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Fruit and Vegetable Resource Maps: Mapping Fruit and Vegetable Waste through the Wholesale Supply Chain

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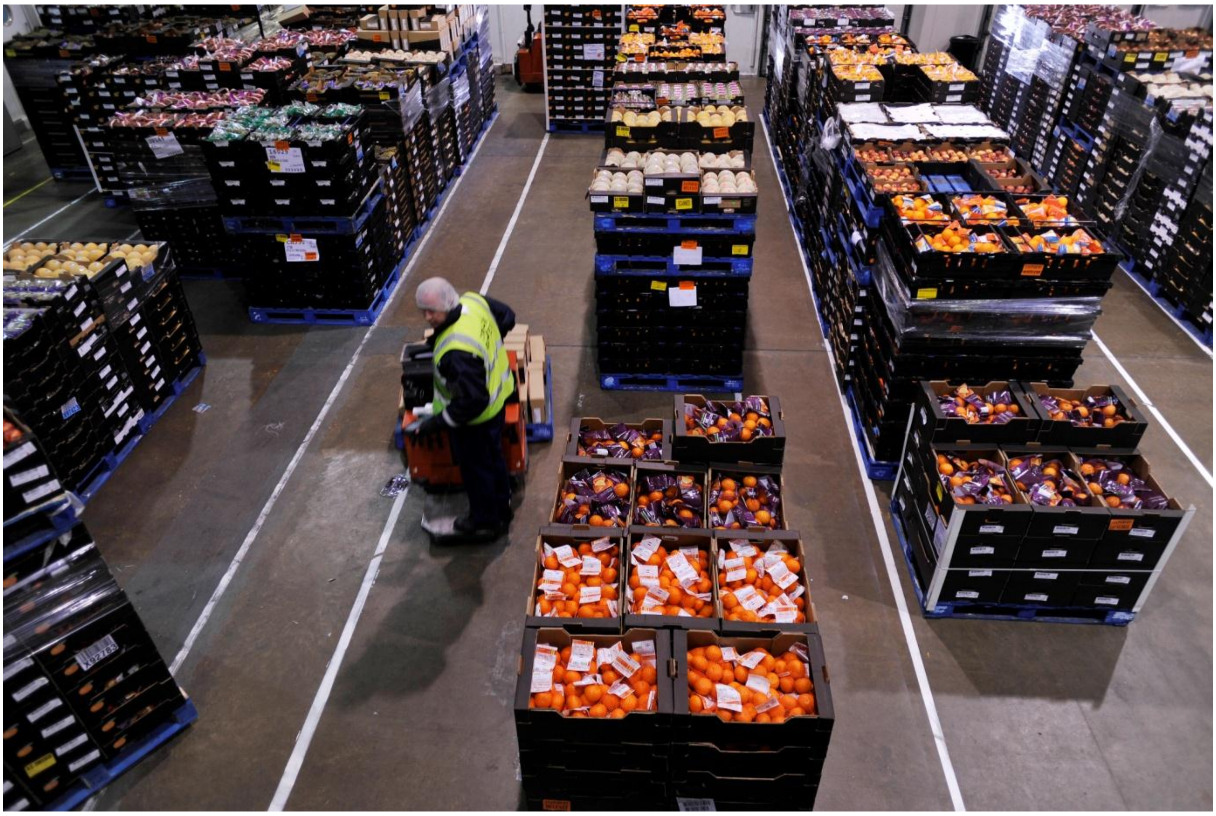
Fruit and vegetable resource maps



Mapping fruit and vegetable waste through the retail and wholesale supply chain.

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WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

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Front cover photography: View of goods being prepared for retail distribution at Mack Multiples

Executive summary

Research by WRAP[1] has shown that households waste around three million tonnes of fruit and vegetables per year, raising concerns about the economic and environmental impacts of food waste. This study has been conducted to quantify the level of loss and waste of fruit and vegetables before they reach consumers, through the retail and wholesale supply chain. Furthermore, the study determined how, where and why the product was wasted.

Eleven fresh produce types were selected based on their consumption, post-harvest physiology and management. The 11 products chosen were strawberries, raspberries, tomatoes, lettuce, apples, onions, potatoes, brassicas, citrus, avocados and bananas; these being representative of fresh produce categories consumed in the UK. The research focused on the retail and wholesale supply chains from field (UK grown products only) to final (retail) customer.

Through structured interviews, lasting around an hour each, over 45 UK fresh produce suppliers, wholesalers and retailers were asked for their views on the causes, level and destination of waste for the 11 products studied in this research. In addition to the interviews, secondary data on waste was collected by tracking specific fresh produce consignments through the supply chain, which provided a valuable sense-check on the data provided during the interviews; both have been used to inform this report.

Key Findings

The level of loss and waste from field to retail store together with views about the causes of fresh produce waste have been collated into 11 resource maps. Each resource map shows the levels of loss and waste at each stage of the supply chain, the main causes and how loss and waste are managed. The resource maps each comprise a chart showing the main flows together with a detailed discussion of key supply chain management practices for each product. They represent a benchmark for each product sector and can be used to develop resource efficiency strategies.

A summary of percentage loss and waste identified through this research is provided in Table E1. Taken as a whole, loss and waste in the supply chain is typically less than 10%, though it can approach 25% for some products.

Table E1: Summary of resource maps detailing percentage loss and waste for eleven different fruits and vegetables through the supply chain.

Product	Field loss (Central range)	Grading loss	Storage loss	Packing loss	Retail waste
Strawberry	2-3%	1%	0.5%	2-3%	2-4%
Raspberry	2%	No data	No data	2-3%	2-3%
Lettuce	5-10%	No data	0.5-2%	1%	2%
Tomato	5%	7%	No data	3-5%	2.5-3%
Apple	5-25%	5-25%	3-4%	3-8%	2-3%
Onion	3-5%	9-20%	3-10%	2-3%	0.5-1%
Potato	1-2%	3-13%	3-5%	20-25%	1.5-3%
Broccoli	10%	3%	0%	0%	1.5-3%
Avocado	No data	30%	5%	3%	2.5-5%
Citrus	No data	3%	No data	0.1-0.5%	2-2.5%
Banana	No data	3%	No data	0-3%	2%

NB. For presentational purposes the stages in the supply chain are shown sequentially. In practice, harvested product will either be graded and packed for immediate sale or where appropriate stored and then graded and packed. As a result the data for all stored products cannot be used cumulatively.

[1] *Household Food and Drink Waste in the UK, WRAP, 2009*

The results (Table E1) show that the level of waste at any single stage of the supply chain varied but was generally between 1% and 3%. For certain products however, loss is more significant at different points in the supply chain. For lettuce, apples and broccoli, loss is most significant at the field end of the chain. At grading, loss is most significant for onions, apples, potatoes and avocados. In storage, weight loss is significant for onions and potatoes. The majority of losses, at these stages, will result in product being sent to an alternative market to the one intended, or it will be ploughed back into the field or sent for animal feed, with very small proportions being disposed to landfill or energy recovery. Packaging will usually be recycled but where it cannot be segregated, may be disposed of as mixed waste to landfill.

Across the products studied, the levels of waste at retail were low at between 1-3%, with products that are susceptible to physical damage and which have high variable demand being those most prone to producing waste. Consequently, the level of retail waste was highest for strawberries, raspberries and avocado and lowest for onions. Although levels of waste are generally low, the majority of waste arising back of store will be disposed to landfill, in-vessel composting or for energy recovery to anaerobic digestion. This waste presents a significant opportunity for both waste prevention and diversion. WRAP's report[2] indicated that of the total retail waste produced some 361,800 tonnes (25%) is food waste. Furthermore, an analysis of waste management routes by material type in the same report noted that for the retail and distribution waste streams, 64% (234,000) is food waste that is sent to landfill or other disposal routes.

Generally, the majority of retail waste was disposed to landfill[3], although all interviewees had plans to divert their food waste into other disposal routes. Downgraded or damaged products can be offered to consumers at a lower price, made available to staff or given to organisations like Fareshare. Some interviewees were also progressing plans to divert waste to anaerobic digestion and were taking advantage of machinery to segregate packaging from product. However, no figures were collected through this research regarding how much waste is treated through anaerobic digestion compared to that being sent to landfill. With rising landfill tax costs, these options are becoming increasingly cost competitive for retailers and suppliers to pursue.

According to Sainsbury's:

'We are making significant progress in generating energy from our waste as part of our zero food waste to landfill programme. Since autumn 2008, the food waste from 38 of our supermarkets and our Northampton Depot has been sent for anaerobic digestion where it is broken down into fertiliser and methane gas, used to generate electricity. Following success of this trial, our zero food waste to landfill programme is now being rolled out to all supermarkets by the end of 2009. This will reduce the amount of food waste we send to landfill each year by 56,000 tonnes.

While anaerobic digestion is our preferred option for generating energy from food waste, there are not yet enough sites operating within the UK. We plan to connect a further 160 stores to an anaerobic digestion plant by the end of 2009. Dependent on the availability of suitable sites we aim to send all food waste from supermarkets, depots and convenience stores to anaerobic digestion by 2012.'

Source: Sainsbury's CSR Report

Causes of waste in the supply chain

The four most significant causes of waste and loss identified through the research are:

- Products that do not achieve their intended market outlet because, for example, they have to be marked down for sale or because they do not meet the required specification. Such products are channelled to manufacturing or wholesale markets and in several cases to animal feed. This type of loss can represent a significant economic loss to business even though it reflects an efficient use of the product because it is being channelled into its next best market rather than being disposed of.
- Field losses, where the volume of product that is harvested is less than that which was planted. In some cases field loss also relates to the potential yield based on utilising the optimum amount of product if all growers performed in line with the best. Field loss may arise because of weather or diseases and harvesting

[2] *Waste Arisings in the Supply of Food and Drink to UK Households, WRAP, 2010*

[3] *While informing the review that their waste did go to landfill, the majority of retailers were unwilling to disclose just how much waste went to landfill and no specific data was made available on the proportion or amounts of product sent to landfill or to other waste destinations.*

damage, for example, as well as through supply chain management practices. Again this is an economic loss to business.
- Storage weight loss related, in part, to the inherent physiology of the fresh produce type (and variety) in question, and the efficacy and appropriateness of the control systems applied throughout the supply chain. Factors such as temperature and ethylene management, horticultural maturity, gaseous composition within store and packaging are known to affect the post-harvest life of many fresh produce types.
- Loss of product because of changes in supply chain management, for example, changes to packaging specifications or incorrect demand forecasting leading to disposal of product either to landfill or anaerobic digestion. Such losses are estimated to equate to the order of 100,000 to 150,000 tonnes or around 5% of the total waste arising. Although precise estimates are not available, disposal to anaerobic digestion is increasing while disposal to landfill is falling.

Using these figures it is possible to compile an estimate for the overall loss and waste arising from UK fruit and vegetable production. To do this the project team used provisional 2008 production figures together with imported quantities for the three products not grown in the UK. To the production figures the research team applied a central estimate for each stage in the supply chain on a product by product basis (based on industry practices), progressively reducing the original production figures with loss/waste at each stage. For the stored products an indicative figure for the combined field, grading and storage loss was used. The resulting figures were then combined with the estimates of field loss and factored to total fruit and vegetable production (and imports). The result is an estimate of overall loss/waste of approximately 2.23 to 2.48 million tonnes for the fruit and vegetable industry, where products either:
- do not achieve their prospective grade;
- are ploughed back into the field;
- suffer loss through storage; or
- suffer loss through inconsistencies in supply chain management.

To a certain extent the waste and loss found through this research has been identified as being caused by natural events and therefore cannot always be controlled by changes in management practices and other levers. However, there remains a significant opportunity to reduce waste and as a result benefit the environment and decrease costs across the supply chain.

Based on the interviewees' comments, the main causes of waste that were identified reflect the biological nature of the product and the difficulties of growing, harvesting and storing such product under optimum conditions; they were:
- disease and insect infestation;
- temperature; and
- crop maturity.

On management factors the following root-causes were identified: waste management responsibilities in the supply chain, information sharing, promotions management, performance measurement and inaccurate demand forecasting e.g. introducing waste by changing monthly and weekly plans.

In the current economic climate, the consequences of wasting food have tended to be more visible for the entire supply chain. Waste has always affected directly the viability and profits of businesses and takes on an increasing profile given the ongoing debate over food security[4]. The context for improved waste management therefore spans economic, environmental and food security considerations.

Recommendations

The following recommendations are not in order of significance. Taken together they offer the fresh produce industry an opportunity to minimise all types of waste, reduce costs and benefit the environment.

- Improve data on waste and loss

At present it is not possible to develop an accurate benchmark that enables comparison across retailers and leads to commercial improvement. Clear accountability is a prerequisite for managing waste. Organisations that have

[4] *The Future of Food and Farming: Challenges and choices for global sustainability. 2011. Government Office For Science, Foresight Report. http://www.bis.gov.uk/foresight/our-work/projects/current-projects/global-food-and-farming-futures/reports-and-publications*

a person responsible for waste management tend to have a much better understanding of the scale and causes of the waste problem. This understanding is a first step for reducing waste. The interviews revealed that some organisations promoted a culture of waste reduction (often because they focused on continuous improvement using lean manufacturing principles) and this culture was driving all other activities in the organisation, such as training, performance measurement and incentives.

- Improve supply chain communications

As any crop grows and matures, good communication along the supply chain is essential particularly if the crop is ahead of or behind schedule because, for example, of weather conditions. This is desirable both to avoid an 'off sale' (low on-shelf availability) but also to find an alternative market – which might involve a promotion - if there are gluts as certain of the products examined cannot be stored for long periods with current technology.

Linked to crop planning is accurate forecasting of customer demand through monthly and weekly plans. Poor forecasting was one of the most common issues identified during the interviews as a cause of waste. However, estimating the demand for a product can be a complex and inherently inaccurate task for some products that can be affected by factors, such as weather, seasonality, marketing campaigns, product launches, promotions and special occasions like Christmas and Easter. The research showed that a variety of forecasting practices exist in the industry, with some companies using a scientific approach while others use more informal methods. At this stage there is not, to our knowledge, any analysis showing which approach or methods are most successful and a more detailed analysis of the 'demand planning' methods may well be beneficial to industry. Improving forecasting practices can reduce forecast error, however, it has to be recognised that uncertainty will continue to exist and that forecast error cannot be eliminated.

- Review consumer specifications

Part of the perceived problem by many throughout this research is that consumer expectations of quality have increased continually. It is inevitable that once customers are offered better quality then they will expect this quality as standard. It could be argued that this perpetual feedback loop needs to be re-examined so that mechanisms can be considered to halt or at least suppress the ever-increasing quality demands imposed on the industry especially in a climate of price deflation. The formulation of policies to improve food security may help to tackle this issue. This research suggests that the losses at grading are not sustainable and are usually based on aesthetic appearance or indeed rudimentary quality control measures (e.g. Brix[5]), which are recognised by the scientific community as not being appropriate for some fruits and vegetables.

It is evident from this research that one of the main criticisms raised by suppliers is the inflexibility of some retailer specifications to take into account natural variability with retailers often citing concerns regarding consumer acceptability. This is particularly the case at the transition between seasons and storage regimes. If natural variability and differences in product quality at key periods in the calendar are not taken into account then there can be greater waste/loss in the field and at grading.

- Work to optimise packaging

In recent years, packaging suppliers have developed optimised packs for the category, for example, reducing the pack weight, using recycled content materials and implementing technologies, such as modified atmosphere or improved seal integrity techniques, to increase shelf life. Although for some products interviewees believed that light-weighting had gone as far as possible, some examples of novel approaches were still being found to further optimise packaging; both to optimise the pack throughout the supply chain and increase shelf-life.

- Promote technology development and knowledge transfer

The use of appropriate technology has a major role to play in reducing fruit and vegetable waste and some novel techniques were identified through this research, e.g. heat sealed punnet lids that reduce pack weight considerably without compromising product protection and also enable the use of Modified Atmosphere Packaging (MAP), which can extend product life post-harvest. In general, however, it is thought that the technological and

[5] *Brix is the measurement of the dissolved sugar-to-water mass ratio of a liquid.*

research base within the EU is underutilised by the industry. It is evident that more could be done to explore cost effective solutions that either transfer good practice from one product to another or are truly novel.

- Increase use of production planning systems

Retailers' replenishment systems have become very sophisticated and are shown to good effect by the high levels of on-shelf availability achieved. In turn, sophisticated production planning systems have been introduced by suppliers to cope and deal with the diversity of product that has been introduced to provide 'a point of difference'. Generally ERP (enterprise resource planning) technology has had a positive impact on reducing waste.

Many fresh produce businesses have invested considerably in this technology to manage large volumes of produce through the production process, whilst meeting the demands of quality, packaging, delivery and traceability standards. For example, by rapidly sharing the quality control results with the grower, the packer can pinpoint quickly any issues regarding quality, enabling the grower to take action to rectify the problem. With real time systems, date related alerts can be sent out pinpointing product that needs moving for dispatch. The benefits of such systems are best realised when the whole chain is involved rather than using them to 'optimise' just one stage in the replenishment process.

Concluding remarks

This research has highlighted the extent to which fresh fruit and vegetables are wasted or lost in the UK's food supply chain. By identifying how, where and why the products are wasted, these resource maps have enabled the identification of where science and better management practices can be used to develop more resource efficient strategies within the fresh fruit and vegetable sector. The project team estimates that about £400-£500 million can be realised through commercial improvements based on the recommendations outlined in this report.

Contents

Glossary and acronyms

- 1-MCP (1-methylcyclopene) [SmartFresh™] – ethylene binding inhibitor principally applied in the UK on some apples.
- 3-in-line – three items packed in a line e.g. three netted onions bulbs.
- Avoidable waste - waste and product damage occurring within the Retail Supply Chain that could be eliminated through the introduction of good practice techniques. For example, through optimising packaging to ensure it is fit for purpose.
- Avoidable food waste - food that could have been eaten if it had been better managed, but is thrown away because it is no longer wanted or has been allowed to go past its best. Examples include an apple or half a pack of cheese. N.B. avoidable food waste is not necessarily edible at the point of disposal, for example a pack of bacon that has passed its use-by date.
- Brix - measurement of the dissolved sugar-to-water mass ratio of a liquid. Used by industry but usually confused with total soluble solids (%).
- Cannibalisation: in this report the term is used to refer to a reduction in sales for one product as a result of a promotion of another.
- CIPC – is a sprout suppressant used on some UK potatoes to increase the period of sprout suppression and thus extend storage life. The chemical is typically applied after harvest as a fog.
- Climacteric - a stage of fruit ripening observed in some fruit species (e.g. apples, bananas and tomatoes) associated with ethylene production and rise in respiration rate. Climacteric is the final physiological process that marks the end of fruit maturation and the beginning of fruit senescence.
- Consumption (in the resource maps) – is defined in its 'economic' sense, i.e. the purchase of fruit and vegetables by consumers.
- Controlled atmosphere (CA) – used to reduce the respiration rate of fresh produce (typically reduced O_2 levels whilst elevating CO_2). Principally used for apples and onions.
- Curing – the process whereby heat is usually applied after harvest for example to onions.
- Cultivar (cv.) is another term for variety.
- CV - coefficient of variation is equal to the standard deviation divided by the mean.
- Downgraded – By-product from the grading process for which an alternative use has been established.
- DPA – diphenylamine is an anti-scalding agent used to reduce superficial scald in apples.
- EfW – energy from waste.
- EPS – expanded polystyrene.
- ERP - enterprise resource planning software.
- Ethylene scrubbers - materials or technologies used to remove ethylene from a storage environment.
- Field heat – the residual temperature of a product in the field. Usually a necessity to cool a product rapidly in order to extend storage life. This is critical for some products such as strawberries and lettuce.
- Forced air cooling – a standard cooling system that uses forced air as a medium for heat transfer. The simplest design is achieved by building parallel stacks of palletised cartons in a refrigerated cold room. A small fan is placed at one end. The exhaust fan removes air from the enclosed space, so that the pressure falls. Cold air then flows through the ventilation slots in each carton (4). Advantages of forced-air cooling are its capital cost, its flexibility (cartons, bins, before or after packing) and lack of condensation. Forced-air cooling is more rapid and even than air-cooling but not as rapid as hydro-cooling or vacuum-cooling.http://www.fao.org/docrep/004/AC300E/AC300e03.htm - top.
- GHG (green house gases) - greenhouse gases absorb solar radiation and contribute to the potential for global warming. The global warming potentials of gases are related to that of CO_2, and are expressed as CO_2 equivalents: CO_2e. The main gases dealt with here are methane and nitrous oxide, which have global warming potentials (GWP) of 25 and 298, respectively, using the 2006 IPCC coefficients.
- Gondola Ends- the free standing shelving units at the end of aisles in supermarkets
- Hydrocooling - involves immersing the produce in cold water. The advantages of this method are speed, uniform cooling and no weight loss by dehydration. Disadvantages include the necessity of drying the product surface after cooling and avoiding a build-up or transmission of disease in the hydro-cooling water.
- Lead time - the amount of time between the placing of an order and the receipt of the goods ordered.
- Loss - product that is not used for its intended purpose and therefore has no (or very little) value. Losses can be incurred for a variety of reasons and at different points in the chain.
- MAP - modified atmosphere packaging is a preservation technique used to extend the shelf life of processed and fresh food by changing the composition of the air surrounding the food in the packaging. The creation of a modified atmosphere within a package (usually higher levels of CO_2 and lower O_2) by the fruit or vegetable is thus reliant on the respiration rate (including temperature effect) of the product and the nature and gaseous permeability of the polymer used.
- MH - maleic hydrazide is a sprout suppressant used on some onions to increase the period of sprout suppression and thus extend storage life. The chemical is typically applied two weeks prior to harvest.
- Non climacteric – fruit that ripen without ethylene and respiration burst, although the role of ethylene in non climacteric is still under debate.

- Outgraded – Product that does not meet its specification and for which no alternative use has been established.
- Ozone – post-harvest gas treatment that has been used to reduce post-harvest disease in fresh produce.
- PE – polyethylene.
- PET – Polyethylene terephthalate
- PP – polypropylene.
- PS – polystyrene.
- RA – is regular atmosphere i.e. standard air as opposed to CA.
- RTE – ready-to-eat.
- Senescence – the condition or process of deterioration with age.
- SKUs – stock keeping unit.
- Spp. – species.
- Superficial scald - a post-harvest disorder of some apples and pears which results in browning of the fruit skin.
- Unavoidable food waste - waste arises from food preparation and includes foods such as meat bones, egg shells and hard vegetable or fruit peelings (e.g. melon rind); it also includes used teabags and coffee grinds.
- VFF - vertical form film – form fill seal (FFS) machines are packaging machines that form, fill and seal a package on the same machine. The main types are vertical form fill seal (VFFS) and horizontal form fill seal (HFFS) machines – a term often used in the market place to cover horizontal versions of flow-wrappers, sachet machines, blister pack machines, four side seal machines and thermoform fill and seal machines.; in both cases packaging material is fed off a roll, shaped, and sealed. The bags/packs are then filled, sealed and separated. VFF is increasingly used as preferred packaging format for some fresh produce types.
- Waste - EU Council Directive Waste 75/442/EEC [91/156/EEC] (EU, 1991), which defines it as 'any substance or object the holder discards, intends to discard or is required to discard'.
- Water footprint - an indicator of water use that looks at both direct and indirect water use of a consumer or producer. http://www.waterfootprint.org/?page=files/home.

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1.0 Introduction

The management of food waste is a significant and prevailing political issue which has a strong economic and environmental impact. WRAP is undertaking research to quantify waste arising in the supply of food and drink to UK households in order to support the food industry to put effective reduction strategies in place and improve resource efficiency.

1.1 Background

UK households produce an estimated 8.3 m tonnes of food and drink waste[6] and 3.6 m tonnes of grocery packaging waste per year[7]. The 'Household Food and Drink Waste' report[8] shows that 36% of all food wasted in the home is fresh fruit and vegetables. This equates to 1.9 m tonnes of vegetables and 1.1 m tonnes of fruit, around half of which is avoidable (i.e. could have been eaten). Potatoes, apples and bananas account for 40% of avoidable household fruit and vegetable waste.

Figures 1 and 2 below show the weight of fruit and vegetables waste split by whether the waste could be avoided or whether waste was unavoidable.

To complement the research on household waste, during 2009, WRAP commissioned DHL Exel Supply Chain and Oakdene Hollins to develop a baseline of waste arising in food manufacture, distribution and retail outlets. Table 1 below, taken from the report[9], shows the estimated waste arising within each of the three areas of the UK food and drink supply chain for 2008 and waste generated by households.

Table 1 Estimated waste arisings within the UK food and drink supply chain

Supply Chain Stage	Million Tonnes	% of total waste
Manufacturing	5.0	27.2
Distribution	0.1	0.5
Retail	1.4	7.6
Household	11.9	64.7
Total	18.4	100

Household waste accounts for 65% of the estimated 18.4 million tonnes of waste generated, with food and drink manufacture accounting for 27% of waste. WRAP's report[8] indicated that of the total retail waste produced some 361,800 tonnes (25%) is food waste. Furthermore, an analysis of waste management routes by material type in the same report noted that for the retail and distribution waste streams, 64% (234,000) is food waste that is sent to landfill or other disposal routes.

Although this work is the most comprehensive assessment available to date, it excludes waste arising in agriculture, the processing and packaging of fresh produce, meat, fish and other first stage processing activities, for example dairies. To fill the gaps in knowledge and to examine whether the high levels of fruit and vegetable waste in households is typical of the supply chain, WRAP commissioned this project to develop detailed 'resource maps' for fruit and vegetables. It is one of a series of projects that will focus on different categories within the retail and wholesale supply chain with others for meat, fish, pre-prepared foods and drink in development.

