households waste 34% more fresh fruit and vegetables compared to other households (almost 40% more fresh vegetables and 25% more fresh fruit), amounting to an additional 4kg a year of fruit and vegetable waste for single-person households.

There are 7.7 million single-person households in the UK, resulting in an additional 33,000 tonnes of fresh produce waste a year, worth almost £80 million. Greater availability of loose fresh produce could benefit those living in smaller households and reduce this waste.

What the evidence clearly shows is that correct at-home storage is critical to reducing fresh produce waste.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{At_home_store_below_5C.png}
\caption{At home store below 5°C}
\end{figure}

If UK fridges were turned down to less than 5 degrees (and we stored products that are often stored ambiently, such as apples, in there), WRAP estimates there would be £200 million in cost savings and a reduction in CO\textsubscript{2}e emissions of 210,000t considering the additional energy required to do so. The size of the food waste prize is (conservatively) estimated at 70,000t from turning down fridges alone.\textsuperscript{36}

\textsuperscript{35} Household Food and Drink Waste – A People Focus

\textsuperscript{36} http://www.wrap.org.uk/sites/files/wrap/More%20effective%20use%20of%20fridge%20freezer.pdf
Without packaging to carry at-home storage guidance, there is an opportunity for retailers to provide this at-fixure e.g. the Little Blue Fridge (pictured here) and on the packaging provided to contain and carry loose fresh produce. Employees can also be equipped to provide customers with at-home storage advice and there are multiple opportunities in-store, such as till dividers, posters and bags for life; online and via home delivery services: key touchpoints where the retail environment meets the citizen.

Other opportunities to reduce any potential impact on household food waste include:

- Positioning plastic-free ‘meal-maker’ companion products alongside loose fresh produce e.g. cooking sauces, herbs and spices, oils and vinegars to help customers to plan meals and use up what they buy; and
- Position (and demonstrate) at-home storage solutions alongside relevant fresh produce items e.g. re-usable airtight food storage containers.

Pictured below: a glass storage container with a bamboo lid, one of a range from IKEA.
6.0 Conclusion

The findings above suggest that further research is needed in several areas.

The impact of plastic packaging on the shelf-/storage-life of fruit and vegetables versus loose has not been consistently, thoroughly or recently researched for many popular products.

Learnings can certainly be made from retailers’ current practices and these might be supplemented by further investigation of citizen behaviours and packaging innovations.

There is always going to be a need for some fresh produce to be packaged so it is protected, and more research into the different environmental factors and trade-offs between plastics, alternative materials and food waste is necessary. For example: biodegradable materials need specific conditions to decompose and can still end up as marine litter, if not treated properly.

Retailers are encouraged to consider all the environmental impacts when thinking about alternative options. A decision based on one aspect whilst neglecting others can result in unintended consequences.
7.0 Further WRAP research and resources

**Good Practice Labelling**

*Food date labelling and storage advice*

Key information on how to apply food date labels, storage and freezing advice to:

- Ensure food is safe to eat
- Reduce citizen food waste
- Remove barriers to redistribution

**Category Guides:**

- Uncut, packed fruit and vegetables
- Fresh chicken
- Cheese
- Milk
- Yogurt
- Pork, beef and lamb

**Checklists**

Step-by-step best practice guidance on date labels, storage advice, freezing advice and product life

**Labelling Guidance**

Best practice on food date labelling and storage advice

**Food Waste Reduction**


**Household Food Waste**

*Consumer Attitudes to Food Waste and Food Packaging*

- Helping Consumers Reduce Fruit and Vegetable Waste
- Household Food Waste in the UK 2015
- Household Food and Drink Waste: A People Focus
- Household Food and Drink Waste: A Product Focus
- Impact of more effective use of the fridge and freezer
- Review of Literature About Freezing Food at Home
- Reducing food waste through the chill chain Part 1: Insights around the domestic refrigerator

**Supply Chain Waste**

*Extending product life to reduce food waste*

- Quantification of food surplus, waste and related materials in the supply chain report
- Using surplus food in animal feed
Recycling

National Recycling Guidelines
National industry agreement on what can and cannot be collected for recycling from householders and how those materials should be presented for collection

Recycling Tracker
Annual survey of UK households to gather evidence on citizens’ current recycling attitudes, knowledge and behaviour dry recyclables/packaging and food

Recycling on the Go Guidance (England)

Packaging

Analysis of Retailers’ Front of Store Plastic Film Collection

End Markets for Recycled Household Plastic Film

On Pack Recycling Label (OPRL)

Plastic Film Packaging

Recycling Post-Consumer Film Trials

Resources to Enable Recycling of Household Plastic Films

Understanding Plastic Packaging and the Language we use to Describe it

Understanding Reprocessing Technologies and Collection Systems for Plastic Films
**Abbreviations**