[6] *Household Food and Drink Waste in the UK, WRAP, 2009*

[7] *Waste Arisings in the Supply of Food and Drink to UK Households, WRAP, 2010*
Packaging figure includes packaging associated with non-food products purchased at grocery retailers

[8] *Household Food and Drink Waste in the UK, WRAP, 2009*

[9] *Waste Arisings in the Supply of Food and Drink to UK Households, WRAP, 2010*

Figure 1 Weight of fresh vegetable and salad waste by type, split by avoidability

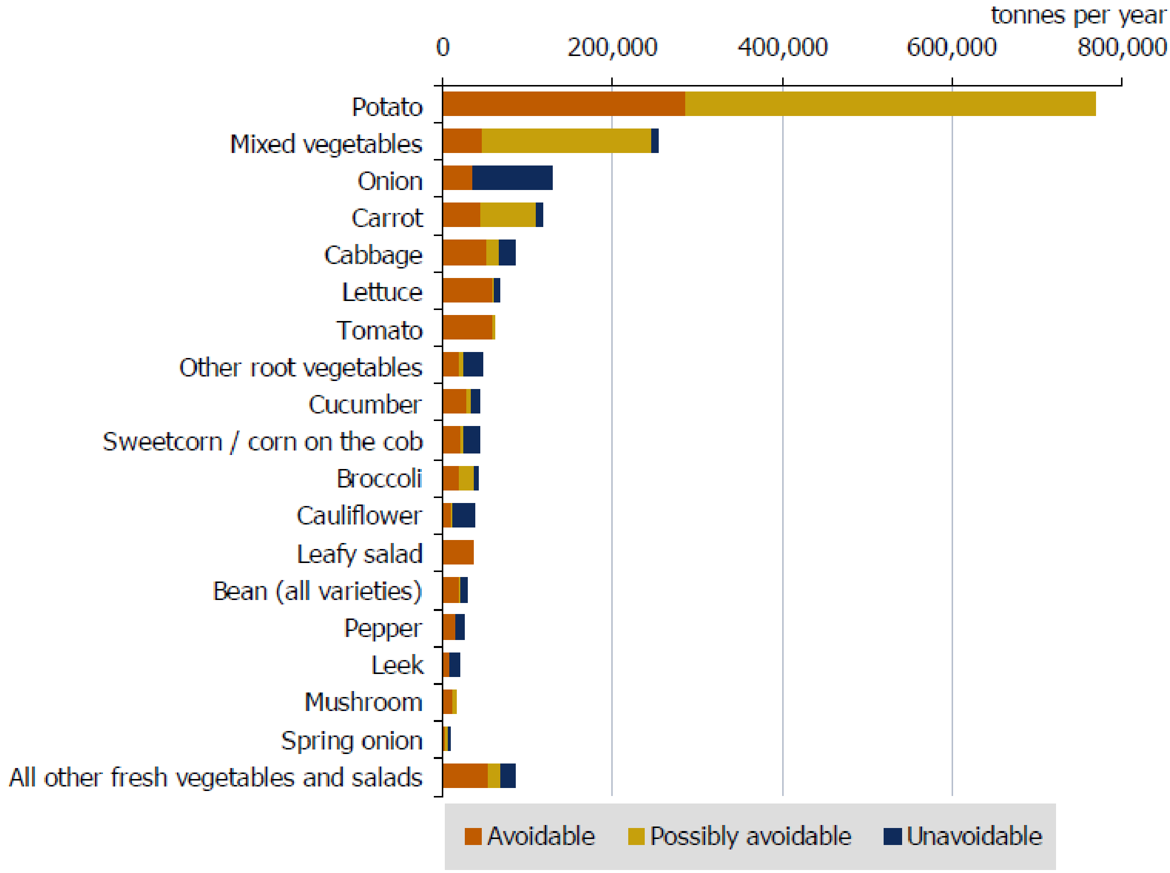
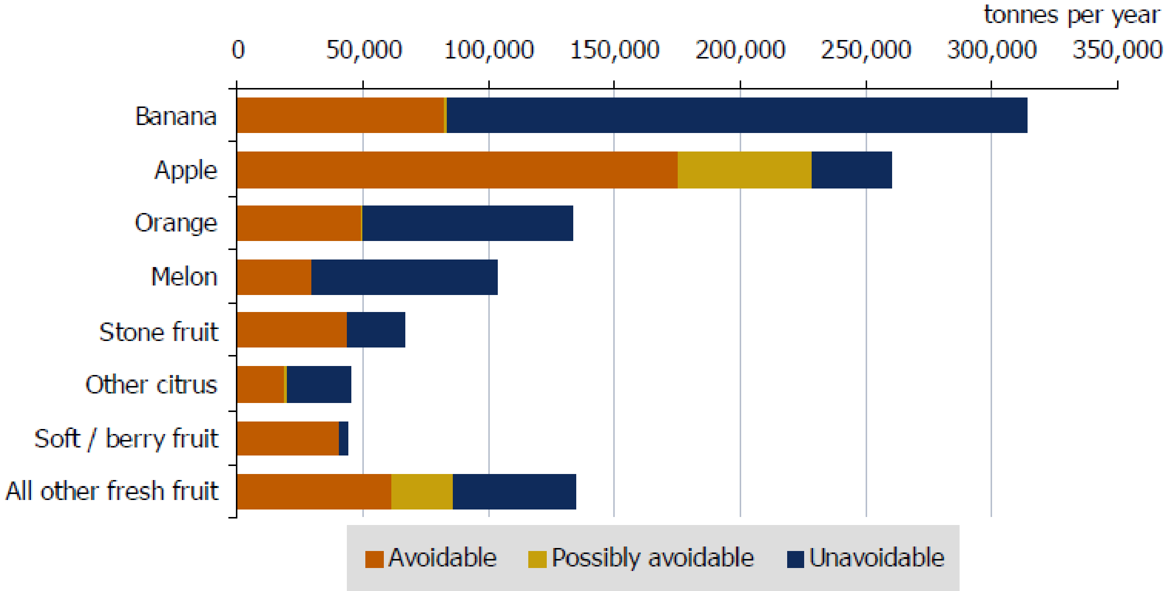


Figure 2 Weight of fresh fruit waste by type, split by avoidability



Previous work by the Food and Climate Research Network (FCRN) in 2006[10] indicated that some 25% of fruit and vegetables by volume are wasted in the supply chain. However, if household waste and waste arising in foodservice are excluded from these estimates making them broadly comparable with the scope of this project, then waste falls to around three per cent (530,000 tonnes). The author of this work accepts that the estimates are 'very rough approximations and should be treated with caution' but they represent the best estimate available to date for the whole supply chain.

[10] *Fruit and vegetables and UK Greenhouse Gas emissions: Exploring the relationship. Working paper produced as part of the work of the Food Climate Research Network Tara Garnett February, 2007*

There are many studies that show losses of fruit and vegetables in the field are caused largely by climatic issues, disease, harvesting damage as well as fluctuation in product demand. Post-harvest losses are related, in part, to the inherent physiology of the fresh produce type (and variety) in question, and the efficacy and appropriateness of the control systems applied throughout the supply chain. Factors such as temperature and ethylene management, horticultural maturity, relative humidity, gaseous composition within storage and packaging are known to affect the post-harvest life of many fresh produce types and therefore if not managed appropriately will increase the risk of creating waste.

In addition to these biological and post-harvest management factors, the root causes of waste are affected by supplier/retailer relationships and management, which have been identified in the recently completed Defra project 'Evidence on the role of supplier-retailer trading relationships and practices in waste generation in the food chain' (code SFFSD0705).

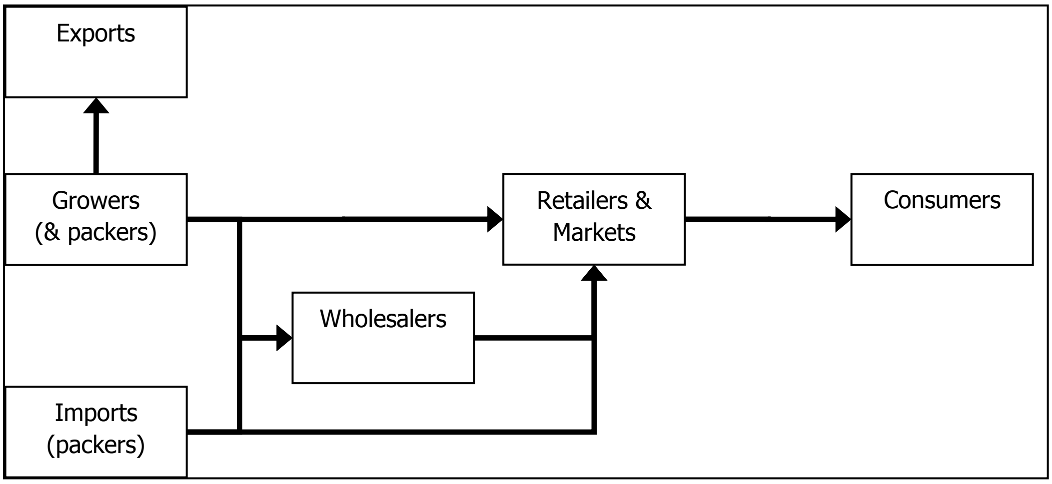
1.2 Industry structure

1.2.1 Overview

Overall, the food and drink industry accounts for seven per cent of the UK's Gross Value Added (GVA) and provides employment to 3.7 million people, representing around 14% of total employment. However, it is difficult to estimate how much of this is dedicated to fruit and vegetables, especially given that around 60 % of fruit and vegetables are imported to the UK.

The supply chain structure of the fresh produce industry is shown in Figure 3. Other activities not shown in the figure include brokers, breeders, logistics service providers, packaging suppliers and waste managers.

Figure 3 The Fruit and Vegetable Supply Chain.



A wide ranging report on the future of the fresh produce sector was published by the National Horticulture Forum in 2006[11]. This showed that there had been an increase in the overall level of professionalism among growers and suppliers in order to meet the technical and commercial demands of the multiple retailers who account for nearly 80% of the market. As a result, fresh produce supply chains are often short and exhibit a high degree of customer awareness. There is also considerable vertical integration and consolidation in the sector. Collaborative relations are also well developed to deliver year round supply.

[11] *Promar International, 2006. The Future of UK Horticulture. A Case Study Analysis and Overview of the UK Horticultural Production Industry and its Future over the Next 10-20 Years. Prepared for the National Horticultural Forum*

1.2.2 Primary production

Horticulture (including ornamentals and food) accounts for only about three per cent of the UK's agricultural area yet directly employs around 95,000 people. A further 34,000 individuals are employed in processing and manufacturing of fruit and vegetable products. The vast majority of horticultural activity takes place in England though Scotland has significant plantings of potatoes, soft fruit and brassicas. The level of horticultural activity in Wales is relatively small.

According to the Horticultural Development Company (a subsidiary of the Agriculture and Horticulture Development Board (AHDB)), the number of commercial growers of fruit and vegetables in Great Britain is around 1,250; the result of consolidation in the sector over the last 10 years. As a result, a number of highly effective and efficient co-operatives and producer/marketing organisations have emerged. These, in some cases, will include a collection of relatively small growers. Some of these arrangements are established as 'producer organisations' under the EU Fruit and Vegetable Aid Scheme, which provides access to funding support.

There are around 500 workplaces that process and manufacture fruit and vegetables in Great Britain (accounting for five per cent of all manufacturing workplaces); however, this number has declined by 30% between 2000 and 2006. Despite an eight per cent fall in workforce, the turnover of these remaining fruit and vegetable manufacturers has increased by some 19%.

The UK is more than 74% self-sufficient in agricultural products. Around 60% of the total supply of fruit and vegetables are imported to the UK, mostly from within the EU. Between 1996 and 2006, vegetable self-sufficiency fell from 80% to 51% whilst fruit self-sufficiency remained relatively constant increasing from 9% to 11%. The reasons for these changes are complicated but do include the increased demand for non-indigenous produce as consumers seek greater variety. Increasingly, consumers expect all year round availability, which has led to increased imports of produce produced both inside and outside the domestic growing season, even though the growing season for many UK crops has been extended through breeding and/or uptake of new husbandry techniques.

Over the past 10 years, UK plantings for fruit and vegetables have fallen, though production levels have in many cases remained stable or even increased due to increased yields and efficiencies in husbandry techniques. As a consequence, and due in part to a shifting of the crops being cultivated, the value of domestic fruit and vegetable production has increased (Table 2). That said, of the eleven products studied in this research project and of those grown in the UK, only strawberries have not experienced a decline in the planted area (Table 3).

Table 2 Overall change in fruit and vegetables production and value (farm gate not retail) for all fruit and vegetables (excluding potatoes) grown in the UK.

	1997	2007	%change	1997	2007	%change
	Fruit			Vegetables		
Planted area (ha)	31,943	27,580	-12.9	152,672	118,439	-22.4
Value (£000)	228,233	446,764	95.7	957,235	1,065,348	11.3

Source: Defra, Basic Horticulture Statistics, 2008 (Defra, 2009)
Available at: https://statistics.defra.gov.uk/esg/publications/bhs/default.asp

Table 3 Overall change in production for selected fruit and vegetables grown in the UK.

Product	Planted area (ha) 2007	%change 2000-2007	UK production (000 tonnes) 2007	%change 2000-2007
Strawberries	4,426	34.6	87.2	133.8
Raspberries	1,571	-11.7	13.5	37.8
Tomatoes	2,10	-23.1	85.6	-24.2
Lettuce (all)	2,25	-57.5	117.0	-24.3
Brassica*	27,043	-16.9	449.9	-10.7
Apples**	8,670	-33.4	242.0	16.3
Potatoes	124,000	-7.2	5,413.0	-9.8
Onions	10,376	-3.9	323.0	21.2

Source: (Defra, 2009, https://statistics.defra.gov.uk/esg/publications/bhs/default.asp)
** = sprouts, cauliflower, cabbage and calibrese only,*
** * = culinary and dessert. No domestic commercial production of bananas, avocados and citrus.*

N.B. There are tables in the AHDB report Feeding Britain (2009) http://www.ahdb.org.uk/publications/documents/FeedingBritain.pdf. These numbers in the AHDB paper are different to the Defra statistics.

Tables 2 and 3 show that:

- Soft fruit (inc. strawberries and raspberries) production has increased dramatically over the past seven years due to season extension in an expanding market. The potential still exists for continued growth. Increased pressure from imports during the main UK cropping season may be inevitable, but since strawberries have such a short shelf-life and command a strong brand presence then prospects for this threat are somewhat diminished yet cannot be ignored.
- Salads (lettuce and tomatoes) have been put under considerable pressure from imports from Spain and the Netherlands, respectively, which have in some cases seen UK-based production become less economically viable, especially for commodity varieties. This has encouraged various UK-based companies to purchase land in Spain and Portugal, to supplement their domestic production.
- Apple production has increased but the proportion of fruit that is domestically sourced in relation to the overall market has declined.
- Potato production has declined slightly, though the number of potato growers has declined rapidly, falling by 80% in the last ten years.
- Onion production has slightly declined because of lower production costs outside the UK.

Given that the UK is becoming increasingly reliant on fruit and vegetable imports, it is not surprising that many marketing intermediaries have focused on non-UK sources rather than on the development of a sustainable domestic supply chain. Recent (as yet unpublished) research for Defra suggests that UK supply is increasingly being seen as a 'top up' supply. Given that a great deal of imported product will be graded and packed at source, it is not clear how much waste is generated in the production of fruit and vegetables for the UK market. As the consumption of imported products in the UK has risen, it is likely that waste in the countries of origin will have increased as well.

1.2.3 Retailing

The total household expenditure on food and non-alcoholic beverages across UK retailers for 2008 was estimated at around £85 billion (ONS, 2008; Table 4). This figure has been increasing steadily since the 1970s and in the last ten years has grown significantly (ONS, 2008). Fruit and vegetables account for 21% of the total. It is forecast that the 2012 UK fruit and vegetable market will have increased by 23% from 2007 (Datamonitor, 2008).

Table 4 UK Consumer Expenditure on Food by Sector at Current Prices 2004-2008.
(£m at retail selling prices).

Product	**2004**	**2005**	**2006**	**2007**	**2008**	**Increase 2004 - 2008**
Bread and cereals	9,480	9,815	10,124	10,571	12,081	27%
Meat	13,597	13,622	13,867	14,859	16,459	21%
Fish	2,290	2,488	2,726	3,260	3,471	52%
Milk, cheese & eggs	8,006	8,415	8,675	9,280	10,455	31%
Oils and Fats	1,216	1,256	1,333	1,563	1,969	62%
Fruits	**4,824**	**5,311**	**5,703**	**6,416**	**6,769**	**40%**
Vegetables	**8,413**	**8,824**	**9,143**	**10,344**	**11,280**	**34%**
Sugar & Sweet products	7,245	7,349	7,434	8,945	10,104	39%
Food products n.e.c.	1,596	1,610	1,622	1,887	2,202	38%
Non-alcoholic beverages	8,163	8,497	8,783	10,019	10,203	25%
Total food and non-alcoholic beverages	64,830	67,187	69,410	77,144	84,993	31%

Source: Consumer Trends Q4 2008, National Statistics website.

The retail sector is represented by over 55,000 enterprises, with over 100,000 outlets employing over 1.157 million people[12]. Major multiples (with turnover greater than £1 billion) dominate the market, particularly the 'Big Four' supermarket groups; Tesco, Sainsbury's, Asda and Morrisons, which account for 75% of grocery sales[13]. Some commentators have argued that the recent acquisition of Somerfield's by The Co-operative has created a 'Big Five' (Table 5). All the major multiple retailers were interviewed for this project.

[12] *Defra (2008), Farming and Food Brief, , Defra, London and Defra (2007a), Report of the Food Industry Sustainability Strategy Champions' Group on Waste, Department for Environment, Food and Rural Affairs May 2007 , DTI, London*

[13] *Cabinet Office (2008), Food: an analysis of the issues, The Strategy Unit, London*

Table 5 Market share of major retailers.

	12 Weeks to 02 November 2008		12 Weeks to 01 November 2009		Change
	£000	**% ***	**£000**	**% ***	**%**
Total Till Roll	**28,073,670**		**28,435,490**		**1.3**
Total Grocers	**20,363,830**	**100.00%**	**21,267,740**	**100.00%**	**4.4**
Total Multiples	**19,869,000**	**97.60%**	**20,799,900**	**97.80%**	**4.7**
Tesco	6,228,468	30.60%	6,521,371	30.70%	4.7
Asda	3,443,222	16.90%	3,669,899	17.30%	6.6
Sainsbury's	3,197,227	15.70%	3,374,885	15.90%	5.6
Morrisons	2,296,264	11.3	2,492,014	11.70%	8.5
Total Co-operative	1,860,639	9.10%	1,682,987	7.90%	-9.5
Co-operative	*1,077,726*	*5.30%*	*1,138,760*	*5.40%*	*5.7*
Somerfield	*782,913*	*3.80%*	*544,227*	*2.60%*	*-30.5*
Waitrose	758,215	3.70%	851,587	4	12.3
Iceland	346,449	1.70%	369,243	1.70%	6.6
Aldi	611,668	3.00%	647,133	3	5.8
Lidl	471,626	2.30%	497,606	2.30%	5.5
Netto	161,104	0.80%	163,020	0.80%	1.2
Farm Foods	108,645	0.50%	117,027	0.60%	7.7
Other Freezer Centres	48,954	0.20%	50,179	0.20%	2.5
Other Multiples	336,517	1.70%	362,948	1.70%	7.9
Total Independents	**494,837**	**2.40%**	**467,845**	**2.20%**	**-5.5**
Total Symbols	**174,048**	**0.90%**	**161,408**	**0.80%**	**-7.3**
Other Independents	320,788	1.60%	306,437	1.40%	-4.5

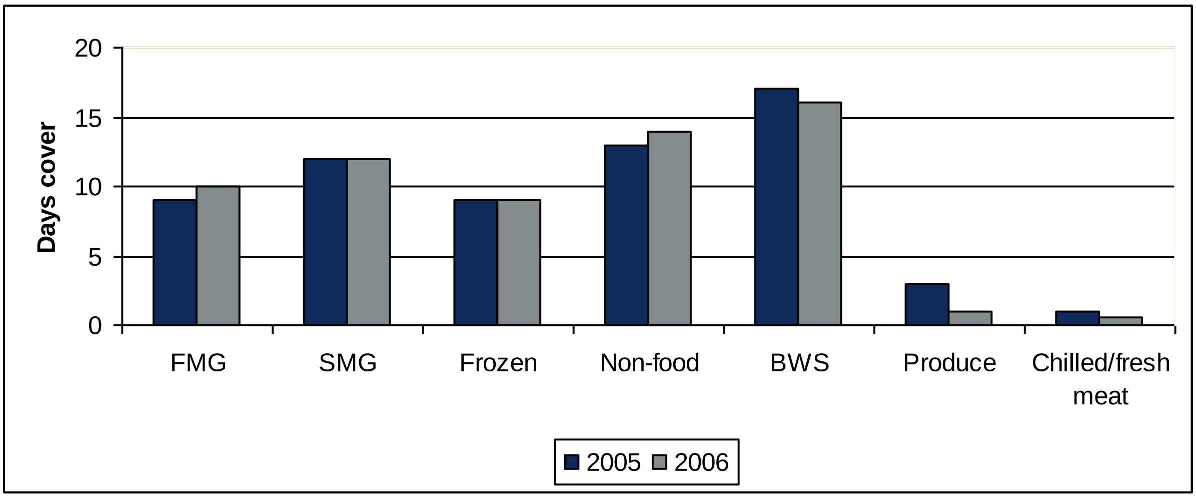
** = Percentage Share of Total Grocers*
Source: Gardner, E. (2009) Tesco share turnaround (plus an update on grocery price inflation), TNS Worldpanel 10/11/09, available from: http://www.tns-global.co.uk/news/uk-press-office/news-6439.aspx

A spectrum of retail formats, ranging from convenience stores through to hypermarkets, is available in the UK. The diverse range of formats is intended to serve different customer segments and tend to stock different product ranges. It is likely that the different formats will lead to different levels of waste, although this research has not been able to detail waste levels by retail format.

The competitiveness in the market, the diversity of products on offer and the complexity of retail operations in the UK demand a logistics system that has to be both efficient and adaptable. This is arguably one reason why logistics has become an important differentiator in the marketplace. Retailers have used it as the mechanism to control, organise and manage end-to-end supply chains. To protect fresh produce, temperature, ethylene (where appropriate) and humidity levels should be managed during all stages of the supply chain. Accordingly, refrigeration systems play a critical role in reducing waste.

One major difference in the logistics of fresh fruit and vegetables, compared to other products, is the way inventories are managed, as the higher the inventory levels, the more likelihood there is that the product will be damaged or exceed its date mark. It is estimated that the stock cover for the main product categories shows that inventories for produce have the second lowest inventory level after chilled fresh meats (IGD Retail Logistics 2007 report) (Figure 4). This IGD study also indicated that the fresh produce category had shown a substantial reduction in inventory levels reflecting the efforts to reduce waste in this area.

Figure 4 Inventory levels (stock cover in days) by product category.



Source: IGD Retail Logistics 2007 report
FMG = Fast Moving Goods, SMG = Slow Moving Goods, BWS = Beers, Wines and Spirits.

1.2.4 Wholesalers

Fresh produce wholesalers are a very important channel for grocery distribution in UK, retaining their market share and extensive presence in the supply chain by responding quickly to demand and changing trends. The wholesale (and foodservice) sector accounts for 32% of the market share by value for fresh produce. There are 26 fresh produce wholesale markets in the UK with an estimated turnover of £2.4 billion. In addition, there are 200 wholesale and foodservice companies at independent locations with an estimated turnover of £1 billion.

Wholesalers form an essential component of the supply chain, connecting the supply activities (agriculture and manufacturing) with the market activities (retailing as well as catering and public sector procurement). Foodservice and public procurement are key customers for the wholesale sector, with the market for eating out worth £31.1 billion. Some of the most important wholesale markets in the UK were interviewed for this research. The main services provided at this stage are warehousing, transportation, product consolidation, inventory management and retail/catering advisory services.

1.3 Lean manufacturing

Several of the businesses that were interviewed have implemented 'lean manufacturing' approaches within their operations and reported that 'waste' was any activity that did not add value. 'Lean' opens up a very broad approach to waste analysis and reduction because it is a business logic focused on eliminating non-value adding steps from the supply chain for particular products. The rationale for going lean centres on waste reduction both inside and between companies, as this can expose underlying quality and management problems. Within lean, seven production wastes have been identified as follows:

1. Over-production – producing too much or too soon, resulting in poor flow of products or information and excess inventory.
2. Defects – problems with product quality, errors in paperwork or poor delivery performance.
3. Unnecessary inventory – excessive storage and delay of products or information resulting in excessive cost and poor customer service.
4. Inappropriate processing – going about work processes using the wrong set of tools, procedures or systems, often when a simpler approach maybe more effective.
5. Excessive transportation – excessive movement of people, information or goods resulting in wasted time, effort and cost.
6. Waiting – long periods of inactivity for people, information or goods resulting in poor flow and long lead times.
7. Unnecessary motion – poor workplace organisation, resulting in poor ergonomics including excessive bending, stretching and lost items.

Previous work by IGD's Food Chain Centre to identify and reduce waste piloted lean manufacturing principles with seven fresh produce supply chains and ten 'shop floor' pack-house based projects. Reported benefits[14] from this programme amounted to several million £'s in cost savings. A number of the companies that participated in these pilots were contacted during the course of this research and confirmed their commitment to roll out and embed lean more fully within their operations. A greater take–up of lean within the fresh produce industry would help to reduce waste while at the same time reducing costs and increasing value.

This project did not examine wasted time, energy and resources, although it is expected that there is a relationship between actual waste and these facets.

Loss and waste are ultimately undesirable, and all businesses will do their utmost to ensure they maximise the value of product.

1.4 Fresh produce packaging

Packaging has a number of functions but the fundamental role is to deliver the product to the consumer in perfect condition. Packaging also differentiates products, describes them and helps meet legal requirements on labelling.

Many fruit and vegetables have 'natural packaging' i.e. the peels that have to be removed before consumption and which lead to an unavoidable waste stream, primarily in households. Individual products are often packaged further both to protect the product from damage and, in some cases, to extend its shelf-life. Packaging also provides convenience for the consumer. Less product is generally sold loose now compared with ten years ago because consumers choose pre-packed products in preference to 'free-flow'. This has led to an increase in the amount of primary packaging that has to be disposed of at home.

There are a number of techniques that have been used to delay spoilage and ripening of fresh produce. Optimised packaging and the correct temperature control can be effective. For example, the life of broccoli can be lengthened by two days if kept packaged and in the fridge. Storing certain types of apples in a bag in the fridge at home can extend their life by as much as two weeks[15] (depending on variety).

The main packaging formats used on the 11 products researched through this study are given in Table 6. Although recyclable materials such as cardboard and plastics prevail, as produce moves up the supply chain it is not always possible to recycle them. This is because packaging would need to be separated from the product (e.g. decant the strawberries from the punnet) or the materials are not widely recycled by household waste collectors[16]. Energy recovery, particularly anaerobic digestion when coupled with a de-packaging system, is a more resource efficient way of disposing of 'mixed' waste than disposing of it to landfill and is being pursued by a number of the major retailers and some suppliers as part of their waste diversion strategies.

Table 6 Main packaging formats used on the 11 products researched through this study.

Product	Primary	Secondary
Strawberry	Generally a PET or rPET punnet with either a clip-on lid or a heat seal film. Within each punnet a small piece of bubble wrap at the base to prevent damage. Typically about 25g in weight for the total packaging.	Usually delivered in plastic returnable trays or corrugated trays.
Raspberry	Generally a PET or rPET punnet with clip-on lid. Bubble wrap in base for protection. Generally smaller depth than the strawberry punnet. Estimate 18g.	Usually delivered in plastic returnable trays or corrugated trays.

[14] *Food Chain Centre Completion Report, IGD, 2007*

[15] *Helping consumers reduce fruit and vegetable waste, WRAP, 2008*

[16] *http://www.wrap.org.uk/retail/about_us/onpack_labelling.html*

Lettuce	Dependent on leaf type. Broad leaf lettuce is typically in a 30 micron bag film, with top open to stop crushing of the leaves. Material either PE or PP.	Most retailers have their iceberg lettuce delivered in corrugated trays and other lettuce tends to be in plastic returnable trays.
Tomatoes	Six-pack tomatoes are packed in either a flow wrap (PP) or a PET tray with over flow-wrap, some come in nylon bags. (Typical weight 2-4g). Large vine tomatoes are presented in a black or clear tray with an over flow-wrap. (weight about 4g). Baby plum tomatoes are packaged either in a punnet with film over flow-wrap (this is most common format and about 10g in weight), one retailer sells them in a punnet with a film lid which is about 8-9g and another retailer sells them in a flow-wrap about 2g in weight. Can also be bought loose.	All tomatoes are distributed in plastic returnable trays.
Apples	Apples are sold either loose with PS inserts within plastic returnable tray or cardboard box to give protection. Or in PE bags. Can also be bought loose.	Distribution via plastic returnable trays or via corrugated trays.
Onions	Onions are either sold loose with a PE or PP liner within a plastic returnable tray, or in a corrugated tray or they are supplied in PE bags, nylon bags or nets (3 in line).	Plastic returnable trays or corrugated trays.
Potatoes	Depending on the weight and variety being sold potatoes are packaged in a number of formats. All can be packaged loose with a PE or a PP liner within a returnable tray. New potatoes and salad potatoes 500g-2kg – often in PE/PP films with micro perforations to allow them to breathe, typically 30-70 microns. Baking potatoes – either in a PE or PP bag about 50 micron thick or in a PS tray with a film overwrap. Red potatoes and other normal cooking potatoes sold in a variety of weight sizes and can come in PE or PP bags, nets or 25kg paper sacks. Can also be bought loose.	Depending on the weight and primary packaging it can be corrugated cases, plastic returnable trays with a liner, or stacked on a pallet with shrink wrap (the latter being for sacks).
Broccoli	Either sold loose in plastic returnable trays with PE or PP liner, or whole broccoli is shrink-wrapped. If broccoli head only, then they can be supplied in a PE or PP flow wrap bag or a PS or PET tray with over wrap.	Depending on format – mainly plastic returnable trays with liners, or, if primary packaging, no liner.
Avocado	These can be purchased loose, sitting in PS trays within a returnable plastic tray, in PE or PP flow-wrap bag. They can also be in PS tray with plastic over wrap.	Secondary packaging – primarily plastic returnable trays or delivered in corrugated cases.
Citrus	Citrus are sold loose with PS trays that the citrus sit on (indent for each one). These are either within a returnable tray or a corrugated tray. Alternatively, they are sold in nylon bags.	Plastic returnable trays or corrugated trays.
Bananas	Loose bananas are supplied in a corrugated case with a PE liner within it. Other bananas are supplied in returnable trays or corrugated cases within a PE bag, or a perforated film (PP) flow wrap.	Wooden pallets, corner boards, plastic strapping go around the corrugated cases or plastic returnable trays.

The plastic returnable trays used by most retailers have a dual function providing both a means to transport product from packers to store as well as a way to ensure that fruit and vegetables are displayed in store.

1.5 Marketing Standards

The EU Marketing Standards set out the quality standards that must be applied to the supply of fruit and vegetables. They were introduced some time ago to drive up quality and facilitate trade. They are important because they set a quality floor in the market. The standards are also enforced and the inspection results are available to provide a quantitative indication of the extent and nature of quality defects. In practice, the quality specifications in place, set commercially by retailers that govern the supply of product, are significantly more stringent than the EU 'floor'.

Following a recent change, the marketing standards were split into two groups with one comprising the most traded 10 products that are covered by 'specific marketing standards'. Most other fresh products are covered by the 'general marketing standard'. These standards are enforced by the Horticultural Marketing Inspectorate (HMI) (part of Defra's Rural Payments Agency).

The purpose of an HMI inspection is to make sure that products are of an acceptable standard and that consumers are not being presented with poor quality goods. The rules also cover labelling and are intended to ensure that fresh produce offered to consumers are labelled accurately. Following an inspection product can either be accepted, or where applicable, down-graded (from Class 1 to Class 11) or out-graded. Down-grading or out-grading might result in unpacking or re-shipping to an alternative non-UK market.

Looking at the inspections of imported products in 2008, 0.5% were out-graded and 0.2% were downgraded. Labelling defects amounted to a further two per cent (these will rarely lead to waste). The most significant causes of these defects are shown in Table 7. The main cause of quality defects is rotting, while the main cause of label defects is failure to state a product class.

Table 7 The top 10 quality defects

Quality defects	**%**	**Labelling defects**	**%**
Rotting	23	No class stated	37
Damage	7	No identity of packer/dispatcher	22
Bitter Pit	6	Product not stated	10
Discoloured Bruise	5	Country of origin not stated	8
Not clean	5	Insufficient labelling	6

Source: FPC/HMI

Only in a very small number of instances would waste arise as a result of these actions, though there may be significant economic losses if product fails to comply with its intended class.

1.6 Consumption and supply of fruit and vegetables

The Office of National Statistics (ONS, 2008) estimates that over £18bn was spent on fruit (£6.8bn) and vegetables (£11.3bn) in the UK in 2008. This amounts to around 21% of the total spent in food and drinks (ONS, 2008).

The Expenditure and Food Survey (ONS) shows that fruit and vegetable consumption has been increasing steadily during the current decade, although the latest years (2007/8) have shown a slight fall. A good deal of the overall growth has been due to the increased importation of exotics from overseas that cannot be grown in the UK. Around 60 per cent of fruit and vegetables are imported to the UK, providing consumers with produce outside the UK season as well as varieties that cannot be grown in the UK climate.

In October 2009, a new 'task force' was established by Defra to develop an action plan to increase the consumption and production of fruit and vegetables in England[17]. The task force aims to identify the key barriers to increased production and consumption of fruit and vegetables in England, to develop practical proposals to remove these barriers, and to outline realistic routes for implementation.

[17] *http://www.defra.gov.uk/news/latest/2009/food-1021.htm*

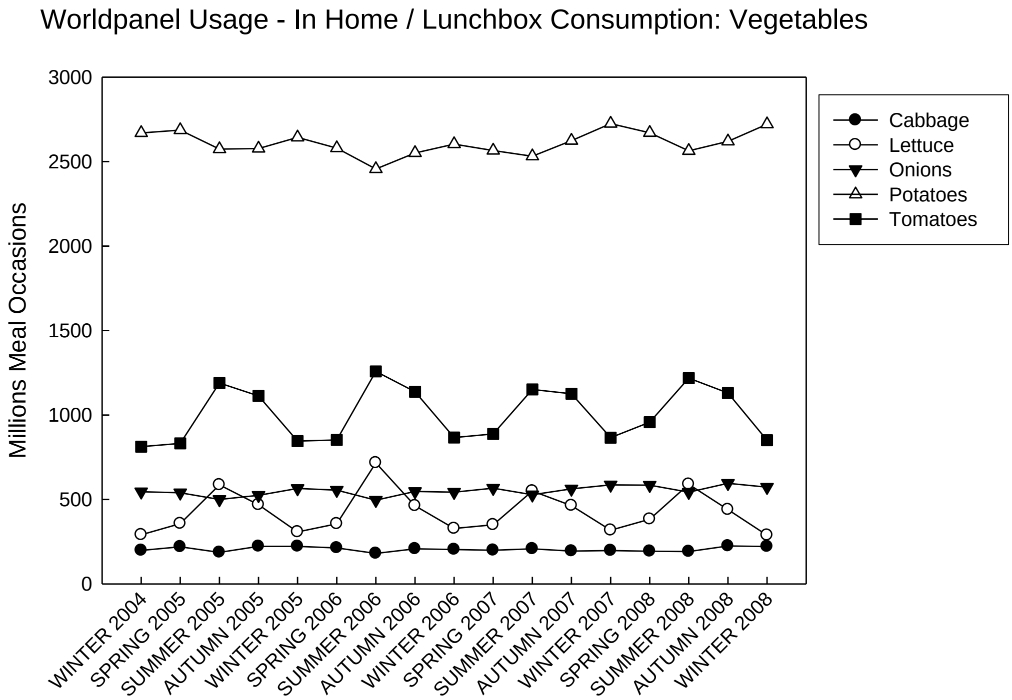
The consumption of fruit and vegetables is seasonal and varies between products. For the 11 products selected in this study, potatoes and bananas dominate (Table 8). The greatest increases in consumption since 2003 appear to be for strawberries and, to a lesser extent, bananas. Yet these increases need to be put in context in terms of scale. For example, the average consumer eats seven times the amount of bananas and nearly 17 times the amount of potatoes per week as compared to fresh strawberries. Indeed, three out of five meal occasions involve potatoes in some form (Figure 5). Consumption of certain fruits and vegetables is still largely seasonal and often not only reflects home production, but more importantly, seasonal consumption patterns and preferences (Figures 5 and 6). For example, consumption of strawberry and raspberry fruit rises by as much as six-fold in the summer, whereas for citrus, consumption peaks during the winter months. In contrast, potato, onion and apple consumption remains relatively stable.

Table 8 Fruits and vegetables purchased over the last five years for household consumption in UK (grams per person per week (Defra, 2009)).

Item description		**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**
Vegetables	Potatoes	600	570	587	565	537
	Tomatoes*	98	99	99	100	95
	Onions	83	87	97	93	91
	Other Brassica[1]	76	72	79	71	73
	Lettuce[2]	44	44	44	44	40
	Cabbage	43	45	46	42	43
Fruits	Bananas	211	217	225	226	230
	Fresh apples	171	173	179	180	178
	Total citrus[3]	152	144	151	145	148
	Oranges	64	57	59	55	59
	Strawberries	23	27	30	29	32
	Avocados	5	6	8	8	8
	Raspberries	3	4	5	5	8

1: Includes cauliflower and headed broccoli
2: Includes watercress, mustard and cress and crispy seaweed
3: includes oranges
** = classified as a fruit but often grouped with salads by industry.*

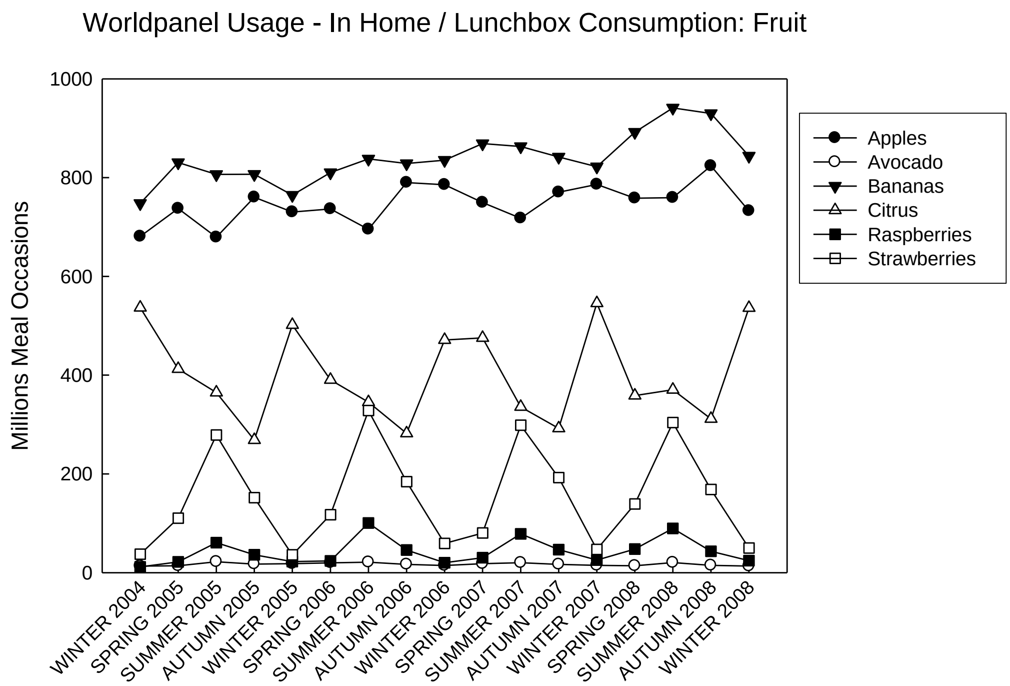
Figure 5 Seasonal change in consumption at home and lunchbox of six vegetables.



Source: TNS Worldpanel, 2009

NB Tomatoes classified as a fruit, but often grouped with salads by industry.

Figure 6 Seasonal change in consumption at home and lunchbox of six fruits.



Source: TNS Worldpanel, 2009

2.0 Methodology

The UK fresh produce supply chain is complex and covers a wide range of products with different characteristics, such as shelf-life, temperature requirements, and demand variability. To cater for this diversity, a methodology was designed that allowed: the analysis of quantitative data - to establish the magnitude of fresh produce waste; and qualitative data - to identify and understand the causes of, and potential solutions to reduce, loss and waste.

2.1 Aims and objectives

The project's overall aim was to provide a quantitative and qualitative analysis of fresh produce waste and associated packaging waste arising through the retail and wholesale supply chains. The specific objectives of this project were:

1. To develop a methodology to quantify the amounts of fresh produce waste in the UK retail and wholesale supply chain.
2. To quantify the waste arisings in terms of carbon equivalents and economic value.
3. To identify the waste profile of specific fresh produce types based on their post-harvest life (avoidable vs. unavoidable food waste and packaging materials).
4. To identify and quantify how product loss is managed (i.e. redistribution – e.g. Fareshare, recycling, composting, energy recovery or landfill).
5. To identify good practice for reduction of product damage, fresh produce waste and associated packaging waste.

2.2 Data collection

Based on the objectives of the project and on the fragmented nature of the fresh produce sector, it was decided to conduct multiple case studies using in-depth and semi-structured interviews (the questionnaire is included in Appendix 1). In total 45 interviews were conducted with fresh produce companies, including suppliers (34 interviews), retailers (seven interviews) and wholesalers (two interviews), in England, Scotland and Wales. The aims of these interviews were to quantify waste, to establish the causes of waste, and to record the destination and secondary uses of waste.

Interviews lasted for around one hour and were conducted between April and September 2009. Data included in this report is based on that stated by interviewees.

The interviews covered 11 fresh products and catered for the differences in post-harvest physiology, inherent storage and shelf-life, and their ability to withstand low temperature (strawberries, raspberries, tomatoes, lettuce, apples, onions, potatoes, brassicas, citrus, avocados and bananas). The selected fruit and vegetables also represented fresh produce types that are sensitive or less sensitive to ethylene (e.g. climacteric versus non-climacteric), are imported (both temperate and tropical), and/or are home-grown.

Previous work suggests that short shelf-life products may be more susceptible to being wasted, particularly when combined with high demand variability. There are no precise definitions of 'short' or 'long' because it is recognised that in practice some products may not be stored for the optimum time achievable, for example, under laboratory conditions.

In addition to the interviews, secondary data on waste was collected by tracking specific fresh produce consignments (lettuce, tomatoes, onions, citrus, avocados, potatoes and banana) through the supply chain to trace and quantify 'real time' loss for specific fresh produce types. For this task, 25 companies were approached out of which 10 responded and provided waste data. The tracking data only represents a 'snap-shot' of loss and waste data occurring at specific time points in the calendar for the different products. However, it provided a valuable sense-check on the data provided during the interviews and has been used to inform the resource maps.

It was important, in order to collect any data, that the identities of participants remained anonymous. As such, the project team secured data from businesses with a combined UK market share of ca. 60-85% or, in the case of very consolidated product markets, more than three companies. This is shown in Table 9. Seven multiple retailers were interviewed along with two of the most important wholesale markets in the UK.

Table 9 Summary of number of suppliers who participated in data collection and total market share for each fresh product type

Product	Number of Suppliers	UK Market Share (%)
Strawberry	3	75
Raspberry	3	70
Lettuce	3	75
Tomato	3	70
Apple	6	60
Onion	4	81
Potato	6	60
Avocado	3	70
Citrus	3	60
Broccoli	3	55
Banana	4	85

2.3 Data analysis

Data from the interviews was synthesised into resource maps indicating the levels of loss and waste expressed as a percentage range, at each stage in the supply chain and detailing the main causes of waste at each stage.

Chapter 3 details the resource maps that have been produced for each of the products investigated through this research. Each resource map is divided into key supply chain stages, shown sequentially for presentation purposes. Timelines are not presented with each resource maps as these will vary, based on, for example, length of the growing season and storage requirements.

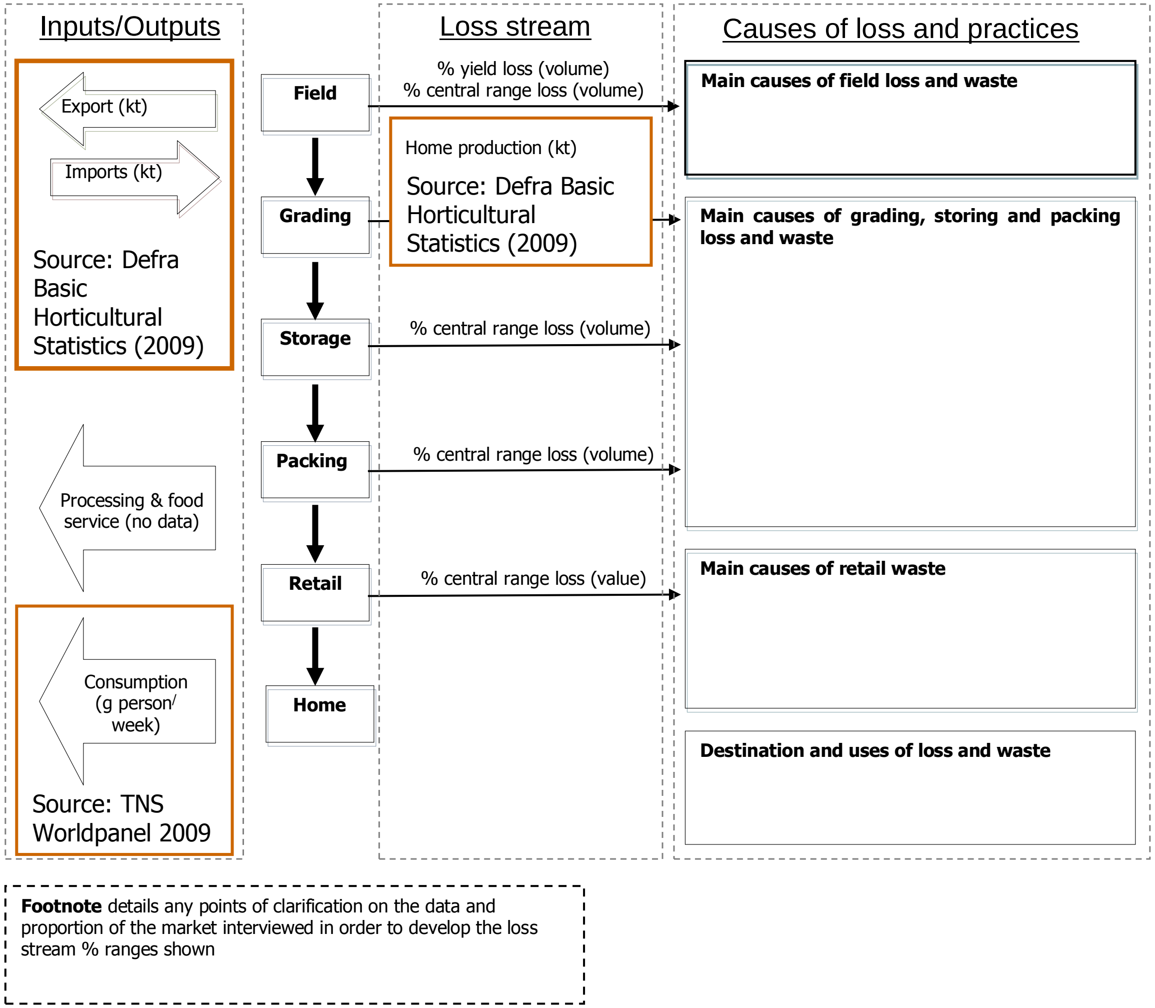
In practice, all 11 products go through each of the stages shown. However, for those products that can be stored, grading could take place post-harvest for immediate sale or when the product comes out of storage and is packed for sale. As a result, for six of the 11 products where storage (weight) losses are recorded the data cannot be cumulated to give an overall total.

Data collected through the interviews and product tracking is presented as percentage loss or waste for each stage in the supply chain. In most cases the project team found that waste and loss varies from year to year and therefore the percentages are given as central ranges. For all the stages in the supply chain up to retail the percentage figures are volume measures but at retail the percentages are of total value. This difference partly reflects the way that waste is managed by different parts of the supply chain as well as commercial sensitivity.

The leading causes of loss and waste have also been included in the resource maps, with more detailed discussion given after each resource map. The main ways that loss and waste are managed have also been identified in each map.

Each of the resource maps can be used to benchmark performance by individual suppliers and retailers. Lower levels of loss could be used by businesses to inform their strategy to reduce waste.

Figure 7 Outline resource map. 'Consumption' is defined in its 'economic' sense, i.e. the purchase of fruit and vegetables by consumers.



NB, TNS Worldpanel announced in January 2010 that it has changed its name and identity to Kantar Worldpanel across its global network.
The home production figure includes that which is harvested excluding any losses. Any discrepancy between inputs and outputs of the resource maps may be due to a number of factors, including, for example, outputs being used within the pre-prepared foods category or in the food service sector (not included herein)

2.4 Definition of waste and loss

Waste is defined by the EU Council Directive Waste 75/442/EEC [91/156/EEC] (EU, 1991) as 'any substance or object the holder discards, intends to discard or is required to discard'. This includes all facets of physical waste including produce and packaging. The main focus herein was waste arising during grading, packing, distribution and retailing. However, where data were available information on field waste, genetic diversity within a product category, and the effect on post-harvest loss and waste, was recorded. Some estimates of yield loss were also provided by interviewees and these are expressed as a percentage range of product lost in the field. A central range value was used to describe the most commonly reported levels of loss in the field so that extremes did not distort the results.

The term loss is used in this report to describe product that is not used for its intended purpose and therefore has less real monetary value (or none in extreme cases). Many activities that take place within the fruit and vegetable supply chain lead to an economic loss, i.e. planted product not making the required grade/specification and product being out-graded or down-graded at packing. Across the supply chain an economic loss arising from the types of activity described above was regarded as 'waste', although clearly such activity did not lead to product being landfilled. Although such products cannot be used to supply retail customers they are used for processing or for animal feed, thus providing some revenue, though significantly lower than from the primary market. This loss should not be confused with waste (disposed to landfill or energy recovery).

In a commercial context most retailers also viewed waste as product that is marked down and sold for less than its intended price.

2.5 Challenges and limitations

It has not been possible to obtain a full data set to populate all parts of every resource map. Some of the products covered are not produced in the UK and therefore critical stages in the supply chain have been omitted. For other products commercial confidentiality proved a significant barrier.

Apart from the household waste data there are no recent surveys on fruit and vegetable waste in the retail and wholesale supply chain. The data used by Oakdene Hollins in the waste arisings baseline study[18] were derived from surveys undertaken by the Environment Agency, the Scottish Environment Protection Agency, the Food and Drink Federation and DHL which exclude the 'upstream' parts of the target supply chain. In fact, no waste data are available on generic products or product categories sold in the UK at various stages in the supply chain.

The project team proceeded by collecting data on product and packaging waste from individual companies across the supply chain. While the fresh produce industry fully supported the work and co-operated with the interview programme, it was significantly more challenging to collect certain data than was envisaged at the outset of the research. Although more interviews were conducted than planned, it was not possible to meet objectives 2, 3 and 4 (given in Section 2.1) in full. Specifically:

- It has not been possible to provide a detailed estimate of the economic value of the waste and loss because details on economic value are commercially sensitive to industry partners and were often withheld (objective 2).
- Participants were not able to provide detailed data so that the waste profile (objective 3) could be determined, nor, in the majority of cases, could they quantify precisely how waste was managed (objective 4).

All the data and insights provided in this report are those collected during the structured interviews and thus their accuracy and completeness are reliant on the honesty and openness of participants. Tracking data was used to verify some of the data on waste levels, but these are only 'snap-shots' from specific consignments and thus must be treated with caution. Further, losses for imported produce and packaging were not always apparent.

The project team was also unable to collect tonnage figures for the loss and waste identified. Rather, these have been expressed as a percentage figure, in a range. This is because companies either regarded the data as

[18] *Waste Arisings in the Supply of Food and Drink to UK Households, WRAP, 2010*

commercially sensitive or because, in some instances, tonnages were simply not known. Waste management contracts were sometimes managed on a 'pick-up' basis, with payments based on the number of 'lifts' rather than on the tonnage collected. The lack of data on the measurement of waste to provide a key performance indicator has been identified as an issue by WRAP in other recent studies.

Due to the diversity of products studied it has not been appropriate to compile an overarching resource map for the whole of the fruit and vegetable category. However, themes are evident according to each fresh produce grouping that may be transferrable to similar fresh produce types. The project team has drawn out several over-arching conclusions and recommendations that may have wider applicability.

Seven retailers and two major fresh produce wholesale markets were interviewed. Only one retailer gave details on the breakdown of waste for each of the 11 products and as such data on retail waste for each product type is based on this and views from suppliers. Generic data on waste levels for fresh produce were supplied by some retailers, but without specific waste levels for each product the usefulness of this data is questionable and hence has not been used. However, details on the generic causes of waste are included.

3.0 Resource maps

3.1 Strawberries and raspberries

3.1.1 Overview

The UK produces 102.1 kt of strawberry fruit (*Fragaria* x *ananassa*), 14.2 kt of raspberry fruit (*Rubus* spp.) and imports 44.8 kt of strawberry fruit (Defra, 2009). Raspberries are also imported, but there is no data available regarding amounts. Home-grown strawberries and raspberries are available in the UK from March/April to October with peak production during the summer. Spain is the main exporter of strawberry and raspberry fruit to the UK.

The quantities purchased for household consumption have increased and stand at 32g per person per week for strawberries, and 8g per person per week for raspberries (Table 8). The UK strawberry and raspberry industry is dominated by four key suppliers/marketing companies, making up over 90% market share with production centred in England and Scotland. Consumption peaks in the summer for both fruits, typically with as much as a six-fold sales uplift. Strawberry sales are highly dependent on weather.