CFB  Corrugated Fibre Board  
MAP  Modified Atmosphere Packaging  
NP  A multi-layer film obtained by laminating Nylon and Polyolefin  
NVT-100  A biodegradable polyester-based film  
OPP  Oriented polypropylene  

**Plastics glossary**

**Biodegradable**

A product that can be broken down by microorganisms (bacteria or fungi) into water, naturally occurring gases like carbon dioxide ($\text{CO}_2$) and methane ($\text{CH}_4$) and biomass. Biodegradability depends strongly on the environmental conditions: temperature, presence of microorganisms, presence of oxygen and water. The biodegradability and the degradation rate of a biodegradable plastic product may be different in the soil, on the soil, in humid or dry climate, in surface water, in marine water, or in human made systems like home composting, industrial composting or anaerobic digestion ([www.ows.be](http://www.ows.be)).

Currently biodegradable plastics cannot be recycled in the same way as non-biodegradable plastic. It must be separated from non-biodegradable plastic streams and dealt with separately. If not, it causes problems during the recycling process. Biodegradable packaging needs to be clearly labelled and easy for citizens to identify, separate and correctly dispose of. The route for treatment and disposal must not compromise other existing recycling routes. Biodegradable packaging can only be composted when it meets the appropriate composting standard.

**Compostable**

Compostable materials are materials that break down at composting conditions. Industrial composting conditions require elevated temperature (55 - 60°C) combined with a high relative humidity and the presence of oxygen, and they are in fact the most optimal compared to other everyday biodegradation conditions: in soil, surface water and marine water. Compliance with EN 13432 is considered a good measure for industrial compostability of packaging materials.

Compostable plastics can be composted at industrial scale composting facilities or, in some cases, may be suitable for home composting. It is vital that only compostable plastics are sent to these routes as non-compostable plastics can contaminate the final compost produced. Compostable plastic packaging needs to be clearly labelled and easy for citizens to identify, separate and correctly dispose of in an appropriate collection and recycling scheme for compostable plastics. The route for recycling compostable packaging must not compromise nonbiodegradable recycling routes.

**PBAT and PBS**

Polybutylene adipate terephthalate and Polybutylene succinate – two biodegradable polyesters ([Muthuraj et al 2014](#)).

**PE Polyethylene**

A type of resin and a polyolefin and one of the world’s most widely produced synthetic plastics. High density PE is used for milk bottles, bleach, cleaners and most shampoo bottles. Low density PE is used for carrier bags, bin liners and packaging films ([WRAP 2018](#)).
PET Polyethylene terephthalate
A type of resin and a form of polyester; it is commonly labelled with the code on or near the bottom of bottles and other containers. PET has some important characteristics such its strength, thermo-stability, gas barrier properties and transparency. It is also lightweight, shatter-resistant and recyclable (WRAP 2018).

PHA Polyhydroxyalkanoate
A naturally occurring family of biodegradable polyesters (NNFCC 2018).

PLA Polylactic acid
A biodegradable polyester produced from lactic acid, used in wide range of service ware products and as filament for 3D printing (NNFCC 2018). Industry example: PG Tips is using PLA for their tea bags (NNFCC 2018).

PP Polypropylene
A recyclable polyolefin that is commonly used for margarine tubs and microwaveable meal trays, also produced as fibres and filaments for carpets, wall coverings and vehicle upholstery (WRAP 2018).

PTT Polytrimethylene terephthalate
A type of polyester that differs from the common one polyethylene terephthalate (PET) as it contains one more methylene group in the aliphatic chain that links the terephthalic moiety (European Commission Joint Research Centre 2013).

PA Polyamides (Nylon)
Comprise the largest family of engineering plastics with a very wide range of applications. Polyamides are one of the major engineering and high-performance plastics because of their good balance of properties. Polyamides are very resistant to wear and abrasion, have good mechanical properties even at elevated temperatures, have low permeability to gases and have good chemical resistance, good dimensional stability, good toughness, high strength, high impact resistance, good flow.

Starch blends
The majority of bio-based plastics are currently manufactured using starch as a feedstock (around 80% of current bio-based plastics). The current major sources of this starch are maize, potatoes and cassava. Other potential sources include arrowroot, barley, some varieties of liana, millet, oats, rice, sago, sorghum, sweet potato, taro and wheat (BPF 2018).

PLC Polycaprolactone
A biodegradable polymer that is suitable for applications requiring years of stability. In recent years it is becoming of increased interest to manufacturers of medical devices and drug delivery particles (polysciences.com 2018).
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