Key supply chain characteristics include:

- Post-harvest life for both strawberries and raspberries typically ranges from 4-8 days but tends to be longer for imported fruit (e.g. 8-14 days for strawberries and 11 days for raspberries), due to varietal differences (e.g. more robust, firmer fruit with higher dry matter).
- Lead times range from 12-24 hours. Stock levels range from 1-3 days, but are commonly 1-2 days. End of season fruit are never 'held' (stored).
- Shelf-life is short and ranges from 2-11 days (typically three days) for strawberries, while for raspberries it ranges from 2-6 days. For both fruits shelf-life is highly dependent on adequate and efficient removal of field heat (e.g. forced air cooling as a minimum) and maintenance of the cool chain, in-store and in households.
- Looking at the whole chain, the most loss is generated at the field, but only 0-0.5% of this is likely to go to landfill or energy recovery, with the majority being ploughed back into the land.
- The level of final mean product waste at retail over the season is ca. 2-4% for strawberries and ca. 2-5% for raspberries, but may be greater for convenience retailers (ca. 6-7%). It is likely that most of this is disposed to landfill or energy recovery because the product is associated with its packaging.
- For both imported and home-grown fruit, waste tends to be greater at the shoulders of the season, i.e. towards the end of the season or at the beginning, because the quality deteriorates.

3.1.2 Resource Maps

See over page for resource maps for strawberries and raspberries

Figure 8 Resource map for strawberries

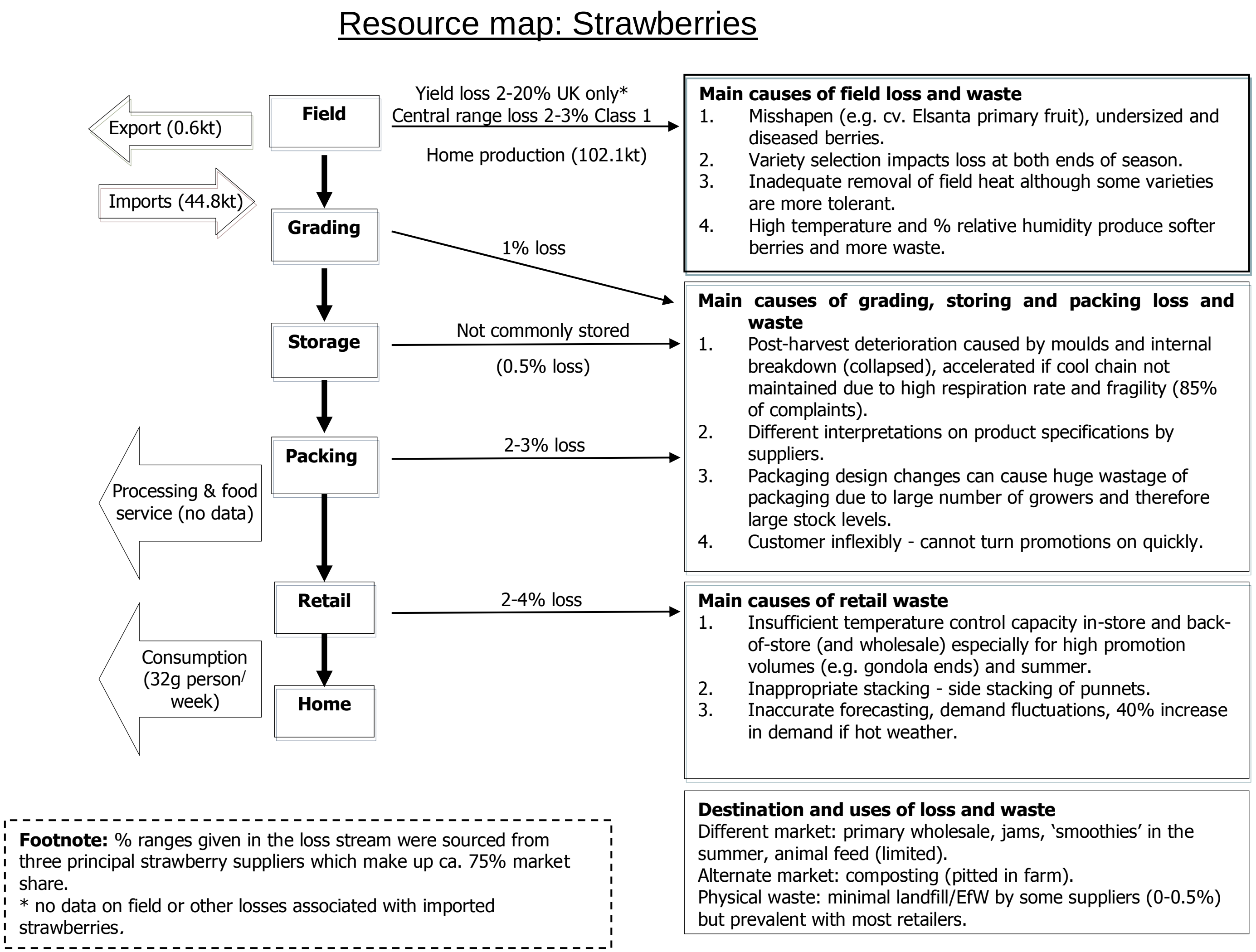
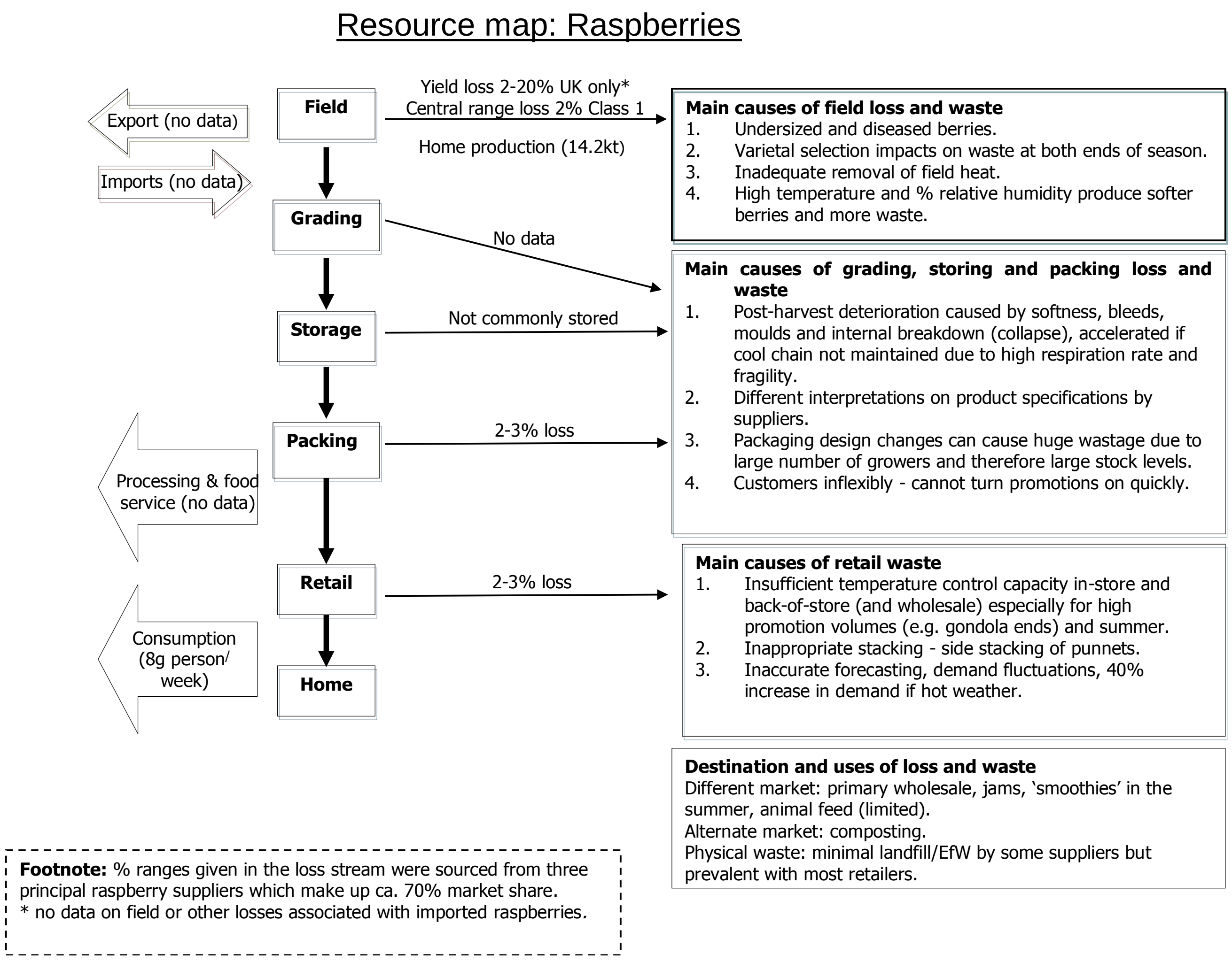


Figure 9 Resource map for raspberries



3.1.3 *Causes of waste*

Strawberry and raspberry fruit have an inherently short shelf-life that is fundamentally associated with their fragility and high respiration rate. Post-harvest disease, physical breakdown and handling are considered the most important factors affecting waste generation in the soft fruit industry, with the incidence and severity of disease dependent on varietal selection, adequate temperature and relative humidity management. Breakdown and mould cause 85% of customer (retailer) complaints. The principal post-harvest pathogens that cause disease in strawberries are *Botrytis cinerea* (grey mould) and *Rhizopus stolonifer* (leak rot). Ethylene management is not considered to be very important as strawberry and raspberry fruit are non-climacteric.

Correct temperature management throughout the cool chain is paramount. The vast majority of soft fruit are cooled quickly after picking to remove field heat (e.g. forced air cooling) and then maintained at 4-8°C during retail, although this can vary according to customer requirements. However, during gluts (oversupply) chill capacity in-store cannot always cope with the increased volumes and as a result, ambient shelf space and gondola ends are sometimes used, increasing the fruit temperature above 4-8°C and affecting the product quality and potentially increasing the rate of spoilage. If there is insufficient cold storage capacity at back of store and on-shelf then shelf-life can be reduced by as much as 3-4 days. This may not always drive waste in-store if sales are predictable (e.g., because of sustained good weather) and the produce are transferred to a fridge when the consumer gets them home.

Despite continued season extension in the UK (using varietal selection, improved plant scheduling and protected production, for example, poly-tunnels - which in themselves have reduced the incidence of grey mould disease and provided protection from the elements – and, to a limited degree, propagation under glass), short-term consumption trends are still highly dependent on immediate weather conditions. High temperatures can lead to as much as a 40% uplift in demand, such that accurate short-term forecasting is critical. Demand for UK strawberry fruit triples between the start of the season and main cropping period (June). If temperatures are stable for an extended period then forecasting works better as sales are predictable. This will tend to result in less wastage at retail as the residence time in-store is short. Suppliers commented through the interviews that promotions are very effective at reducing waste by removing gluts at times of high availability; promotions can help to drive demand by between 20-50%, though some retailers are not flexible and cannot turn promotions on quickly enough to respond to surpluses.

High temperatures lead to an acceleration in fruit production, i.e. shorter times from flowering to harvest, both for home-grown and imported fruit. Where flushes do not match demand, loss in the field will result, i.e. fruit are not picked and are left on the plant. This sounds wasteful yet is understandable since picking constitutes by far the greatest cost to growers. Picking fruit that have no market would result in greater loss further down the supply chain. Class II fruit are often not picked as there is little demand due to stringent product specifications (though this may affect levels of disease in the field because of the higher pathogen load resulting from non-picked fruit). Predicting fruit production is therefore paramount so that demand can be met.

One supplier commented that as temperatures increase in Spain (during April/May 'late picks'), berries become darker and are more prone to bruising, which can mean waste increases. There is also more scrutiny from retailers during this time so rejections increase. During the winter, soft fruit is given less shelf space in-store and customer demand is more stable, but production is more volatile e.g. as a result of frost in Spain. Wet weather, leading to higher humidity levels, will result in softer fruit and may drive increased waste.

Because Class I fruit are picked straight into the punnet for retail ('one punnet' system) the effect of poor handling throughout the supply chain is reduced. Proper selection at harvest is critical to minimising loss.

Varietal selection also affects waste. Varieties are selected based not only on taste and yield, but also on shelf-life capacity and ability to withstand the supply chain (particularly important for imported fruit). For example, cv. Sonata leads to less loss early in the season compared to cv. Elsanta as less misshapen fruit are observed on the primary truss. However, more loss is encountered for cv. Sonata later in the season due to excessive softness. UK–grown strawberries tend to have a shorter shelf-life compared to imported fruit as they are less robust.

3.1.4 Packaging and packaging waste

Given their fragility appropriate packaging for strawberry and raspberry fruit is essential and reduces waste by providing physical protection. The 'one-punnet' system fundamentally reduces handling (as the fruit is 'ready for shelf') and therefore reduces product damage, assuming the punnet size is appropriate to the product volume in the pack. Some commented through the interviews that retailers sometimes take the punnets out of crates and stack them on their ends for shelf space reasons, a practice that increases waste as punnets should be presented flat as per their design.

Punnet design has remained substantially unchanged over recent years, though strides have been made to optimise the packaging by reducing the thickness of the punnets whilst still maintaining adequate rigidity and strength. Some suppliers commented that punnet thickness is now probably at the limit if berry damage is to be limited.

There is a trend, however, to use heat sealed lids that reduce the pack weight considerably (Figure 10) without apparently compromising product protection rather than using conventionally moulded lids. Heat seals also enable the use of MAP, which could extend post-harvest life. One supplier commented that MAP leads to reductions in rots and moulds. However, if temperatures are not kept stable throughout the supply chain then MAP/ and/ or sealed punnets can have a negative impact on product quality.

Figure 10 Heat sealed strawberry punnet (Sainsbury's).

Packaging waste through the supply chain is minimal (ca. 0.5 - 1%), but much depends on the periodic, although rare, packaging changes imposed by the retailer. If retailers do not work with suppliers to reduce stocks then the one-off financial losses can be significant. This situation can be exacerbated by there being approximately 100 strawberry packers in the UK, each with various stock levels of packaging.

Most suppliers and wholesalers separate damaged or diseased fruit from the crop during picking/grading. This cannot be done by retailers due to logistics and labelling; a punnet with one less fruit will not be the same weight as that advertised on the label. Current practice is that the whole punnet is usually discarded even when the majority of fruit within the punnet are sound and fit for human consumption. Working with retail customers on their specifications, accepting the idea of 'waste tolerance' and increased consumer education would be beneficial to prevent whole punnets being rejected because of an isolated rotten berry.

3.1.5 Technical recommendations

- More research to mitigate against misshapen fruit to help reduce in field waste.
- Improve real-time forecasting of field production and picking cycles to better inform promotional activity and match supply with demand fluctuations.
- Explore ways of better utilising Class II fruit.
- Punnets protect the fruit and thereby reduce waste. Although decreasing punnet thickness is thought to be at the limit, heat-sealed lids should be encouraged to further reduce pack weight and waste in the chain.
- Explore ways in which isolated diseased berries can be removed from a punnet and the remainder of the sound fruit sold whilst not breaching legislation on weight misrepresentation.
- Improve in-store temperature management and handling, particularly ensuring that punnets are displayed flat as per their design.
- More timely dialogue between retailers and suppliers to better forewarn packers about packaging design changes.
- Improve understanding of losses and physical waste associated with imported fruit and packaging.
- When altering punnet size (weight) due to price/promotion requirements, select the correct punnet size to restrict fruit movement thereby avoiding fruit-to-fruit damage in the punnet.

3.2 Lettuce

3.2.1 Overview

The UK produces 124.2 kt of lettuce per annum and imports 172.4 kt (Defra, 2009). Spain is the main exporter of lettuce to the UK. After harvest lettuce is cooled to 4^{o}C and then put into cool store with ca. 100% relative humidity to stop dehydration and benefit shelf-life.

The quantities purchased for household consumption have increased and stand at 40g[19] per person per week (Table 8). The UK lettuce industry is dominated by four key suppliers/marketing companies making up over 90% market share. Consumption peaks in the summer months typically with as much as 70% uplift compared to winter and, as such, sales are highly dependent on weather. Winter is the busiest period for growers (suppliers).

Key supply chain characteristics include:

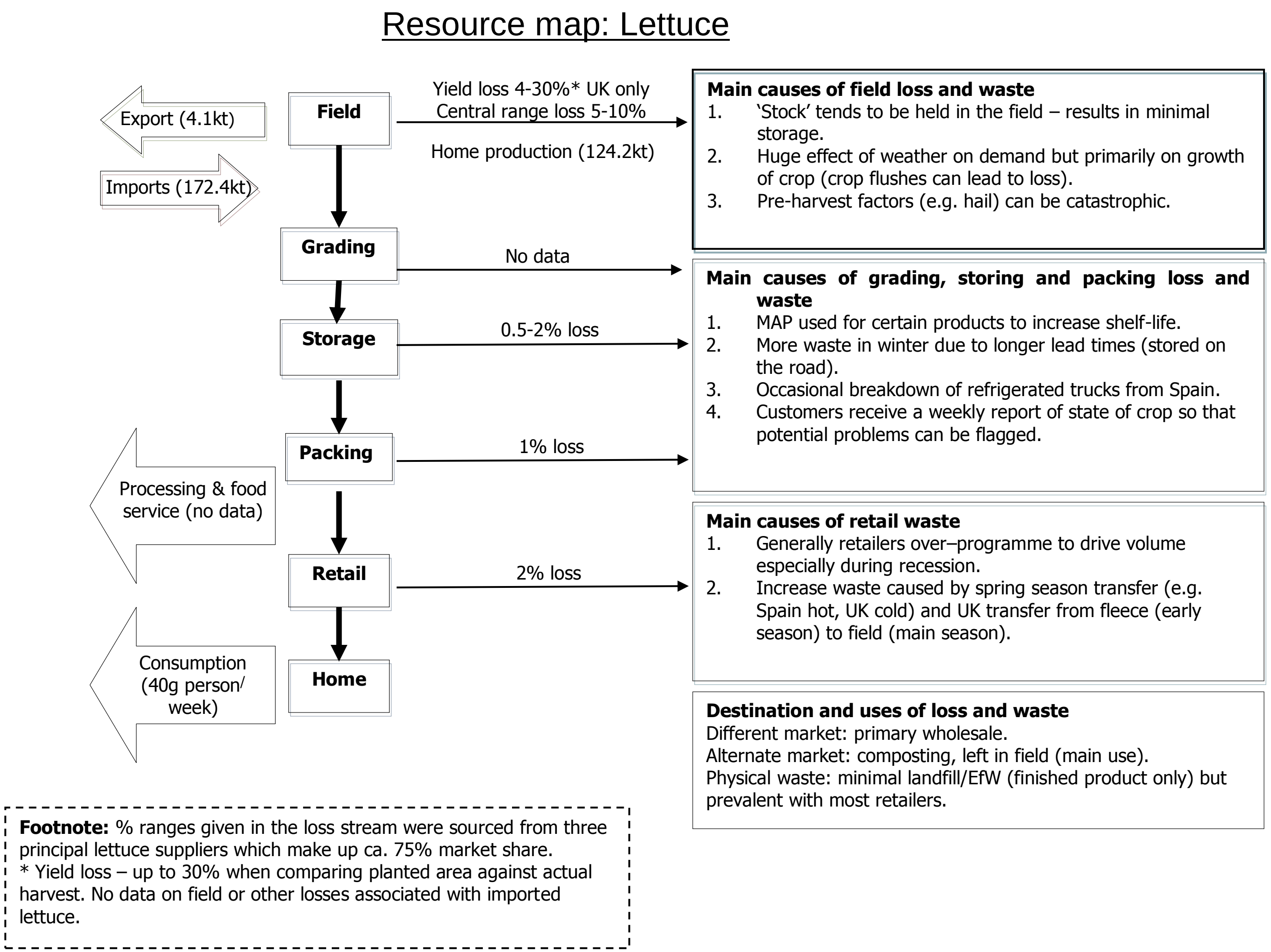
- Post-harvest life typically ranges from 3-9 days.
- Lead times range from 12-96 hours. Stock levels range from 0-2 days, but are commonly 2 days. Some suppliers hold no stock.
- Shelf-life is short and ranges from 2-4 days. Four days in winter.
- Looking at the whole chain, the most loss is generated at the field with growers aiming to harvest between 70-100% heads planted. However, of the loss, only <1% of this is likely to go to landfill or energy recovery, with the majority being ploughed back into the land and a small proportion being sold to wholesalers as Class II. Some weather events can lead to as much as 30% field loss.
- The level of final mean product waste at retail is ca. 2%, which is likely to go for disposal to landfill or energy recovery.

3.2.2 Resource map

See over page for resource map for lettuce

[19] *Includes watercress, mustard and cress, crispy seaweed, but does not include prepared salads.*

Figure 11 Resource map for lettuce



3.2.3 Causes of waste

There are four principal types of lettuce grown with over 28 varieties. Selecting a variety that generates minimal waste through the supply chain is a key selection factor. Varieties used are constantly changing to improve the yield throughout the season and meet specifications. The transition between seasons can cause difficulties in supply and may impact on waste, particularly from Spain to England (more than the other way). Spain's hot climate can mean that the season is over before UK produce is available and in this case lettuce is flown in from the USA to meet demand.

Lettuce has an inherently short shelf-life, yet despite continued season extension in the UK, short-term consumption trends are still highly dependent on immediate weather conditions. High temperatures can lead to as much as a 70% uplift in demand such that accurate short-term forecasting is critical, though suppliers commented through the interviews that they will often aim to satisfy demand by 'over planting'. No supplier wishes to be 'short' and will trade off delivery to their customers 'in full' (as well as on time) for high levels of field waste. If temperatures are stable for an extended period, then forecasting works better as sales are predictable. Suppliers commented that promotions are usually positive; more product is sold and can be used when there is too much product on the market. Sometimes, however, there is little uplift due to poor forecasting and this can drive waste.

Interviewees suggested that a reduction in SKUs (Stock Keeping Unit) on bagged salads could have a positive impact on sales and waste because a plethora of SKUs can overcomplicate choice.

3.2.4 Packaging and packaging waste

MAP is used for some lettuce lines to increase shelf-life and this could be further explored.

There is debate over whether packaging changes are a significant problem. Some suppliers indicated that packaging design changes have a big impact, particularly for customers that have special codes, given that retailers can change their packaging design every 2-3 years. There was also debate around the increased use of plastic trays, rather than cardboard, for distribution with suppliers, indicating that there simply are not enough trays in the system, particularly during the winter. Furthermore, when considering imported product, it is usually uneconomic to ship plastic trays from the UK to suppliers abroad.

3.2.5 Technical recommendations

- Improve real time forecasting of field production and picking cycles to better inform promotional activity and match supply with demand fluctuations.
- Greater tolerance of aesthetic appearance (colour) and size would decrease waste but depends on the relationship with retailer (and consumer expectation/demand).
- Increase number of re-useable trays available for use, particularly in the winter otherwise suppliers revert to using cardboard boxes to transport packs.
- Reduction in SKUs could have a positive impact on sales and waste by presenting a more limited choice.
- Improve understanding of waste associated with imported lettuce.
- Increase use of MAP to increase shelf-life and help mitigate against poor temperature control.

3.3 Tomatoes

3.3.1 Overview

The UK produces 88.7 Kt of fresh tomatoes (*Solanum lycopersicum*) per annum and imports 416.7 kt (Defra, 2009). Spain is the main exporter of tomatoes to the UK.

The quantities purchased for household consumption have remained relatively stable since 2003 and stand at 95g per person per week (Table 8). The UK tomato industry is dominated by three key suppliers/marketing companies making up over 75% market share with production centred in the South and East of England. Consumption peaks between June and July typically, with as much as a 7-fold uplift in the 8-week summer peak.

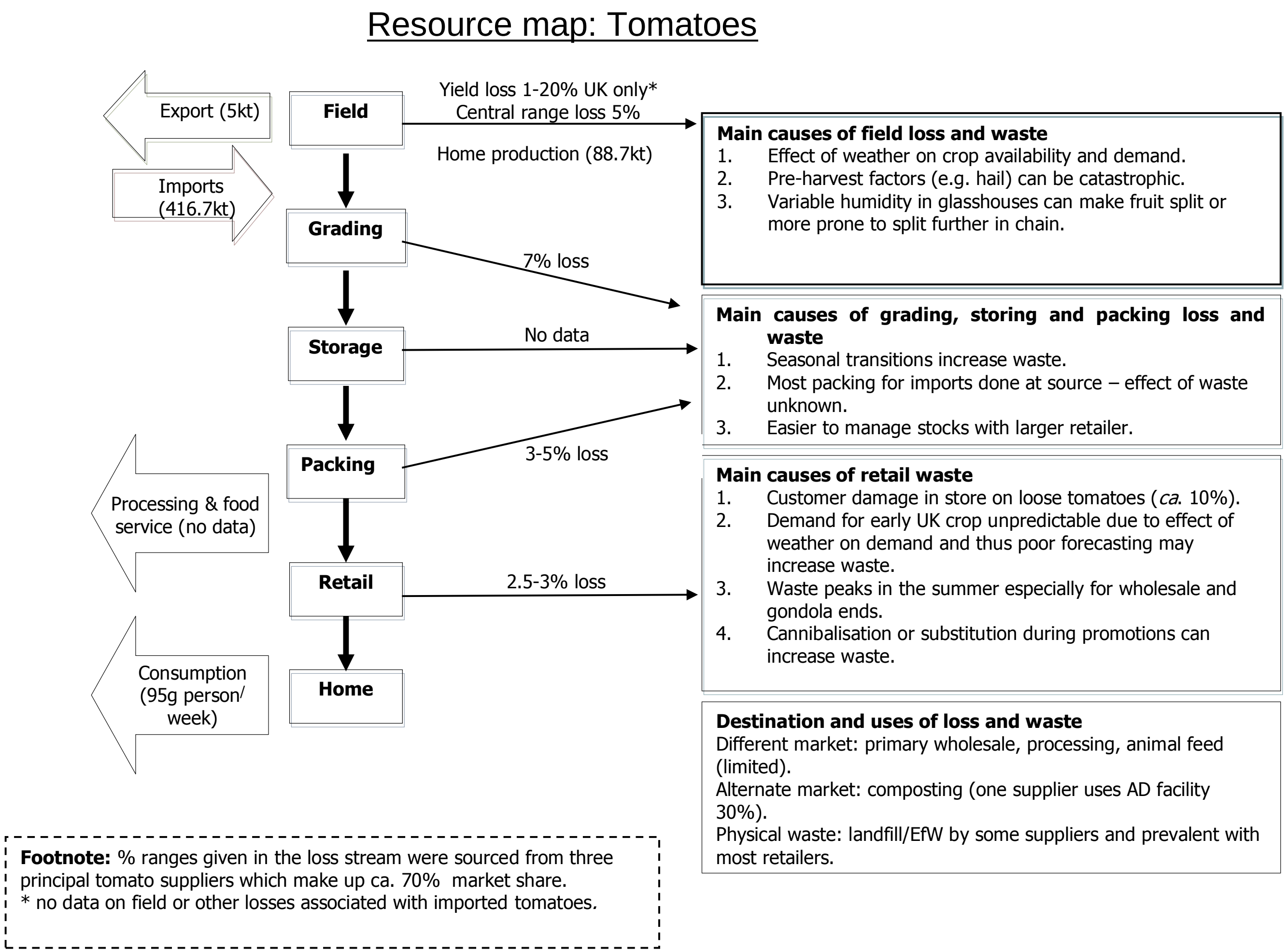
Key supply chain characteristics include:

- Post-harvest life typically ranges from 3-7 days but can be 14 days with some varieties. Total residency time from pick to end of display is from 7-14 days.
- Lead times range from 6-24 hours. Stock levels range from 0-3 days, but are commonly no more than three days. During the winter, transport from Spain to the UK takes three days.
- Shelf-life is short and ranges from 2-4 days.
- Again, looking at the whole chain, the most loss is generated at the field but a supplier noted that just <1-2% goes to landfill or energy recovery. The remainder is ploughed back into the land, sold as animal feed or sold on for a secondary food use (e.g. ready meal ingredient).
- A significant proportion of the crop is also lost at grading and packing as a result of product not meeting stringent colour, size and Brix specifications.
- The level of final mean product waste at retail is ca. 3%, the majority again, will go to landfill or energy from waste.
- Some weather events can lead to as much as a 20% field loss but this is rare.

3.3.2 Resource map

See over page for resource map for tomatoes

Figure 12 Resource map for tomatoes



3.3.3 Causes of waste

The tomato is a diverse fruit, which has a relatively short shelf-life depending on variety (e.g. cv. Jack Hawkins and cv. Baby Plums have a seven and 21 day shelf-life, respectively). Speciality tomatoes tend to have an inherently shorter shelf-life due to their higher respiration rate and thus can have higher waste levels. Varieties have different levels of waste and are selected on a 'whole cost' approach; those with lower yield (and higher waste) will be more expensive. Tomato shelf-life is influenced by ethylene and control measures have been trialled, e.g. ethylene scrubbers and SmartFresh (1-MCP).

Horticultural maturity and storage temperature are also key to defining shelf-life. Tomatoes are ideally stored at between 8-10^{o}C. They are chill sensitive and thus should not be stored at lower temperatures due to chilling injury and other physiological disorders. Suppliers commented that gondola ends are occasionally used to merchandise tomatoes and, where used, this can lead to the fruit being kept at higher temperatures (e.g. during summer months), and reduction in shelf-life by up to two days. Temperature control in-store is critical to reducing waste.

A high moisture content in tomatoes will increase the incidence of splitting and disease. Large variations in relative humidity in the glasshouse can cause problems. Poor structures (e.g. old glasshouses and polytunnels) increase waste. The primary complaint of 'split' cherry tomatoes during the winter is caused by old glasshouses and polytunnels.

As with the other products researched through this study, demand is highly weather dependent resulting in variability in supply, a main cause of waste. One supplier commented that in 2008 there was as much as 10% waste (up to 20% for early planted crop) due to unpredictable demand. The following year, 2009, had a poor summer, and this, combined with the start of the economic recession, saw waste levels fall again to around 5%. Another told the research team, however, that if the provisional order differs from actual order, over-packed product will be debagged and repacked. They also noted that there is often a tendency to over stock 'just in case' so they do not sell short. Increased storage (stock cover) can increase loss and waste because weight loss and disease are higher.

Planting for the following year takes place in November so growers need to be able to predict demand. Demand peaks in June/July with a 70% uplift from winter consumption levels. Fruit are imported between October and June with UK fruit only becoming readily available in April. Losses are greater early in the UK season and during the transition between seasons. Suppliers commented that at the beginning of seasons products are too large (non-compliant with specifications). At the end of the season the 'sugar' content (measured by Brix) is too low though they also commented that colour specifications can be adapted to cope with potential supply problems.

3.3.4 Packaging and packaging waste

At retail, tomatoes are either sold loose or on the vine, sold 'free-flow' or pre-packed. Free-flow produce can have higher waste levels to pre-packed because of damage caused by consumer handling. If a product is reduced to clear by retailers or damaged it usually does not get decanted, due to the fragility of the tomatoes and cost, and will go to landfill or energy recovery even though it would be safe to eat.

Again, suppliers commented that packaging designs change frequently, which can create waste through 'write offs', while others cited the frequency of packaging design changes at around two years, which they did not believe to be a problem.

3.3.5 Technical recommendations

- More flexibility around specifications; aesthetic appearance (colour), Brix and size grades would decrease waste.
- Consider using better temperature control in retail as this could increase shelf-life by two days.
- Continued investment in modern glasshouse structures to reduce field waste and ensure better product uniformity.
- Invest in R&D to investigate ways by which to extend horticultural maturity and the storage life of ripe product.

3.4 Apples

3.4.1 Overview

The UK produces 243.0 kt of apples (*Malus domestica*) per annum and imports 477.2 kt (Defra, 2009). France, New Zealand, South Africa and USA are the main exporters of fresh apples to the UK. UK production is mainly centred in the South East and the West of England.

The quantities purchased for household consumption have remained relatively stable since 2003 and now stand at 178g[20] per person per week. The UK apple industry is dominated by six key suppliers/marketing companies making up over 70% market share; however, the structure is far more disparate than most other fresh produce types. Consumption is relatively stable over the year unless promoted, but demand does increase slightly at the start of the English season. The most popular apple varieties consumed in the UK include: cv. Gala (1), cv. Braeburn (2), cv. Jazz (3), cv. Pink Lady (4), cv. Granny Smith, cv. Golden Delicious, cv. Queen Cox and the 'earlies' (e.g. cv. Discovery).

Key supply chain characteristics include:

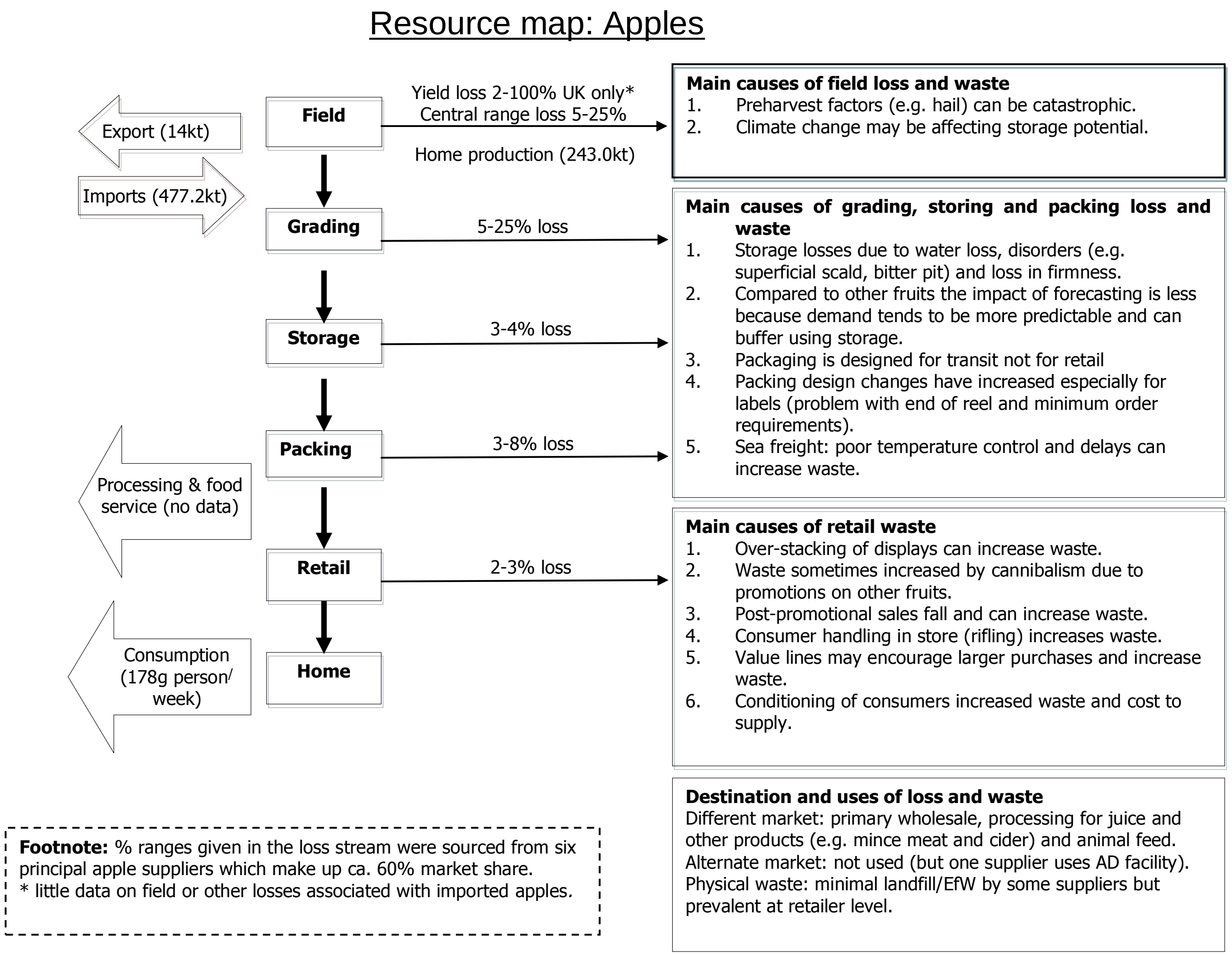
- Post-harvest life typically ranges from 0-365 days, but is reliant not only on variety, but also on storage regime (e.g. temperature, controlled atmosphere, ethylene control/suppression [DPA (diphenylamine), 1-MCP, $KMnO_4$, Platinum group metal-based ethylene removal etc.]). The best crop is stored longest with optimal storage regime (e.g. early harvest cv. Queen Cox for controlled atmosphere (CA)). Mean storage is 50 days.
- Lead times range from 6-24 hours. Stock levels range from 0.5-60 days, but are commonly between 7-21 days (variety dependent).
- Shelf-life is again very variety dependent and can range between 4-12 days.
- Out of specification product arising in the field is diverted from landfill and sent for juicing, typically resulting in just <0.01% going to landfill. However, the data shows that loss levels can be catastrophic resulting in 100% of the crop not making it to the retail shelf.
- There can be quite high levels of loss and waste at grading and packing as well, as product is rejected due to not meeting prescribed specifications, though this is also usually diverted from landfill and juiced.
- The level of final mean product waste is 3%, which will likely go to landfill or energy recovery.
- Suppliers commented that waste for imported fruit can be as high as ca. 5-8%.

3.4.2 Resource map

See over page for resource map for apples

[20] *Includes cooking apples and toffee apples.*

Figure 13 Resource map for apples



3.4.3 Causes of waste

Apples are a fairly robust yet diverse fruit consisting of many varieties that differ in terms of how long they can be stored for (Table 10). For example, cvs. English Discovery and Delbard can only be stored for around three weeks and hence are usually supplied without storage, whereas cv. Bramley's Seedling can comfortably be stored for 11, or even 12 months if the correct storage regimes are adhered to.

Table 10 Storage regimes employed for UK-grown and imported apples.

Variety	Storage-Marketing Period	RA-storage *	CA-storage or SmartFresh *
Discovery	2-4 weeks	All RA	not applicable
Worcester Pearmain	6-8 weeks	All RA	not applicable
Spartan	4-6 weeks	All RA	not applicable
Royal Gala	6-7 months	2 months	4-5 months
Cameo	6-7 months	2 months	4-5 months
Cox's Orange	6-7 months	2 months	4-5 months
Kanzi	6-7 months	2 months	4-5 months
Pink Lady	5-6 months	2 months	3-4 months
Red Delicious	5-6 months	2 months	3-4 months
Egremont Russet	3-4 months	All RA	not applicable
Braeburn	7-8 months	2 months	5-6 months
Golden Delicious	11-12 months	2-3 months	8-9 months
Granny Smiths	11-12 months	2-3 months	8-9 months
Jonagold	AYR *	2-3 months	9-10 months
Bramley's Seedling	AYR *	2-3 months	9-10 months

Source: courtesy of anonymous supplier
** RA = regular atmosphere (air); SmartFresh = 1-MCP; CA = controlled atmosphere, AYR = all year round*

The range of storage potentials governs whether certain post-harvest treatments can be applied or are worth applying, and thus has a major influence on the level of loss and waste. Storage potential is not only dependent on the storage technologies employed, but also quality and horticultural maturity (e.g. climacteric) in that early fruit (with the first pick being the best fruit) tend to be stored for the longest durations under the most sophisticated storage regimes, so that windows of availability can be accessed and higher prices achieved. Most storage practitioners use an 'oldest first' policy.

Suppliers commented that apple varieties that tend to produce higher waste in-store are being phased out (e.g. cvs. Temptation and Queen Cox) in favour of those that have better storage potential. Though taste is the main selection criterion for varieties, storage potential is still important. For example, cv. Jazz was bred to have a firm and crisp texture and good taste profile but it also benefits from having good storage potential.

Poor storage management (and pressure from retail customers) can increase loss by pushing storage durations beyond what is reasonable.

Like some of the other products under investigation through this research, suppliers commented that waste increases at the shoulders of season, e.g. at end of cold storage, and that transitions between storage regimes affect the level of loss during storage (e.g. water loss and disease) and the quantity of product that is out-graded.

Apples are sensitive to ethylene, temperature, and physiological disorders such as superficial scald, though these can be managed using appropriate technology. Control technologies, such as SmartFresh (1-MCP) has extended season lengths and thereby given growers more flexibility, but some suppliers commented that such technologies have had some negative publicity.

The main cause of loss in the supply chain is at grading with fruit being out of specification. The level of grade-out is dependent on storage duration, variety and initial quality. Suppliers commented that grade out for cv. Gala can be as high as 94% and as low as 75% for cv. Bramley at the shoulders of the seasons though this varies according to storage regime and duration.

After storage, apples are usually transferred to retail store within three days. Shelf-life is also variety dependent e.g. four days for cv. Discovery and ten days for cv. Jazz. Suppliers commented that 80% of apple waste arising after grading is a result of bruises, bitter pit, scald, lack of firmness and mechanical damage. It was also noted that a high percentage of waste arises because of over-stocking and product 'giving up'. For commercial and supply chain reasons there is pressure to increase shelf-life even if the product becomes senescent. In-store management is therefore important; cold storage in-store would increase the shelf-life of apples from four days to 6-9 days.

Demand for apples is generally constant and as a consequence predictable. Seasonal demand is highest during September and sales can dip during warmer weather but increase (along with citrus particularly) at Christmas due to the 'full fruit bowl effect'. Weather can have an impact on pre-harvest losses. Accurate forecasting is so critical to success that most importers work to a planned programme to ensure availability. Promotions are used frequently to drive demand, though promotions on other categories, e.g. oranges, can negatively affect usual purchasing patterns. Interestingly, suppliers commented that the economic downturn has resulted in smaller fruit being sold, e.g., on value lines, which have greater quality assurance tolerances. Suppliers commented that this trend is likely to remain after the recession. Selling smaller fruit has had a knock-on effect on the availability of produce for juicing and the quantity of field waste.

Conversely, a supplier commented that promotions (particularly 'buy one get one free' offers) can lead to increased customer complaints because the apples sit in fruit bowls at home and don't get eaten. Promotions also put suppliers under pressure, that is, the more fruit is handled quickly the greater the risk of damage.

3.4.4 Packaging and packaging waste

There is very limited use of MAP for apples, despite trials. Interviewees felt this to be because the benefits would not justify the cost.

Again, suppliers noted that packaging waste can be generated by retailers changing packaging design too frequently or without adequately communicating ahead of the change. Labels seemed to be a particular problem and suppliers suggested that generic labels be developed e.g. £1 per bag rather than different variants of this. Where possible however, any packaging waste arising at the packer site is recycled with just pallet strapping, for example, being landfilled.

3.4.5 Technical recommendations

- Continue to invest in improved storage regimes (e.g. ethylene control and modern controlled atmosphere).
- Improve control over post-climacteric senescence.
- Reduce frequency of packaging design changes (especially labels) and improve communication between retailer, packaging supplier and produce supplier to decrease packaging waste and/or consider generic labelling.
- Explore the use of more flexible Brix and pressure tolerances to help reduce waste.
- Continue with specification changes on size to utilise more apples for the fresh market (NB: though there was some disagreement between suppliers on this point and it is important to improve the understanding of how this will affect overall waste/crop utilisation).
- Improve temperature control during distribution on ships (for imported produce) and in-store.

3.5 Onions

3.5.1 Overview

The UK produces 364.5 kt of onions (*Allium cepa*) per annum and imports 375.8 kt (Defra, 2008). Chile, New Zealand and Spain are the main exporters of onions to the UK. Imports increase from the Southern Hemisphere once UK stored onion supply starts to diminish.

The quantities of onions purchased for household consumption have increased slightly since 2003 and now stand at 91g per person per week. The UK onion industry is dominated by four key suppliers/marketing companies, making up over 81% market share (retail) with most production based in the East of England. Consumption is relatively stable over the year but can decline by 10% in the summer. Typically, more red onions are eaten in the summer than during the winter months, but increased demand for reds has probably also occurred due to their versatility in use. Brown onion sales increase between November and February.

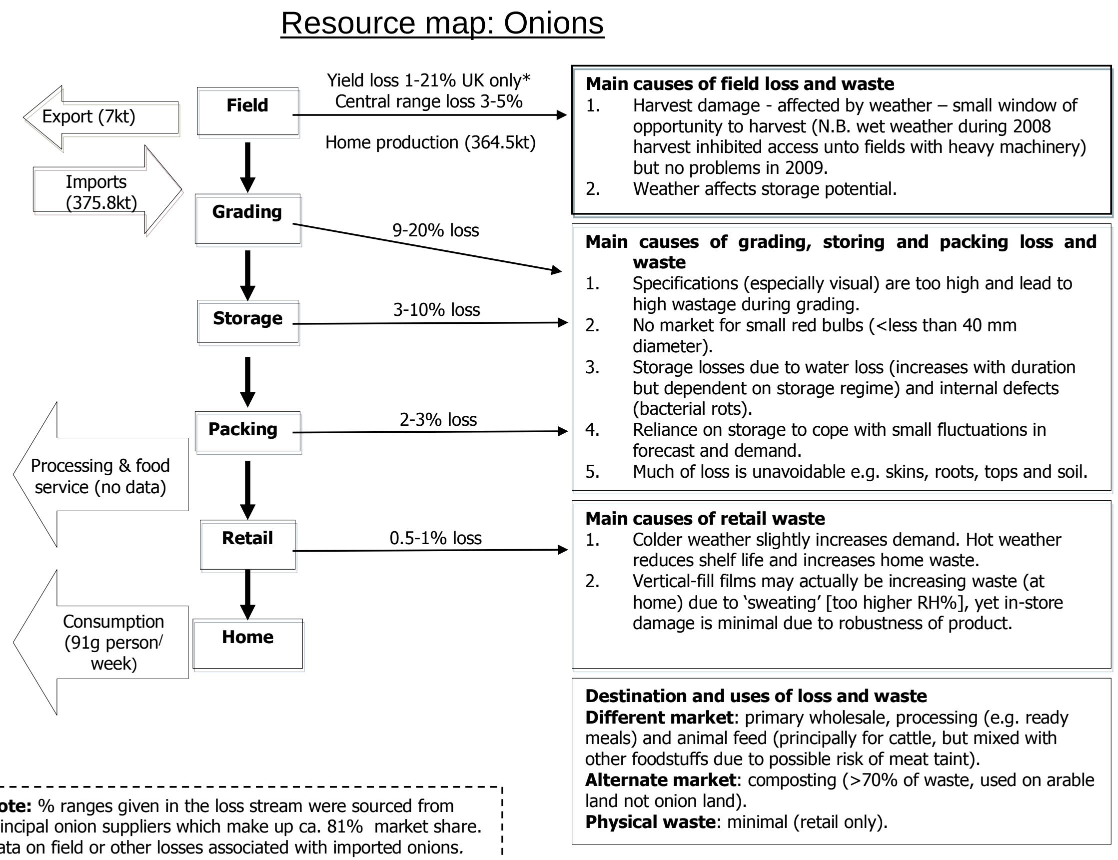
Key supply chain characteristics include:

- Post-harvest life typically ranges from 21-300 days, but is reliant on not only variety (innate dormancy, period of sprout suppression, dry matter), but also on storage regime (e.g. curing, storage temperature, CA, sprout suppressants (e.g. maleic hydrazide (MH), exogenous ethylene supplementation). Mean storage life is between 120-160 days. The best crop is stored the longest with optimal storage regime (e.g. cold with CA and ethylene).
- Lead times range from 3-30 hours. Stock levels range from 1-7 days, but are commonly between 2-4 days for volume lines.
- Shelf-life ranges between 7-10 days, but can be reduced to five days at the end of the season.
- Yield losses can be high (at 21%) but on average there is less loss in the field for onions than for some of the other products in this study. There are, however, high losses at grading as product that does not meet specification is rejected.
- Storage also represents a significant proportion, due to water loss and internal defects.
- The level of final mean product waste at retail is 0.5-1% but can be even lower and the majority will be disposed to landfill or energy recovery.

3.5.2 Resource map

See over page for resource map for onions

Figure 14 Resource map for onions



Footnote: % ranges given in the loss stream were sourced from four principal onion suppliers which make up ca. 81% market share.
* no data on field or other losses associated with imported onions.

3.5.3 Causes of waste

Onions are a relatively robust product with a low respiration rate and therefore some varieties are capable of being stored for almost 10 months. During storage, onions dry out and lose weight, with those that are stored throughout the season able to lose ca. 5% of their weight.

Levels of loss can also be high during grading (9-20%), particularly so for organic lines due to increased incidence of disease. As a result between 15-50% of the crop will be packed compared to 95% for conventional onions.

Onions are graded to remove tops (leaf material), soil, scales, rots, damaged roots and small sized bulbs. Fifteen per cent of loss at grading is in fact skins, dirt, tops and roots (unavoidable waste). The level of loss at grading is affected by the prevailing weather conditions during the growing period and at harvest; however, the impact of different conditions still needs to be researched properly. One supplier commented that in 2009, 17% on average was downgraded, though 9% is more typical.

There is currently a very limited market for small red onions below ca. 45 mm that cannot be sold as class one. Generally, these end up being composted or used for stock feed. Small brown onions, however, can be sold unless rotten, soft or externally sprouting.

Due to the UK's maritime climate, UK onion bulbs are currently cured for up to 3-6 weeks at 28^{o}C after harvest (and before storage) to improve skin colour and reduce incidence of neck rot caused by *Botrytis allii* (Figure 15). New Zealand onions are cured in the field, in open barns or during the sea voyage. Defra is undertaking work to examine whether the curing temperature can be lowered without impacting on the product quality (Defra HortLink 0182). Suppliers commented that onions could be dried harder, but this can lead to more waste during storage.

Figure 15 Neck rot in onions

There is a necessity to store onions for extended periods as the harvest window for the main crop is narrow (between 14-15 days in September) and demand is stable all year round. Suppliers therefore rely on storage to ensure year round supply to a planned forecast, but also to deal with small scale fluctuations. Forecasting is generally accurate and arranged with the customer.

Storage losses, however, are significant and caused by disease, breakdown and water loss (i.e. weight loss), but without storage the UK season would be very limited with knock on effects for production. For instance, red onions (e.g. cv. Red Baron) can be stored for up to 10 months, whilst mild onion cv. Supasweet SS1 can be stored for as little as 3-4 weeks. Onions (harvest September) stored at ambient temperatures can suffer from compression damage as they are stored in piles (bulk storage), resulting in onions at the bottom being damaged.

Quality control and product specifications are the most significant waste drivers for onions. Most onions are downgraded because their visual appearance (i.e. skin finish, colour, size) does not meet the specification. Clearly, onions skins are inedible and are discarded by the consumer. Skin finish has no effect on the eating quality. What is required is an understanding of consumers' tolerance for less attractive onion bulbs if they were made available. To make such a change, visual specifications would need to be reduced across the whole industry and consumers encouraged to choose bulbs based on factors other than visual appearance alone. Suppliers noted that waste and loss is lower between July and September, because product is graded in the Southern Hemisphere before being dispatched to the UK.

Defects like bacterial rot do affect eating quality, but not usually the visual quality of the bulb. The destructive testing (manually cutting bulb) to look for internal defects within a consignment does lead to significant waste.

Demand is fairly predictable and does not deviate much throughout the year, although there is some uplift at Christmas and Easter. Weather does not really affect demand, but high temperatures can increase retail and home waste by encouraging sprouting. Better temperature control in-store would help onions last longer. Product cannibalism is usually accounted for in forecasting as the mechanic is well understood, e.g. promotion on red onions will reduce sales of brown onions (and *visa versa*); forecasts take this into account. Promotions may be used to shift a product when problems are predicted with storage of a batch or consignment. When forecasting does not work as planned then onions can be reworked (repackaged) due to their robustness, but this does lead to wasted packaging, e.g. split films that will usually be recycled.

3.5.4 Packaging and packaging waste

Onions are sold loose in crates, in nets (3-in-line) or increasingly in vertical form-fill bags (VFF). MAP is rarely used. There is debate in the industry over whether nets are better than film in terms of sustaining product quality by enabling airflow and thereby reducing retail (and possibly in-home) waste. Suppliers commented that bags can lead to sweating, which encourages *Pencillium* disease build up. Shelf-life can be 10 days for nets but only eight days for bags. There are barriers to extending the use of nets however, as retailers can find that they do not display well and do not easily enable consumer information to be carried.

Again suppliers noted that packaging design changes can be frequent and made with limited notification (as little as 6 weeks), which can lead to redundant packaging being wasted.

3.5.5 Technical recommendations

- Greater tolerance of aesthetic appearance and size grades would vastly decrease loss. Such tolerances would need to be coupled with consumer education that colour, skin finish and size have no impact on eating quality. This would mean undersized bulbs, for example, which are currently composted, could be eaten.
- Reduce incidence and impact of internal defects, potentially finding an alternative to destructive testing to monitor this.
- Improve storage by, for example, optimising use of ethylene supplementation.
- Improve temperature control in-store.
- Investigate whether netted bulbs reduce waste in comparison to vertical form-fill films, particularly given they provide more ventilation and lower relative humidity for the product.
- Investigate the impact of variable and high relative humidity on skin finish and disease incidence.

3.6 Potatoes

3.6.1 Overview

The UK produces 5,946 kt of potatoes (*Solanum tuberosum*) per annum and imports 1,634 kt (Potato Council, 2009). Production is centred in the East of England and Scotland.

The quantities purchased for household consumption have declined steadily since 2003 and now stand at 537g per person per week. The UK potato industry is dominated by six key suppliers/marketing companies making up over 60% market share; however, the structure is more disparate than for some fresh produce types with multiple growers. Consumption is relatively stable over the year but can increase by 2-50% in for new potatoes in good weather and 20-100% for baking potatoes in cold weather. Typically, more salad-type potatoes are eaten during Easter and the summer than during the winter months.

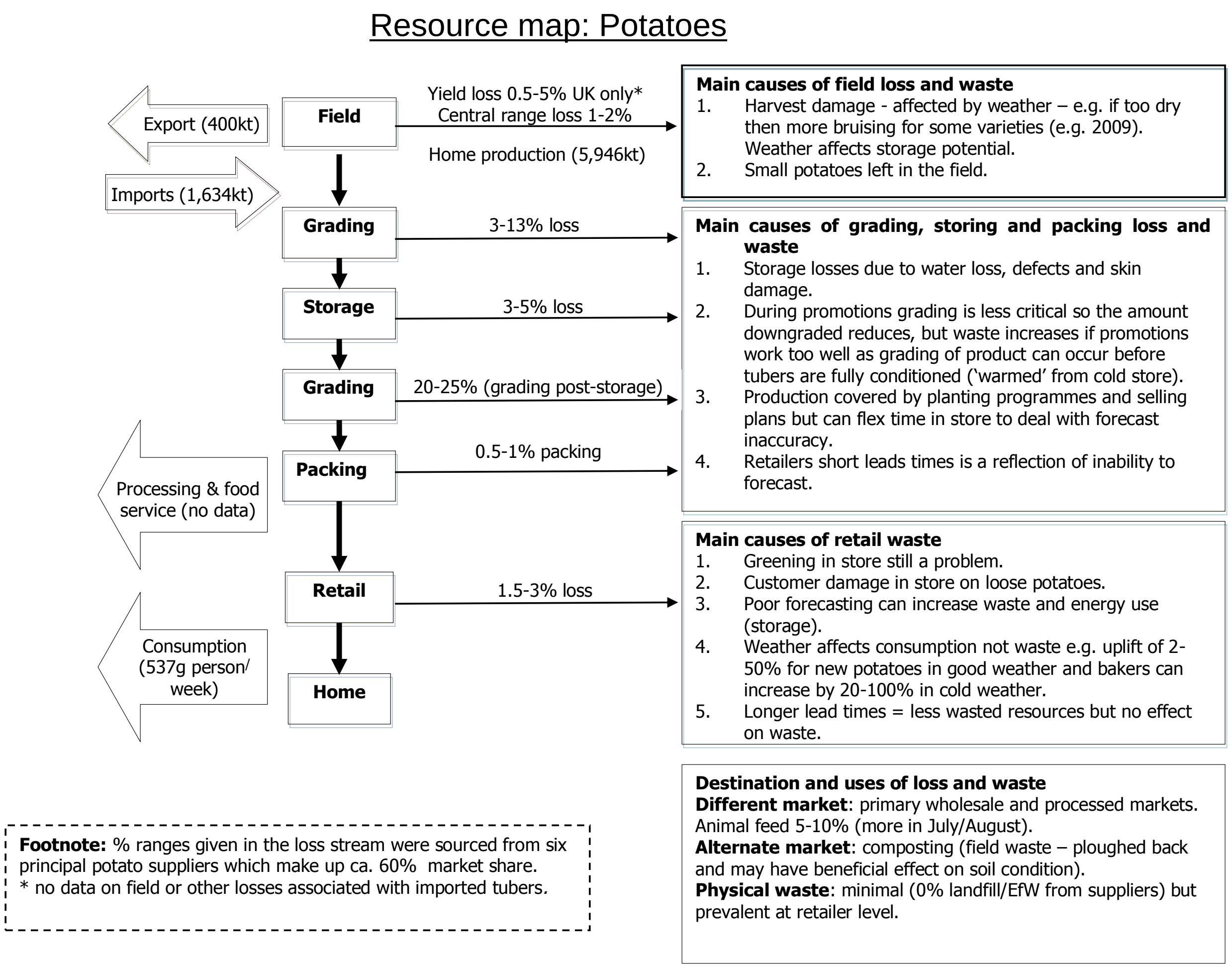
Key supply chain characteristics include:

- Post-harvest life typically ranges from 3 – 270 days (some extended to 365 days), but is reliant not only on variety (innate dormancy, susceptibility to bruising) but also on storage regime (e.g. curing, temperature, sprout suppressants (CIPC or ethylene supplementation)). Mean storage life is between 120-160 days.
- Lead times range from six hours (e.g. cv. Jersey Royals) to 24 hours. Stock levels range from 0.5-6 days, but are commonly between 0.5-2 days.
- Shelf-life ranges between 1-15 days, but is typically 6-8 days.
- All product waste derived from the field and grading/packing, which can reach levels of ca. 10%, but sometimes more, is composted or used for animal feed with nothing going to landfill or energy recovery.
- Packing represents one of the most significant areas of loss and waste as product is rejected due to not meeting prescribed specifications. It is likely that a large proportion of this will go to landfill or energy recovery, though tubers will tend to be re-packed, given that potatoes are quite a robust product.
- The level of final mean product waste at retail is ca. 1.5-3%, with the majority likely to go to landfill or energy recovery.

3.6.2 Resource map

See over page for resource map for potatoes

Figure 16 Resource map for potatoes



3.6.3 Causes of waste

Potatoes dominate the fresh produce industry (Table 8). Effectively there are three markets: fresh, seed potatoes[21] and processed (into, for example, ready meals, oven ready chips and crisps). The fresh market will only be considered in this discussion as the other two markets are out of scope for this research.

Suppliers commented that field waste can be as much as 5% and higher on occasion. Loss is created by blight, greening (when the growing ridge is unstable and open to light), slugs, skin disease, fungal disease (e.g. black dot and blight) and potato cyst nematode. Rotation, chemical use, land quality and varietal selection all help reduce field waste. Product can also be damaged during harvest through the use of new mechanical technologies. Not removing field heat sufficiently may result in poor skin finish. The temperature of water used to wash potatoes is therefore critical and hydro-cooling technologies are used to decrease waste.

Potatoes are stored for up to one year but are usually stored from June to July or from October to July (e.g. main crop). Potato tubers have a wide range of storage potentials, but tend to be relatively robust and have a low respiration rate. There are, of course, exceptions to this rule (e.g. cv. Jersey Royals and other 'new' potatoes). The duration of potato storage is a function of variety and the storage regimes employed. As for onions, two phases dictate the inherent storage capacity of tubers: period of dormancy and period of sprout suppression. Suppliers commented that sprouting is the main driver of waste, because sprouted potatoes would not meet retailer specification. However, potatoes are still edible with sprouts, so retailer and consumer behavioural change would be required to reduce the likelihood of sprouted potatoes being wasted.

Ethylene management is used to extend the period of sprout suppression even though potatoes are low ethylene producers. Ethylene is not used ubiquitously by the industry, however, as there are some concerns that it can induce changes in sugars for some varieties (e.g. cv. Marfona), and increase sprouting when the potatoes are removed from the ethylene storage 'environment', which could drive household waste. The period of sprout suppression can be extended using sprout suppressants (Chlorpropham (CIPC) and ethylene supplementation). There are concerns over the possible withdrawal or restriction of CIPC[22] as, without this, waste caused by sprouting may increase. Storage practitioners only use limited amounts of CIPC to avoid the risk of exceeding residue limits.

Suppliers commented that storage life is not a main driver of waste as cold stores are controlled and monitored. In addition, varieties are selected for their storage qualities and ability to resist storage conditions, which for ambient range between 6-7°C and for cold 2.5-3°C. Some varieties have a short dormant period (e.g. cv. King Edward), whilst others have a long dormant period (e.g. cv. Russet Burbank). Dormancy can be affected by harvest maturity and pre-harvest conditions, e.g. soil temperature and cooling.

Some varieties are more susceptible to deterioration, e.g. cv. King Edward green easily. Different seasons and climatic conditions will adversely affect one variety more than another, e.g. cv. Maris Piper is prone to rots in wet conditions whilst cv. Desiree (a more floury variety) is prone to bruising in cold conditions. Finally, soil taken into stores with potatoes during the harvest period can act like flint on potatoes when grading, leading to damage.

Because the demand for potatoes is fairly predictable and is not particularly affected by weather conditions, forecasting systems tend to work well. Again suppliers commented that promotions are effective at getting rid of gluts but also that extending the shelf-life given to the product would provide the retailers with more flexibility. One supplier felt that where promotions can have a negative effect on waste is when they lead to lower grade product having to be included in the pack to meet demand. This is then rejected at quality control/RDC and they are returned. By then it's too late to re-pack the product and it is often wasted.

Most potato varieties have to be conditioned (i.e. warmed up) from cold storage before sale to encourage sugar conversion. Promotions may lead to product being packed before it has been properly conditioned, which also increases waste.

[21] Seed potatoes are produced to be used for planting new crops of potatoes. Once cut into sets and planted, seed potatoes grow into tablestock potato varieties. Seed potatoes themselves are not intended for human consumption.

[22] For more information, see http://www.potato.org.uk/ref.html?did=2547&pg=1

Several suppliers noted that in-store handling was a problem. Staff should be encouraged to cover potatoes at night to prevent greening, which can start in as little as 24 hours. Providing printed liners and tip cards in-store for staff was one way suggested to limit greening. Some interviewees stated that loose product causes more waste by being picked over by customers, causing bruising.

3.6.4 Packaging and packaging waste

MAP is increasingly being used for potatoes to extend shelf-life with shelf-life potential increased by two days for Jersey Royals and by five days for others. However, there is a limit to its usefulness as a sprout suppressant as the MAP is lost when the consumer opens the bag, so in-home shelf-life may not be increased.

In terms of the primary packaging, one supplier commented that they had reduced the gauge of plastic bags; thereby reducing the weight by 18%.

Integrity seal is a new method of producing hermetic seals on vertical–form–fill–seal bagging machines[23]. Developed with funding from WRAP, it can reduce packaging requirements by 25-30%[24] and is in use by some retailers and suppliers for fresh, whole potatoes (Figure 17).

Figure 17 Integrity seal in use on whole potato packaging

Another supplier indicated that consumers (in attempts to reduce home waste) are moving towards smaller pack sizes and that there may be an opportunity to reduce the number of SKUs to better reflect consumer purchasing behaviour.

One supplier working with a major retailer has moved from the standard plastic film packaging to a combination of net and film for their 2kg premium baking potatoes. The new packaging offers the consumer a clearer view of the product whilst improving the 'breathability' of potatoes. At the same time there is a reduction in packaging weight. The new pack format was introduced in February 2010.

Packaging waste in the supply chain is driven by: machine error; packing product that is not then sold on; packing product incorrectly (which then needs to be decanted and repacked); and, as noted in relation to most of the other products discussed, packaging design changes being communicated at too short notice.

[23] *http://www.wrap.org.uk/retail/case_studies_research/case_study_4.html*

[24] *15mm deep crimp seal replaced by 1 mm welded bead seal gives average 10% film area saving due to shorter bag. Welded bead seal gives high performance seal on lower gauge films. Typically, 14% saving for every 5 micron reduction. Total packaging saving estimated at 25 –30%.*

As noted above, given the robustness of the product, the pack house is able to repack product if an assumed forecast is not predicted correctly, which leads to packaging (but not product) being wasted. Where product can be wasted is through the increased use of VFF, which can lead to bruising (particularly for main crop) due to increased drop height (from nine inches to two feet).

3.6.5 Technical recommendations

- Greater tolerance of aesthetic appearance (e.g. skin finish) and size grades would decrease waste.
- Some retailers have introduced vendor assurance and provide training to growers in order to help them deliver consistent quality. This is where retailers are working more closely with suppliers so that they know what the retailer expects and why.
- Change date codes with seasonality because of product maturity and end of crop storage, i.e. alter date coding as a reflection of changing product physiology and propensity to produce waste.
- Training of store staff is needed to better implement the appropriate stacking policies that can limit greening.
- Inform consumers that potatoes are still edible when they sprout and provide better advice on in-home storage to consumers to keep potatoes at their best for longer.
- Continued research into reducing bruising, bacterial rots, greening and sprouting.
- Investigate the bruising/waste impact of packing in VFF bags, for which the drop height can be as much as two feet.
- Investigate true cost of soil damage during harvesting.
- Reductions in packing waste caused by machine error and packing product incorrectly.
- Continue to investigate better use of CIPC and alternatives to CIPC.

3.7 Broccoli

3.7.1 Overview

The UK produces 472.1 kt of brassica (an example of which is Broccoli) per annum and imports 108.5 kt (Defra, 2009). UK production is from June to October. Spain is the main exporter of broccoli (as an example brassica) to the UK with many of the farms being owned by UK companies.

The quantities purchased for household consumption have steadily declined since 2003 and now stand at 73g[25] per person per week. The UK broccoli industry is dominated by three key suppliers/marketing companies, making up over 50% market share; however, the structure is more disparate than for some fresh produce types. Consumption decreases in hot weather but cold weather can increase sales by 0.75-fold, whilst quality is affected with less product grown.

Key supply chain characteristics include:

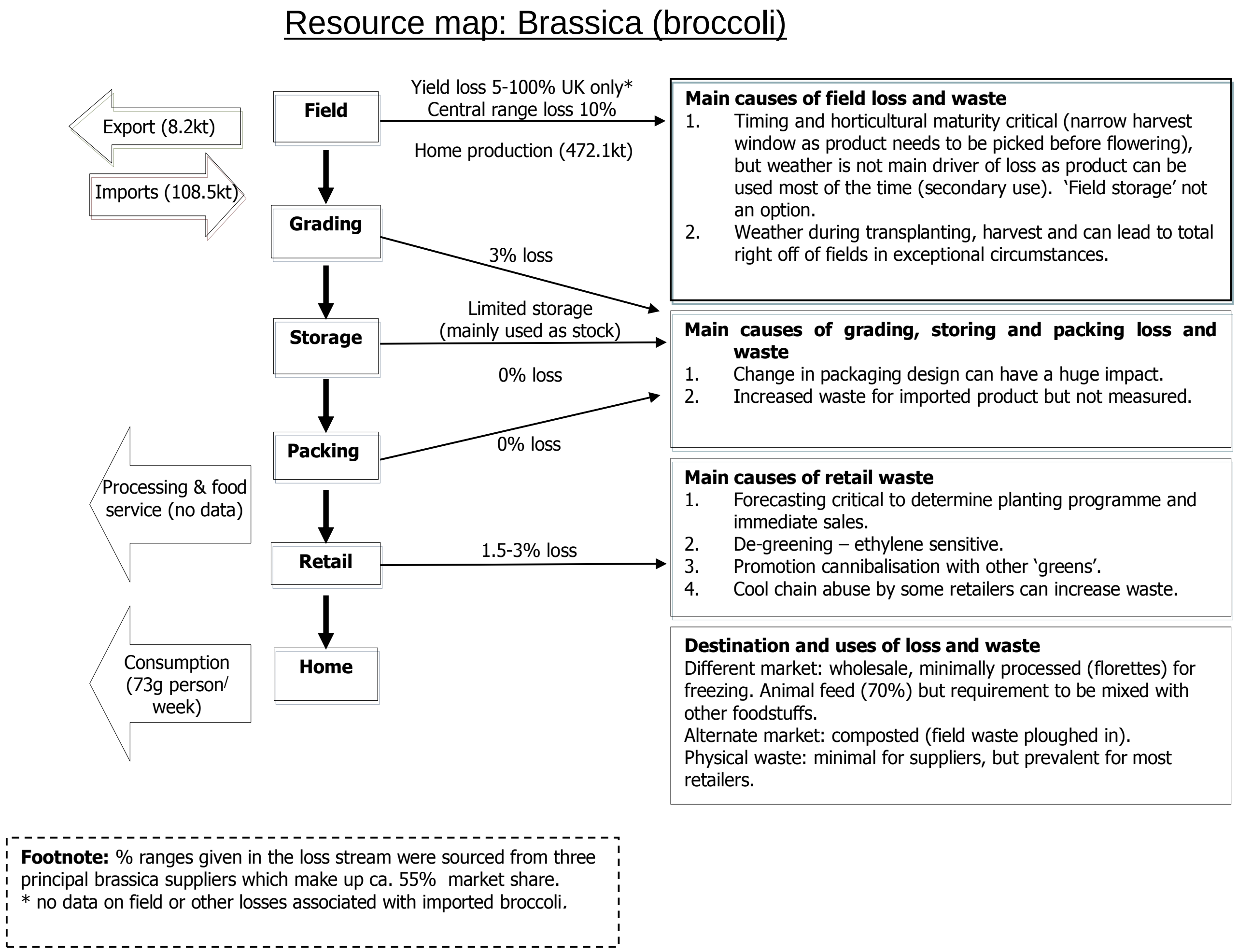
- Post-harvest life for broccoli typically ranges from 3-21 days, but is reliant on not only variety, weather conditions in the field but also, and critically, upon harvest maturity and storage regime.
- Lead times range from 6-12 hours.
- Stock levels range from 0.5-5 days, but are commonly between 0.5-2 days.
- Shelf-life ranges between 4-5 days. Shelf-life is less for imported product.
- Yield losses can be catastrophic with as much as 100% loss. However, all field waste will be ploughed back into the land/composted with the majority of trimmed waste (produced at grading or packing) being sold as animal feed with very little going to landfill.
- The level of final mean product waste at retail is ca. 2% and the majority of this will be sent to landfill or energy recovery.

3.7.2 Resource map

See over page for resource map for broccoli.

[25] *Includes cauliflower and headed broccoli.*

Figure 18 Resource map for broccoli



3.7.3 Causes of waste

Broccoli plants are commonly transplanted as young plants from the glasshouse to the field. Weather can restrict this, which can impact on availability. Time for plants to mature depends on the variety, weather and rainfall. Broccoli has to be harvested before it flowers. Stock is held in the field for up to two days after reaching maturity and thus there is a very narrow harvest window. Storage really refers to transit and no controlled atmosphere (CA) is used. Removal of field heat after harvest is crucial to stop growth.

The main causes of loss result from not being able to match supply to demand due to agronomic practice and weather variations. When the weather is warmer sales fall, but in cold weather when demand increases plant growth is suppressed. Suppliers commented that when broccoli is on promotion, consumers will overbuy, but then not buy any the following week. Periodic mismatch in supply and demand can make forecasting problematic, which can drive waste. If customers (retailers) cannot react quickly enough to 'gluts', suppliers can send florets for freezing, but this is a low value use. Moreover, suppliers noted that because a lot of promotional activity is now pre-planned in advance, this can make retail customers inflexible in responding to gluts.

Again, the shoulders of the season impact on loss, for example one supplier commented that at the end of the Spanish season (June) yields fall from 95% to around 80%. Another, however, commented that because they manage stock and use their pre-prepared side of the business to 'floret'[26] the product, seasonal changes do not cause waste.

Similar to strawberries, grading is primarily done at picking; hence, there is a high proportion of field waste as product that does not meet the specification and will not be picked. Related to this, suppliers also commented that product specifications drive waste in this category. For example, quality standards can mean that those varieties that have a 'hollow stalk' (Figure 19) at certain times of the year may be rejected, even though the product is perfectly good to eat.

Figure 19 Hollow stalk

3.7.4 Packaging and packaging waste

As has been noted in relation to several of the other products, short notice packaging design changes were cited as a main cause of packaging waste. Changes to orders were also noted, for example when a customer orders a lower quantity of stock than has already been packed. Broccoli is increasingly being found in-store in a shrink film, which is used to extend the product shelf-life. Suppliers are investigating ways to extend the shelf-life without the primary packaging, for example using an MAP liner in distribution, yet this may negatively impact on home waste.

[26] Floretted broccoli is basically the immature flowers –i.e. without the stalks. Stalks are of course edible when cooked.

One large vegetable producer is using out of specification product from the company's pack-houses and field to generate renewable heat and electricity. Using digestate from the process on land will reduce the use of inorganic fertilisers in primary agricultural production.

3.7.5 Technical recommendations

- Continue to invest in field heat removal technologies (e.g. hydro-cooling).
- Greater tolerance of aesthetic appearance (e.g. hollow stalk), particularly at certain times of the year. This would need to be coupled with consumer education.
- Retailers to react more quickly to gluts (caused by growing conditions) by having more efficient means of switching on promotions, but guard against cannibalism in the 'greens' category.
- Investigate other options for post-harvest preservation of broccoli besides shrink wrap.

3.8 Avocados

3.8.1 Overview

The UK imports 39.1 kt of avocado (*Persea americana*) fruit per annum with no home production (Defra, 2009). Avocados are sourced and exported to the UK from four principal countries; Spain, South Africa, Peru and Chile; with smaller quantities from Israel, Kenya, Mexico and the USA.

The quantities purchased for household consumption have increased and stand at 8g per person per week. Demand for avocados increases by around 50% during the summer months.

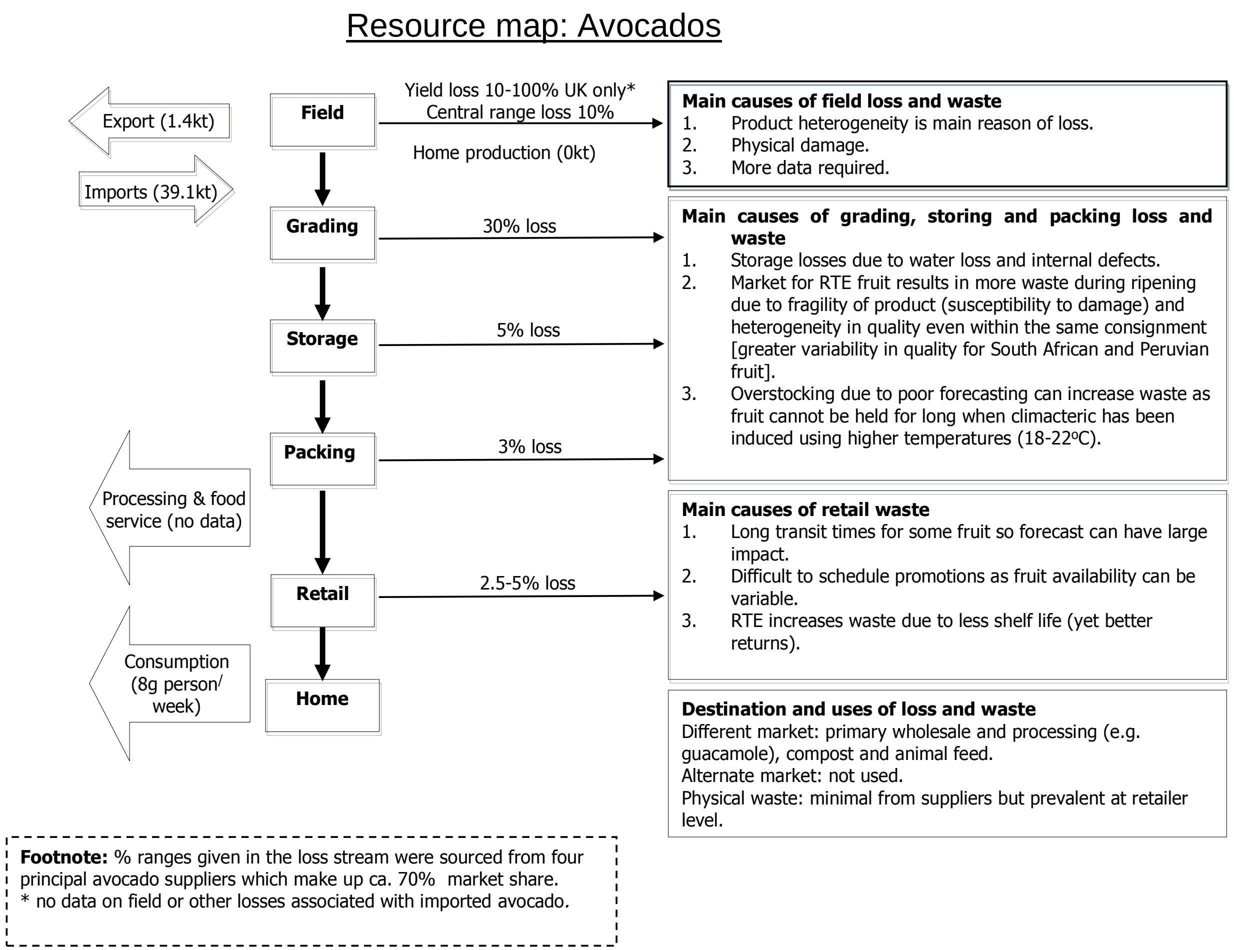
The UK avocado industry is dominated by three key suppliers making up over 70% market share. Consumption peaks in the summer months. Cv. Hass (black to purple when ripe) is by far the dominant variety in the UK but cvs. Fuerte and Etinger/Bacon are also sold in smaller proportions. Fruit quality is dependent not only on pre-harvest factors and country of origin and therefore transit time, but also season (early, middle and late) and post-harvest storage and ripening regimes.

Key supply chain characteristics include:
- Storage life (transit) ranges from 6-40 days (dependent on controlled atmosphere and ethylene control strategies and country of origin – 'time on the water'), but can be extended beyond this.
- Lead times range from 12-24 hours. Stock levels range from 4-10 days but are typically 4-5 days.
- Shelf-life ranges from 2-4 days and is related to whether or not fruit have been conditioned/ripened.
- One of the principal sources of waste occurs at quality control where as much as between 1-5% of the consignment does not meet the specification. Most product waste is sent for animal feed with <1% going to landfill or energy recovery.
- The level of final mean product waste at retail is ca. 2.5-5%, with the majority of this going to landfill or energy recovery.
- Waste arising prior to receipt in the UK has not been measured.

3.8.2 Resource map

See over page for resource map for avocados.

Figure 20 Resource map for avocados



3.8.3 Causes of waste

Avocados are principally sold as unripened (pre-climacteric and hard) or 'triggered'/ripe (increased temperature to induce climacteric ripening) fruit. Twenty-five per cent of the market consists of ripe RTE fruit, which commands a price premium. RTEs require a controlled ripening period. RTE sales have recently declined for some retailers, possibly as a result of the recession. Due to their fragility, RTE fruit have a limited shelf-life and are prone to physical damage, making careful transportation (and packing for transportation) particularly important. Ethylene is not really used to ripen avocados in the UK but some trials are ongoing. Avocados are very sensitive to ethylene during transit.

The main causes of loss in the supply chain are at grading as a result of quality control (QC) measures. One supplier commented that RTE fruit will have 4-5 times the number of QC checks than unripened. QC is principally achieved through assessing fruit firmness using a destructive mechanical firmness tester, which effectively punches a hole into the fruit making it unfit for sale. The damaged fruit then go to animal feed. QC procedures can result in 1-5% loss for fruit destined for the RTE market. Although non-destructive methods are currently available none are entirely adequate for guaranteeing product ripeness, although research is ongoing in this area. Increased retailer flexibility over product specifications for RTE fruit would reduce waste.

Heterogeneity within a consignment differs according to season and origin. For example, avocado fruit derived from Spain tend to be more consistent than fruit derived from South Africa*.* It is unlikely that these differences are solely due to differences in transit time as the consistency of Chilean fruit tends to be good, like that from Spain, but has, like South African fruit, extended time in transit (30-40 days).

Another cause of waste is internal breakdown and disease (neck rot and stem rot), shown in Figure 21.

Figure 21 Stem rot in avocados.

There is often a quality problem during the transitions between seasons. Demand for avocado fruit peaks in the summer, which is the main season for South African fruit (as noted above this fruit tends to be less consistent than that from some other countries), and thus loss levels can increase.

Once the product reaches the store, in-store temperature management becomes critical, particularly for RTE fruit. Shelf-life under chilled conditions can be as much as five days, but for a product held at ambient, shelf-life can be as low as three days. Suppliers commented that educating consumers that the eating quality is not diminished by defect/scarred fruit is required to avoid product being picked over in-store and rejected.

Forecasting can have a huge influence on waste if it is inaccurate as a result of the long transit times. This is especially relevant for fruit from South Africa, Chile and Peru where suppliers are effectively operating two months ahead. Spanish fruit (imported between early February and May) is clearly less affected. The long transit times can also make it difficult to schedule promotions to respond to any over-supply.

3.8.4 Packaging and packaging waste

Avocados are packaged differently according to their ripening stage; RTE products tend to be packed in twin packs to aid in protection whilst unripened fruit are usually sold loose, though this practice does depend on the retailer. Current MAP is not suitable for avocado fruit. More recently, the polystyrene used in trays is being replaced with paper pulp. Packaging design changes are infrequent but can affect waste.

3.8.5 Technical recommendations

- Improve non-destructive quality control to reduce losses associated with destructive testing[27].
- Continue to reduce heterogeneity in quality of supply especially for early season fruit.
- Improve real-time forecasting of field production and picking cycles to better inform promotional activity and match supply with demand fluctuations.
- Agronomic management will become increasingly important and thus requires better vertical integration between supplier and growers.
- Re-educate consumers that aesthetic defects (scarring and other superficial defects) do not affect the eating quality.
- Improve understanding of effects of transit time, and storage/ripening regimes on product quality and damage.
- Develop a better understanding of the impact of ethylene across the whole supply chain.

[27] *cf. Defra FoodLink AFM235 and Terry et al., 2007, for more information on new technologies for non invasive product assessment and shelf-life extension.*

3.9 Citrus

3.9.1 Overview

The UK imports 709 kt of citrus fruit per annum with no home production (Defra, 2009). Spain is the main exporter of citrus fruit to the UK. Citrus fruits are also sourced and exported to the UK from many countries/regions including South America, South Africa, Israel and the USA.

The quantities purchased for household consumption have remained relatively stable since 2003 and stand at 148g per person per week. The UK citrus industry is dominated by three key companies making up over 60% market share. Consumption is relatively stable over the year, but sales can increase by 0.5-3-fold over the Christmas period and Shrove Tuesday for some lines (e.g. easy peel/soft citrus and lemons, respectively). About 65% of citrus products are sold during the winter months (October-March). Sales of grapefruit and lemons are reasonably stable over the year and weather does not seem to affect demand.

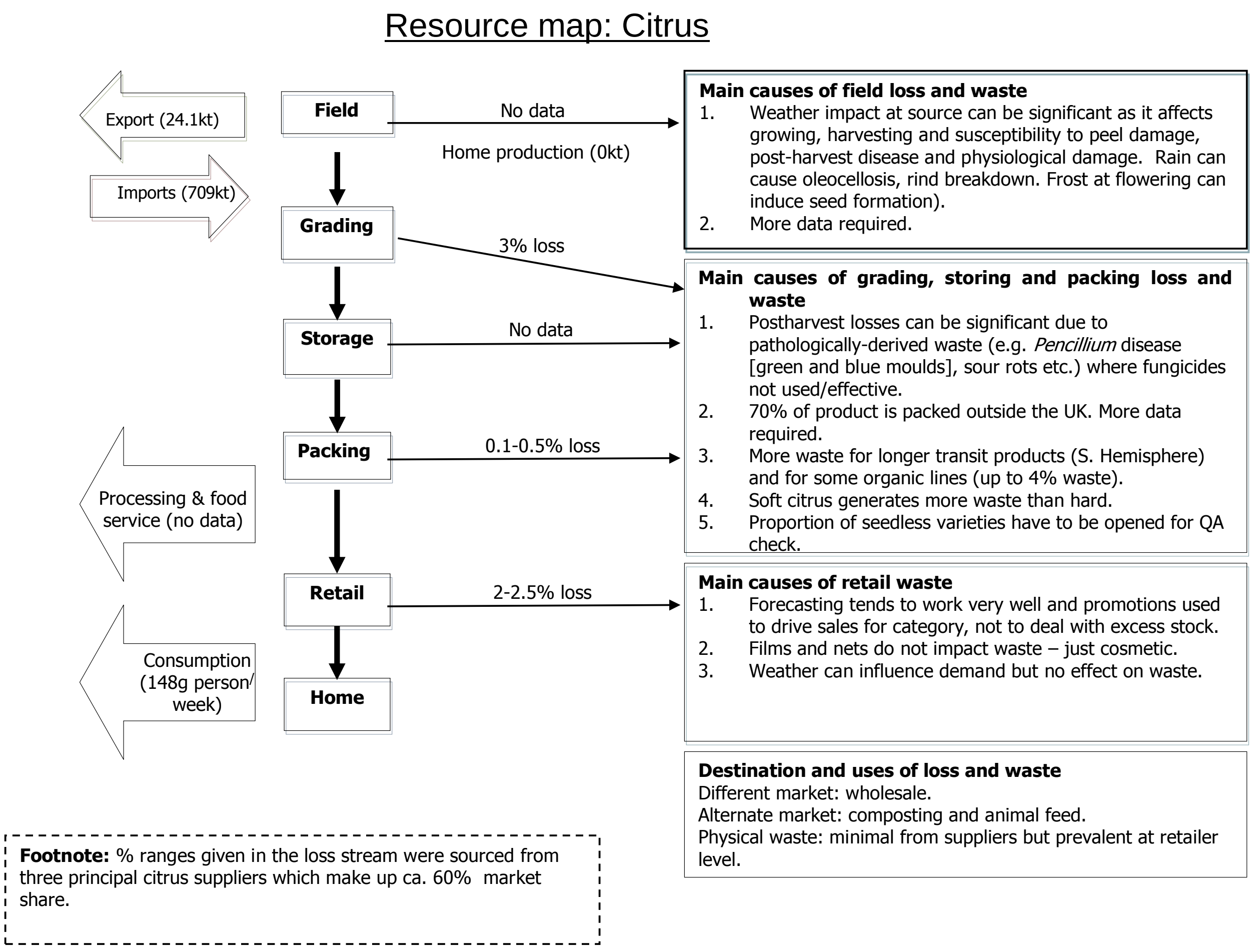
Key supply chain characteristics include:

- Storage life (including transit) ranges from 1-60 days depending on species (e.g. longer for grapefruit), variety, season and origin, but is typically 14 days from Spain.
- Lead times range from 12-24 hours. Stock levels range from 2-21 days with a mean of 3-7 days. Typically lead times range from 10 days for Southern Hemisphere fruit and 2-3 days for Northern Hemisphere fruit.
- Shelf-life ranges from 7-9 days, but can be as low as 4-5 days for some organic lines.
- The principal source of waste after the fruit have been imported into the UK occurs during grading, but this is less than 3%, which is then usually sent for animal feed. It is important to note that some 50-70% of product is packed outside the UK at country of origin.
- The level of final mean product waste at retail is ca. 2-2.5%, which will usually be disposed of to landfill or energy recovery.
- Waste arising prior to receipt in the UK has not been measured.

3.9.2 Resource map

See over page for resource map for citrus.

Figure 22 Resource map for citrus



3.9.3 Causes of waste

The citrus category contains a number different fruit species (e.g. oranges – navels and Valencia; easy peeler/soft citrus – satsumas, clementines and tangerines; lemons; grapefruits and limes). They are all relatively robust, in terms of post-harvest storage, because they have a thick rind and relatively low respiration rates. Soft citrus is more susceptible to physical damage than are thicker rind species.

Citrus require different temperature regimes. For example, oranges and soft citrus are stored at 4-6^{o}C, whereas grapefruit and lemons are stored at 8^{o}C. Most in-store storage is at ambient and suppliers commented that where citrus is kept in chilled conditions in-store, then waste was likely to be reduced.

Post-harvest disease is the major cause of loss in the UK (N.B. field and grading loss/waste at source is not included in this study, as it takes place overseas, and this may also be significant). Post-harvest fungicides are often used before the product is shipped to the UK to control diseases such as green and blue mould caused by *Penicillium digitatum* and *Pencillium italicum*, respectively. Suppliers commented that there are no reliable alternatives to the use of post-harvest fungicides as present. Losses for organic citrus are much higher than for conventional fruit, with one supplier indicating levels at 4%.

Downgraded product arises primarily because of growing conditions in the field; it is, therefore, difficult to introduce measures to reduce this.

Given that demand is relatively stable, forecasting tends to be reliable and long-term. Suppliers stated that there have been few occasions in the last five years when over-ordering has led to product having to be promoted. Promotions are used to drive sales for the category, rather than to try to deal with gluts. Supply for these promotional periods is managed by drawing on stored product or changing orders. In the rare event that a promotion does not work as planned, suppliers have other routes to market to ensure product is not wasted e.g. juicing.

Unlike for some other products, studied in this research, suppliers, in general, did not believe that the transition between sources/seasons (Southern/Northern hemispheres) had any great impact on waste. However, some felt that the longer transit time of fruit coming from the Southern Hemisphere could increase waste.

3.9.4 Technical recommendations

- Greater tolerance/flexibility of aesthetic appearance (peel disorders) at certain times of the year.
- Consider using better temperature control in retail; 5-8^{o}C would suffice and, when considering the waste reduction potential, is also likely to be cost effective.
- Alternative to post-harvest fungicides are required as at present they are still essential before shipping for conventional products (N.B. waste for organic products is higher).
- Measure loss in field and in storage.
- Suppliers noted that films and nets do not protect the fruit any better than loose product. This warrants further investigation.

3.10 Bananas

3.10.1 Overview

The UK imports 987.3 kt of banana (*Musa* spp.) fruit per annum with no home production (Defra, 2009). The quantities purchased for household consumption have increased steadily since 2003 and stand at 230g per person per week. The UK banana industry is dominated by four key companies making up over 85% market share. Consumption is relatively stable over the year, although a 10% reduction is observed during summer school holidays due to the 'lunchbox effect', rather than the weather.

Bananas are exported to the UK primarily from South and Central America. Fruit are transported in a green, unripe (pre-climacteric) state and then ripened on arrival in the UK for 4-6 days depending on temperature. Ripening is triggered using ethylene gas. Bananas are usually sold as a triggered or ripened product, but supplied at different stages of ripeness (i.e. colour stage). Cavendish (AAA) is the main variety making up 98% of banana fruit sold.

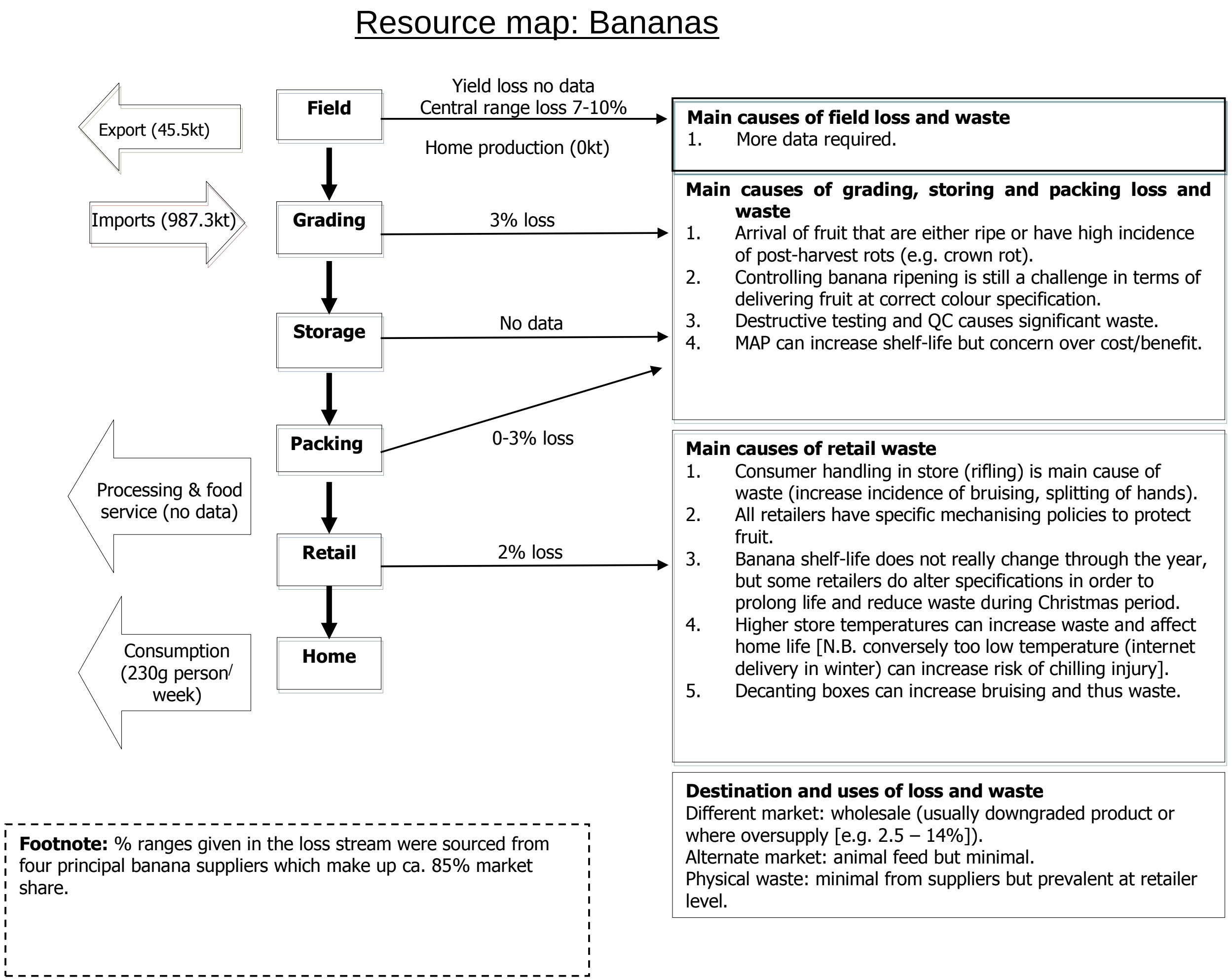
Key supply chain characteristics include:

- Storage life (including transit) ranges from 10-34 days depending on origin, but is typically 10-21 days. Fruit usually take 2-3 weeks to reach UK from Central America and are then kept at the UK dock for up to seven days, ripened (4-6 days) and then dispatched (one day).
- Lead times range from 6-72 hours. Stock levels range from 4-14 days with a mean of six days.
- Shelf-life of ripened/triggered product ranges from 2-5 days. Retailers generally have two days shelf-life for loose product and three days for packed product.
- The level of final mean product waste at retail is ca. 2%, with the majority going to landfill or energy recovery.
- Most product waste produced on receipt in the UK is sent for animal feed such that 1% goes to landfill.
- Waste arising prior to receipt in the UK has not been measured, though an indication of as much as 10% field loss has been estimated.

3.10.2 Resource map

See over page for resource map for bananas

Figure 23 Resource map for bananas



3.10.3 Causes of waste

Bananas have the highest consumption rates in the UK of all the fruit studied through this research (Figure 6). Because of this dominance, a 2% waste figure at retail is low but still significant.

Banana waste is primarily driven by pressure from retailers for suppliers to provide fruit at the correct colour specification (affected by the ripeness of the stock on arrival in the UK). Attempts to meet this specification often lead to fruit being ripened at too high a temperature, which can lead to waste. Suppliers noted that there can be as many as 7-8 separate quality control checks being carried out along the supply chain.

Bananas are most commonly sold as a ready-to-eat product according to colour stage. In-store, customer handling (rifling and splitting of hands of bananas) to select bananas at the ripeness stage they want (which they use as a shelf-life indicator) was highlighted by suppliers as driving product damage and hence waste in-store. Incorrect colour is the biggest consumer complaint, but the hardest specification to achieve on a consistent basis. Retailers often complain about being supplied bananas that are too yellow and this may indicate their concerns over receiving fruit with a reduced shelf-life, with knock on effects for waste. Suppliers also noted that store staff decanting product poorly in-store can lead to damage and waste.

The level of wasted product at packing is influenced by the percentage stock levels and the suppliers' ability and efficiency to divert any oversupply to wholesale markets. For most of the suppliers interviewed, <1% of product waste was being sent to landfill, though for one supplier this figure was higher at around 2-3%. It is thought this was due to the management practices and culture of the organisation, rather than to something specific to the banana supply chain.

Bananas are an ethylene sensitive product when unripe (i.e. before they have been triggered with ethylene in the UK in specially designed ripening rooms). Significant loss can occur if fruit arrive in a ripened state or have significant incidence of post-harvest disease (e.g. crown rot/anthracnose caused by *Colletotrichum musae*). Disease incidence is usually higher for organic lines. Bananas are a delicate and temperature sensitive product. Little protective packaging is used and this may increase the incidence of damage.

Forecasting is critical to success but there were different views from suppliers on how well it worked. This may be a reflection of their different customer base or the efficacy of internal systems. Even though demand and production are relatively stable, the industry often faces problems with supply due to the unpredictability of sea transport and customs. Stock levels vary but can be as much as 10%, even though maintaining stock levels below 7% is desirable to reduce waste (and reduce profit risk).

Orders are estimated two weeks ahead, by which point fruit has already been bought and is on route to the UK. Orders are prepared to forecast 24 hours ahead of the actual order; if the actual order is higher then suppliers can draw on their stock. If the actual order is lower, then there is the potential for waste though fruit can be put into storage and/or downgraded for sale to a wholesale market.

Variations in production between countries can lead to shortages of fruit (i.e. January – March), which gives rise to a focus on waste reduction.

Promotions can increase sales, but suppliers commented that no sustained uplift is observed when promotions end. Suppliers commented that promotions are currently aimed primarily at securing market share (not a sales uplift) because bananas form part of the 'shopping basket'[28], and are therefore mainly price based.

Shelf-life is currently between 2-5 days, and is fairly stable throughout the year, though some retailers will change the colour specifications in response to the weather, i.e. greener fruit during the summer months to prolong shelf-life in warmer conditions in-store (and at home). Increasing ripening temperatures (to meet the colour specification) will tend to reduce the shelf-life of bananas. Increasing shelf-life is usually desirable, though it was noted by suppliers that greater residence time in-store will increase waste by subjecting bananas to

[28] *The 'shopping basket' of items make up the Consumer Prices Index (CPI) and Retail Prices Index (RPI)*

greater levels of customer handling. Suppliers did state, however, that increasing yellow life would be desirable and may reduce the likelihood of bananas being wasted in the home.

3.10.4 Packaging and packaging waste

Bananas are usually transported in ready for shelf 18 kg boxes but increasingly sold in other formats. These traditional boxes have been designed to aid efficient transportation and minimise consumer handling, but have not necessarily been designed to aid banana ripening (i.e. air flow during ripening).

MAP can extend the shelf-life of banana fruit but is not used extensively because, although it may retard skin yellowing, the fruit (pulp) may continue to ripen. Inappropriate MAP can also have an adverse affect on taste. It is also expensive, and although it can add two days to shelf-life, may not be cost effective.

3.10.5 Technical recommendations

- Greater tolerance/flexibility of aesthetic appearance (peel colour (yellowness) and defects).
- Continue to try and limit consumer-induced damage and quantify its effects on both in-store waste and home waste.
- Consider alternative packaging formats to reduce/avoid decanting. Some suppliers noted that they send advisers to train depot staff on quality assessment and product handling.
- Investigate new packaging design so that it is suitable for transit and aids uniform ripening.
- Better temperature control in-store would decrease waste (i.e. display fruit away from chill cabinets (due to heat) and away from entrances).
- Quantify the extent to which extending shelf-life could reduce waste given that demand is very predictable and that greater residence time in-store might increase damage from consumer handling. If an extended shelf-life is thought to have a positive impact on waste, investigate ways by which MAP can be made more cost effective.
- More objective assessment of colour would be beneficial as banana ripening charts have limited use and it is difficult to judge colour in an 18 kg box containing bananas of a range of colours.
- Investigate novel methods to ensure more even ripening and/or slow down the ripening process once climacteric/ripening has been induced.
- Measure loss in field and in storage.

4.0 Retailers and wholesalers

Insights resulting from the discussion with both the retailers and wholesalers interviewed have been incorporated into Chapter 3. However, the following gives more detail around some of the issues specific to this part of the supply chain.

4.1 Retailers

On-shelf availability

Retailers are sales driven and, for all those interviewed, 'on-shelf availability', which measures how often a product is on sale, was a key performance indicator. Indeed availability is a key measure for the whole supply chain and drives behaviour from the grower downstream. To paraphrase what many interviewees said, 'the fear of a lost sale is greater than the fear of waste'. Measures of on-shelf availability for individual retailers is commercially sensitive.

IGD has run a survey of availability since 2004 to provide a benchmark for the industry. The survey covers 160 stores and a similar number of branded and own label products that reflect an average family shopping trip. Audits take place six times a year and provide a view of how availability differs by day of week, time of day and geographical region. The survey includes nine of the fruit and vegetable products that are the focus of this research[29]. The data from the latest audit in February 2010 indicates that levels of availability are 98.5% and that during 2009 were in excess of 99%. On-shelf availability of fresh products is higher than the average for all grocery products. These results demonstrate the supply chains' overall efficiency. Many suppliers commented that they would avoid having 'to short' their customers and that their performance was measured by delivery schedules that were 'on time in full'.

This is not to say that waste takes a back seat in supply chain management. All the retailers in the survey measure waste and their stores, supply chain and commercial teams have waste targets. There was a general view from both suppliers and retailers that waste included all products that are marked down as well as any product or packaging requiring disposal. Although when retailers mark down products there is an economic loss, this is judged to be a better outcome than either the product being 'off sale' or disposed. Some retailers also included theft in their definition of waste.

As indicated earlier, there are seasonal and other peaks in sales, some of which are very weather dependent. There are no regular yearly patterns to waste, though retailers noted that because they require year round availability that leads to non-UK sourcing. Because of the inherent seasonality of the products considered, seasonal 'shoulders' are often characterised by increased waste. This can arise because of the climatic conditions at source when product might be immature or because suppliers will tend to put their best products into long-term storage.

The Christmas trading period was cited as generating the most waste. One retailer commented that in 2008 they reduced waste by £5 million by better controlling the code life of the product and by better management along the supply chain. To do this, they created a matrix across all products sold from the start of December to mid-January.

Retailers also decide how much shelf space is devoted to fresh produce and which products they stock. This has become an increasingly difficult problem as products have been differentiated, for example by variety and provenance. Figure 24 below gives an indication of the ranges retailed for two products: strawberries and tomatoes.

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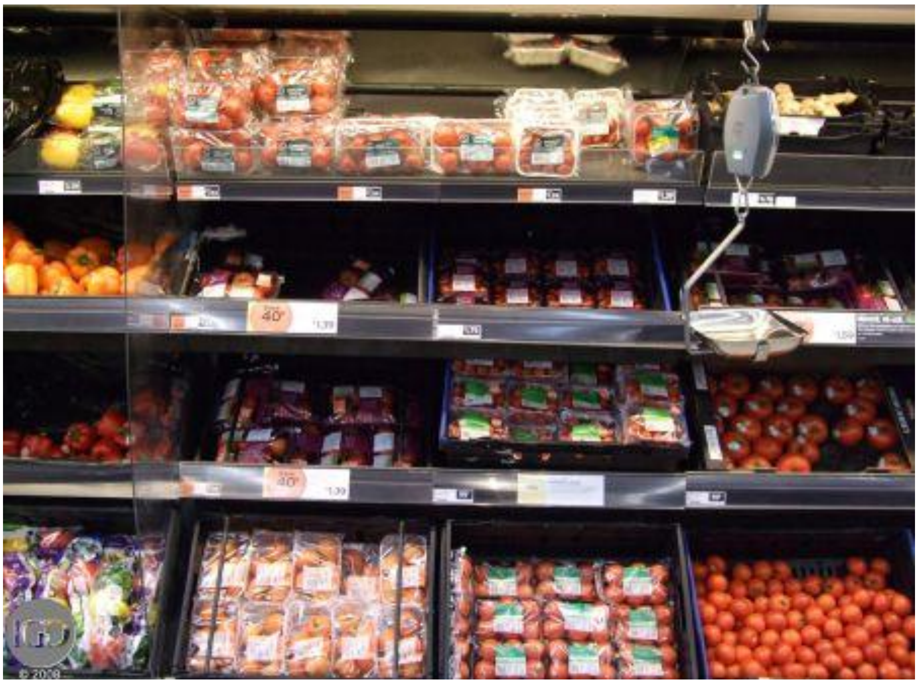
[29] *It does not include raspberries and avocados.*

Figure 24a Strawberry ranges

Figure 24b Tomato ranges



The demand for shelf space is high and retailers need to conduct good category management practices including regular range reviews. Inevitably there will be products that are more prone to mark-downs and disposal. In response, some retailers have reduced the number of SKUs (by as much as 15-20% across the range), which has reduced waste by providing 'choice without proliferation'.

Promotions

Promotions are a way of life and part of the competitive dynamic among retailers. Undoubtedly the number of promotions has been increasing in response to the economic climate.

According to Tesco:

'We have increased the number of promotions we run on produce, updating our fruit and vegetable price pledge and now run up to 100 promotions on produce alone each week and over a quarter of what we sell is on promotion.'

Source: CSR Report 2009

Promotions also perform another function with both suppliers and retailers agreeing that they are useful to 'celebrate' seasons and clear 'gluts'. In most cases promotions are planned in advance between retailers and suppliers and work well when all goes to plan. However, there are instances when suppliers receive little or no warning of a promotion because retailers are focusing on market share. In contrast the research found examples of retailers who were not flexible enough to mount a promotion when provided with such an opportunity by a supplier. To take advantage of optimal crop maturity when there are 'gluts', rapid responses are required if a loss of economic potential is to be avoided.

The success of a promotion is highly dependent on good forecasting together with an element of 'good luck', for example because the weather turns out as forecasted. Promotions do create more unpredictable demand patterns, both for the specific products on promotion and for substitute products that may have their sales impacted, a process known as cannibalisation. Although interviewees said that promotion planning took account of the risk associated with cannibalisation, it was unclear whether it was a significant issue, particularly if the product(s) being impacted were those supplied by a competitor.

Suppliers commented that cannibalisation during promotions can increase waste and although retailers strive to take account of cannibalisation it is recognised that it is hard to achieve. Ideally, forecasts should take into account the potential for a cannibalisation effect of promotions. Retailers did not feel that promotions in themselves increase waste, indeed they can provided a positive sales uplift. However, how the benefits of promotions are evaluated across the supply chain remains unclear.

Another consideration is the actual promotion mechanic; that is the way products are promoted. Retailers are moving increasingly towards 'money off' or 'buy one get one later' offers rather than 'multi-buy' offers, which can help ensure consumers do not end up with a lot of perishable product they cannot use.

4.2 Wholesalers

Wholesale markets make up a significant part of fresh produce sales in the UK. The sector has a broad range of customers with differing requirements, including retailers, foodservice and the public sector. To meet these requirements wholesalers offer a highly flexible range of products and quality. Wholesalers have demonstrated innovative solutions to waste management, with examples of markets with established anaerobic digesters, composting facilities, as well as waste collection and recycling facilities on site.

One of the markets interviewed had recently introduced waste disposal charges for tenants. This has resulted in a significant reduction in waste arisings.

From those interviewed the amount of wasted product was stated as being between 3-5%.

Specifications

With the introduction of the revised EU Marketing Standards in 2009, the wholesale sector has taken on board changes to offer its customers a diverse range of specifications of its products.

The often rigid specifications required by retailers have been identified as driving waste in the retail supply chain. Within the wholesale market there is a greater flexibility: negotiations can take place face-to-face and often there are no written specifications, with products being provided to meet customers' unique needs. This was felt by the interviewees to lead to less waste because produce with superficial defects, e.g. a cosmetic blemish, is perfectly acceptable for certain wholesale customers, in comparison to the more stringent conditions set by the major retailers. For example, a customer requiring product for immediate use will accept good quality product towards the end of its shelf life and without the shelf/home life required by a retailer.

Packaging and destination of waste

From those interviewed, the majority of packaging was recycled where possible (e.g. cardboard, pallets etc.), though it was noted that it was not always viable to separate the product from the packaging. The establishment of waste disposal charges and composting facilities has helped reduce waste to landfill, although to further reduce waste, markets for plastics and strapping are needed. Wholesalers also need access to machinery that can segregate the packaging from the product. Other problems are packaging of products with a high water content, such as cucumbers, for which composting is currently ineffective.

No figures were collected through this research regarding how much waste is treated through anaerobic digestion or in-vessel composting compared to that being sent to landfill.

5.0 Conclusions

5.1 Waste arising

A summary of the loss and waste found at each stage in the retail supply chain by product is given in Table 11. Field loss data are not available for avocado, citrus and bananas because these products are imported into the UK. The data in the table are not cumulative for those products that are stored (apples, onions and potatoes). That is, for apples, onions and potatoes the results convey loss and waste streams for products that are harvested and graded for more or less immediate sale, and similarly loss and waste streams for products that are stored and then graded for sale. Although these stages in the supply chain are presented sequentially, in practice part of the harvest will not be stored but prepared for immediate sale.

It can be seen that there are significant variations in loss and waste by product. However, it is possible to make some generalisations, namely:

- Overall levels of loss and waste are very low at any given stage in the supply chain, varying generally between 1% to 3% with some exceptions.
- Taking the supply chain as a whole, loss and waste is typically less than 10% and can exceed 25% for some products.
- Grading, on average, results in the highest waste losses in the supply chain, primarily influenced by precise customer specifications.
- Storage losses are primarily caused by disease and weight reductions (e.g. water loss) and will increase the longer products are stored.
- Retail waste levels are typically around 2% and only vary within a small range compared to other supply chain stages.

Table 11 Summary of resource maps, detailing percentage loss and waste by product for eleven different fruits and vegetables through the supply chain.

Product	Field loss (Central range)	Grading loss	Storage Loss	Packing loss	Retail waste
Strawberry	2-3%	1%	0.5%	2-3%	2-4%
Lettuce	5-10%	No data	0.5-2%	1%	2%
Raspberry	2%	No data	No data	2-3%	2-3%
Tomato	5%	7%	No data	3-5%	2.5-3%
Apple	5-25%	5-25%	3-4%	3-8%	2-3%
Onion	3-5%	9-20%	3-10%	2-3%	0.5-1%
Potato	1-2%	3-13%	3-5%	20-25%	1.5-3%
Broccoli	10%	3%	0%	0%	1.5-3%
Avocado	No data	30%	5%	3%	2.5-5%
Citrus	No data	3%	No data	0.1-0.5%	2-2.5%
Banana	No data	3%	No data	0-3%	2%

NB. For presentational purposes the stages in the supply chain are shown sequentially. In practice, harvested product will either be graded and packed for immediate sale or where appropriate stored and then graded and packed. As a result the data for all stored products cannot be cumulated.

Using these figures it is possible to compile an estimate for the overall loss and waste arising from UK fruit and vegetable production. To do this the project team used provisional 2008 production figures[30] together with imported quantities for the three products not grown in the UK. To the production figures the research team applied a central estimate for each stage in the supply chain on a product-by-product basis (based on industry practices), progressively reducing the original production figures with loss/waste at each stage. For the stored products an indicative figure for the combined field, grading and storage loss was used. The resulting figures were then combined with the estimates of field loss and factored to total fruit and vegetable production (and imports). The result is an estimate of overall loss/waste of approximately 2.23 to 2.48 million tonnes for the fruit and vegetable industry.

[30] *Defra: Basic Horticultural Statistics*

This estimate includes different forms of loss and waste in the fruit and vegetable supply chain. The four most significant 'types' identified are:

1. Products that do not achieve their intended market outlet because, for example, they have to be marked down for sale or because they do not meet the required specification. Such products are channelled to manufacturing or wholesale markets and in several cases to animal feed. This type of waste can represent a significant economic loss to business, even though it reflects an efficient use of the product, because it is being channelled into its next best market rather than being disposed of.
2. Field losses, where the volume of product that is harvested is less than that which was planted. In some cases field loss also relates to the potential yield based on utilising the optimum amount of product if all growers performed in line with the best. Field loss may arise because of weather or diseases and harvesting damage, for example, as well as through supply chain management practices.
3. Storage losses relate, in part, to the inherent physiology of the fresh produce type (and variety) in question, and the efficacy and appropriateness of the control systems applied throughout the supply chain. Factors such as temperature and ethylene management, horticultural maturity, gaseous composition within storage environments and packaging are known to affect the post-harvest life of many fresh produce types and therefore, if not managed appropriately, will increase the risk of loss.
4. Loss of product because of changes in supply chain management, for example, changes to packaging specifications or incorrect demand forecasting leading to disposal of product either to landfill or anaerobic digestion. Such losses are estimated to equate to the order of 100,000 to 150,000 tonnes or around 5% of the total waste arising. Although precise estimates are not available, disposal to anaerobic digestion is increasing while disposal to landfill is falling.

In addition to the amount of loss and waste in the retail supply chain, WRAP estimate that there is about three million tonnes of household produce waste that is subject to kerbside collection arrangements. The loss and waste identified in the supply chain research herein is different in nature to collected household waste, which is largely disposed to landfill, in-vessel compositing or, increasingly, anaerobic digestion. In the main, retail supply chain loss is diverted to alternative markets. For this reason the two 'waste streams' are not added together within this report.

5.2 Economic value

It is extremely difficult to quantify in monetary terms the value of the loss and waste identified above. Ideally monetary loss should be based on a quantification of the different loss and waste streams together with prices for each stage of the supply chain, for example, farm gate prices are different to final retail prices. For commercial reasons it did not prove possible to estimate the monetary value of loss and waste at different stages of the supply chain.

In the current economic climate, the consequences of wasting food have tended to be more visible for the entire supply chain. Waste has always affected directly the viability and profits of businesses and takes on an increasing profile given the ongoing debate over food security[31]. The context for improved waste management therefore spans economic, environmental and food security considerations.

5.3 GHG emissions

The UK food chain is responsible for around 18% of all UK greenhouse gas emissions (GHG)[32]. Evidence suggests that most of the food chain impacts occur during agricultural production and that this is largely a result of the contribution made by livestock rearing. Research by the FCRN indicates that the fruit and vegetable sector accounts for about 2.5% of the UK's overall GHG compared with about 8.5% for meat and dairy[33]. In the

[31] *The Future of Food and Farming: Challenges and choices for global sustainability. 2011. Government Office For Science, Foresight Report. http://www.bis.gov.uk/foresight/our-work/projects/current-projects/global-food-and-farming-futures/reports-and-publications*

[32] *http://www.foodsecurity.ac.uk/research/current/food-climate-research-network.html*

[33] *http://www.fcrn.org.uk/fcrnPublications/publications/PDFs/Fruitnveg_paper_2006.pdf*

Government's Low Carbon Transition Plan[34] English farmers are being encouraged to reduce emissions to, at least, 6% lower than currently, through more efficient use of fertiliser and better management of livestock and manure.

A great many estimates have been made of emissions for individual fresh products. One of the first assessments was conducted by the Carbon Trust working with Walkers[35] to analyse the footprint of crisps across the entire product life cycle. This work showed that over 30% of the emissions were linked to potato growing. The Co-operative Group[36], working with the Carbon Trust, showed significant differences for emissions from strawberries depending on the variety grown (differences of 46% between varieties), their growing conditions (whether grown in peat, an alternative medium, or in the ground), as well as the place in which the fruit was grown (Scotland or Spain). These estimates used a full PAS 2050 analysis (the first standard method for calculating life cycle GHG emissions of products). The WWF has recently published emission estimates of the main products covered by this research as part of the development of scenarios that explore how greenhouse gas emissions could be reduced by 70% by the year 2050[37].

The project team were tasked to estimate emissions arising from the proportion of the product lost or wasted for each of the eleven products in this research. The detail of the method used and the total emissions arising are given in Appendix 2. Although every attempt was made to be as thorough as possible, some omissions, for example associated with packaging, have occurred. Table 12 summarises the results.

Table 12 Summary of GHG emissions estimates per kilogram of product.

Product	**Emission** (gCO_2 e)	**Product**	**Emission** (gCO_2 e)
Apples	230	Lettuce	160
Avocados	403	Onions	134
Bananas	199	Potatoes	351
Broccoli	121	Strawberries/Raspberries	135
Citrus	184	Tomatoes	249

The results show that avocado, followed by potato and tomatoes, have the largest emissions. These relatively large losses are associated with home wastage and losses at grading and packing. When expressed in relation to the national consumption of the products (Appendix 2), then potatoes have the highest level of emissions (more than twice all the other products combined).

From the work undertaken so far it is possible to speculate on the main drivers of emissions across the fruit and vegetable supply chain, namely:

- The variety grown, it's growing medium and agronomic management.
- Cold storage and temperature controlled transport, which makes the sector dependent on refrigeration.
- Transport, particularly as the reliance on imported products increases, though the research found little evidence that air freight was a significant or growing factor in GHG emissions.

The fresh produce industry is putting in place measures to achieve food production in a low carbon world, calculating GHG emissions, reducing excess packaging and increasing re-use and recycling, as well as reducing food waste and recovering energy. The adoption of alternative modes of transport is embracing the multi-modal concept, for example, utilising coastal sea freight and increasing use of rail.

Table 13 compares two alternative approaches, both of which have benefits, to reducing emissions relating to tomatoes and bananas respectively.

[34] *http://www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx*

[35] *http://www.walkerscarbonfootprint.co.uk/walkers_carbon_trust.html*

[36] *http://www.co-operative.coop/corporate/Sustainability/ecological-sustainability/climate-change/carbon-footprinting/*

[37] *http://assets.wwf.org.uk/downloads/how_low_report_1.pdf*

Table 13 Comparison of alternative approaches to reducing emissions.

Tomato Growers Association	Costa Rica Banana Production (Dole Fresh Ltd)
■ A substantial reduction in energy use for heating glasshouses. ■ The almost complete elimination of pesticide use. ■ Major reductions in the use of fertilisers and their loss into the environment. ■ Efficient use of water, an increasingly scarce resource. ■ Substitution for imports with their associated "food miles" and lower environmental production standards.	■ Research and application of fertilizers that optimize nutrient delivery while reducing nitrous oxide emissions. ■ Discussions with the government rail company to increase the use of this mode of transportation. ■ Ongoing programme to modernize the company's 13,000-unit container fleet with units that are 35% more energy efficient. ■ Operation of some of the largest container reefer vessels in the industry (1,000 container. capacity) that serve to greatly minimize the carbon footprint per unit of product shipped from Costa Rica. ■ Implementation of driver efficiency training programmes for all company employees and agricultural machinery operators to reduce unnecessary fossil fuel consumption.

Looking at waste, a great deal arises as both yield loss and at loss at grading (which can be affected by storage), as well as by households. Of these, household fruit and vegetable waste is a waste of all the energy that goes into producing, storing and transporting the product. More waste is generated by households compared to the rest of the supply chain taken as a whole[38].

Biodegradable waste produces methane, a key component of GHGs. Emissions from waste overall are declining, down 62% from 1990 levels, and are predicted to fall further from the delivery of existing policies encouraging: on-going reduction in landfill; more processing of food waste using anaerobic digestion to produce biogas; and the capture and use of more methane produced from existing landfill.

5.4 Causes of waste

Previous research for Defra[39] identified three groups of issues affecting waste: (a) mega-trends, which are consumer and industry factors that affect waste, for example increasing demand for fresh products; (b) natural constraints, which are factors associated with the nature of the products that can affect waste such as shelf-life; and (c) management root-causes, which are factors affecting waste on which management practices have a direct impact.

Evidence on consumption shows that growing awareness of the five–a–day message has translated into increased sales, although there is still a long way to go before the target is achieved. If this is coupled with the increasing number of single households and consumer preferences for pre-packed produce, then it can be tentatively concluded that fruit and vegetable household waste might have been increasing. There are previous estimates of waste (for example those estimated by the FCRN, though it is acknowledged by the author that these were rough approximations), but it is not possible to make direct comparisons with the estimates provided in this report.

The causes of waste are complex and vary product by product as well as depending on the stage of the supply chain. Table 14 below summarises the main causes of waste.

[38] *Waste arisings in the supply of food and drink to households in the UK (WRAP, 2010), at http://www.wrap.org.uk/retail_supply_chain/research_tools/research/report_waste.html*

[39] Evidence on the role of supplier – retailer trading relationships and practices on waste generation in the food chain (FO0210), at http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=15806#RelatedDocuments

Table 14 Summary of the main causes of waste (see glossary for detailed definition of terms).

Product	Main causes of waste
Strawberries and raspberries	▪ Breakdown, mould. ▪ Poor removal of field heat (residual temperature of a product in the field). ▪ Different interpretations on specifications of different suppliers. ▪ Temperature (waste peaks in summer). Use of gondola ends (the free standing shelving units at the end of aisles), increasing the fruit temperature above 4-8°C and affecting the product quality and potentially increasing the rate of spoilage. ▪ Damage from punnets being stacked incorrectly or being the wrong size for the volume of product. ▪ Strawberries: rots and moulds (collapsed berries). ▪ Raspberries: softness, bleeds, collapsed berries and mould.
Lettuce	▪ Balancing supply and demand. ▪ Pest and disease. ▪ Sales variability (mainly weather related). ▪ Quality (mainly weather related, but also poor harvest management). ▪ Access to information regarding tolerance of aesthetic appearance (some retailers could do it better). ▪ Forecasting (currently looking at new systems – need to be more scientific).
Tomatoes	▪ Weather (both for growing and consumption). ▪ Supply and demand prediction. ▪ Product quality during harvesting. ▪ Product deterioration through, e.g. customer damage in store. ▪ Not storing at low temperatures. ▪ Grade outs due to product not meeting stringent retailer requirements – colour, size, Brix – measurement of the dissolved sugar-water mass ratio of a liquid.
Apples	▪ Quality (fungal disease, post-harvest rots, internal problems, scald, softening). ▪ Weather conditions (post-harvest). ▪ Pushing storage for too long (management). ▪ Sensitivity of apples to temperature. ▪ Equipment failure. ▪ Retailer Specifications. ▪ Handling, display and storage in retail.
Onions	▪ Quality (internal breakdown, rots, disease). ▪ Downgrades through quality control and product specification requirements. ▪ Storage – weight loss. ▪ Destructive testing for internal defects.
Potatoes	▪ In field: fungal, slugs, nematodes, greening, skins finish, scabs. ▪ Harvesting: mechanical damage. ▪ Grading: downgraded product – skins, weight loss. ▪ Sprouting – duration of potato storage is a function of variety and storage regime. ▪ Weight loss in storage. ▪ Wrong temperature. ▪ Product that is packed but, due to poor forecasting, is not needed. ▪ Damage from using Vertical Form Film (VFF) bags. ▪ Damage in-store – handling (riffling), not covering the trays at night, which can lead to greening.
Brassicas	▪ Sales forecasting – matching supply to demand. ▪ Agronomic practice – cold weather promotes increased demand but suppresses plant growth. ▪ Weather variations – in warmer weather sales fall, but plant growth is better. ▪ Harvesting practice (narrow harvest window). ▪ Storage systems, e.g. inappropriate cool chain and/or packaging design.
Avocadoes	▪ Quality (stem end rot; internal breakdown). ▪ Lack of retail flexibility over product specifications for ready to eat (RTE) product. ▪ Temperature control. ▪ Destructive quality control.
Citrus	▪ Quality (post-harvest decay; moulds; physiological disorders). ▪ Distance travelled. ▪ Not keeping at low temperatures.
Bananas	▪ Rots – throw away.

	▪ State of ripeness on arrival (e.g. ship ripe because it's packed too late and at wrong temperatures. It is less frequent now). ▪ Specifications (particularly colour spec). ▪ Weather conditions (post-harvest). ▪ Temperature. ▪ Delays in shipping (lack of capacity and flexibility). ▪ Faster ripening at higher temperature to meet colour specifications will reduce the shelf life and increase waste. ▪ Handling, display and storage in retail (including customer handling).

The vast majority of individuals interviewed were either technical directors or managers of their respective businesses. As such they represent a significant body of opinion about the causes of waste. All were asked to identify and rank the top three natural causes of waste in order to assess whether there are any consistent patterns emerging. The main natural causes of waste that were identified are summarised below:

Highest ranked causes:
- Disease and insect infestation;
- Unseasonable weather impacting growing conditions; and
- Crop maturity, i.e. immature or over mature crops are more likely to be wasted.

Lowest ranked causes:
- Handling;
- Packaging and date coding/ labelling; and
- Gaseous composition, specifically, ethylene concentration.

The three highest ranked causes of loss and waste identified reflect the biological nature of the product and the difficulties of growing, harvesting and storing the product under optimum conditions. To a degree they may reflect participants' recent experience, as many interviewees commented on the poor growing seasons and unseasonable weather of the two most recent summers (2008 and 2009). By their nature these top causes of loss can be catastrophic.

On management factors it is possible to identify the following root-causes:
- Waste management responsibilities in the supply chain;
- Information sharing;
- Promotions management;
- Forecasting;
- Performance measurement – i.e. a lack of measurement of waste produced with very few measuring waste in tonnes; and
- Inappropriate use of packaging e.g.: packaging that is not designed properly, packaging that is not 'fit for purpose', inappropriate packaging specifications.

Unlike previous studies there was no direct correlation between the products with the shortest shelf life (strawberries, raspberries, tomatoes and lettuce) and the levels of waste. It is possible that storage and grading, which are dominant supply chain practices in this research, increase loss and waste but also provide supply chain managers with a degree of flexibility that can help prevent waste. A product such as bananas, which has relatively stable demand patterns throughout the year, also has low levels of waste.

6.0 Discussion and recommendations

Although the project team found little evidence to suggest that significant quantities of fruit and vegetables in the retail and wholesale supply chains are being disposed to landfill, such activity was being practiced by the majority of retailers and by individual suppliers interviewed. Most, however, are in the process of reducing or phasing out this practice.

The following recommendations are not in order of significance. Taken together they offer the fresh produce industry an opportunity to reduce all types of waste, reduce costs and benefit the environment.

■ Improve data on waste and loss

If waste is to have the focus among retailers and suppliers that market share or on-shelf availability have, then greater data transparency is required. At present it is not possible to develop an accurate benchmark that enables comparison across retailers and, from that, commercial improvement. There are different models available to ensure data anonymity and these should be explored and piloted. A similar conclusion on the need for improved data transparency has been reached as part of the review of the Government's Waste Strategy for England:

> *'We recommend that Defra requires food retailers and manufacturers to report the tonnages of food waste from their businesses at least on an annual basis.'*
>
> *House of Commons: EFRA 2010*

Through the Courtauld Commitment 2[40], businesses have agreed to jointly meet a target to reduce supply chain waste (product and packaging) by 5% by 2012 against a 2009 baseline. Progress will be measured annually by WRAP as an aggregated figure (individual data will be kept confidential).

Clear accountability is a prerequisite for managing waste. Organisations that have a person responsible for waste management tend to have a much better understanding of the scale and causes of the waste problem. This understanding is a first step for reducing waste. The interviews revealed that some organisations promoted a culture of waste reduction, often because they focused on continuous improvement using lean manufacturing principles, and this culture was driving all other activities in the organisation, such as training, performance measurement and incentives.

■ Improve supply chain communications

A variety of commercial arrangements exist between retailers and their suppliers. These include the outright ownership of suppliers, through to dedicated, independent pack house facilities supplying a number of customers. Generally, packers have their own growers, although it is the exception to find a direct relationship between retailers and growers of the type recently developed, for example, in the dairy industry. At the margins, packers will also trade products to deal with surpluses or shortages.

Clearly, produce has to be planted and grown well ahead of actual demand. Generally this is done on a collaborative basis, but the project team was told of many instances of 'over-planting' in order not to disappoint the customer or as an insurance against weather and/or disease. As a consequence field loss can be high for certain products and, in exceptional circumstances whole fields can be lost. The project team did not investigate different crop planning models linked to actual and forecast demand and there is a paucity of research into what constitutes industry good practice. This is an area where further research and development is desirable.

As any crop grows and matures, good communication along the supply chain is essential, particularly if the crop is ahead of or behind schedule because, for example, of weather conditions. This is desirable both to avoid an 'off sale' (low on-shelf availability) but also to find an alternative market, that might involve a promotion, if there are gluts, as certain of the products examined cannot be stored for long periods.

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[40] *http://www.wrap.org.uk/retail/courtauld_commitment*

Linked to crop planning is accurate forecasting of customer demand through monthly and weekly plans. Poor forecasting was one of the most common issues identified during the interviews as a cause of waste. However, estimating the demand can be a complex and inherently inaccurate task for some products, which can be affected by factors, such as weather, seasonality, marketing campaigns, product launches, promotions and special occasions like Christmas and Easter. The research showed that a variety of forecasting practices exist in the industry, with some companies using a scientific approach while others use more informal methods. Improving forecasting practices can reduce forecast error; however, it has to be recognised that uncertainty will continue to exist and that forecast error cannot be eliminated.

Poor information sharing and lack of trust among supply chain partners can lead to waste. Some retailers are open to sharing information with their suppliers and in some cases they can even have employees from the supplier (embedded) working on site, so that they can be in close communication. These kinds of practices have proved to be effective in reducing forecasting error and hence waste; however, they can also be expensive since they demand considerable resources from both suppliers and retailers. An on-going study by WRAP and IGD is analysing the financial and waste reduction benefits of pilot projects focused on reducing forecasting error[41].

Retailers suggested that forecasting is most effective when it is based on past history and agreed in partnership with the suppliers. Forecasts will never be perfectly accurate, yet it is possible to reduce forecasting error by using statistical techniques and sophisticated algorithms supported by information systems. Given the impact that accurate forecasting can have on availability and waste, continued investment in forecasting methods is required as is a more 'joined up' approach to the determination of future demand profiles.

WRAP is funding a collaborative forecasting project with IGD which aims to reduce waste and deliver commercial benefit. This project will run through 2010 and involves a number of retailers and their suppliers across different categories. UK produce suppliers are actively involved in this programme which will test the efficacy of the approach to reducing the waste identified by this research.

■ Review consumer specifications

Fresh produce specifications are critical to the success of any retailer. Without control and necessary quality assurance over specifications, guaranteed and consistent product quality is threatened. Fresh produce quality is one of the main factors that persuade consumers to switch stores when they are dissatisfied. Ensuring product specifications are consistently met will avoid customer defections. Without exception in this research, retail specifications exceeded the minimum set by EU Regulation and covered such things as size, shape, skin blemish and colour.

Quality control has a positive impact on the supply chain as suppliers increase the quality of their products and do not put supposedly sub-standard products into the supply chain. Therefore, although depot inspections generate a waste stream, without them, retailers assert that store waste (and potentially in-home waste) would increase. Generally the main reason why product is rejected at depot concerns incorrect labelling (e.g. wrong date code, wrong quantity, wrong variety), where the product can normally be returned to suppliers and be re-worked so as to not add to waste (except for some loss of packaging).

Part of the perceived problem by many throughout this research is that consumer expectations of quality are viewed as having increased continually. It is inevitable that once customers are offered better quality then they will expect this quality as standard. It could be argued that this perpetual feedback loop needs to be reviewed so that mechanisms can be considered to halt, or at least suppress, the ever-increasing quality demands imposed on the industry. The formulation of policies to improve food security may help to tackle this issue. This research suggests that the losses at grading are not sustainable and are usually based on merely aesthetic appearance or indeed rudimentary quality control measures (e.g. Brix), which are recognised by the scientific community as not being appropriate for some fruits and vegetables.

Retailers should review and challenge their product specifications from a waste perspective to ensure they provide appropriate customer value. There is an opportunity to conduct generic consumer research to underpin

[41] *Cross sectoral work programme to reduce food waste arising in the retail supply chain (WRAP, 2011 unpublished)*

these reviews that would identify expectations of quality for different market segments. Research of this nature is lacking and would provide a sound basis to underpin product specification reviews.

In response to the recession, certain retailers have introduced value lines. For example, in 2008 Sainsbury's extended their 'basic' range, adding 70 products of which 16 were fruit and vegetables. The specifications for these, and similar products available from other retailers, were still judged to be well above the EU floor. The general consensus view was that value lines are good for crop utilisation, although different products are impacted in different ways. In the case of apples, smaller fruit have been sold through value lines, which have recently led to trees being picked bare and the availability of fruit for juicing being affected. However, for some products such as small onions, where they are ploughed straight back into the ground, finding a means to sell these products may offer an improved alternative.

It is unclear how the revised EU Marketing Standards for fresh produce will affect waste as the changes have only recently been implemented. It is the belief of some in the industry that the effect will be minimal, as alternative markets are already available for fresh produce and the change will simply re-route product from one market to another. Nevertheless the changes introduced by these regulations have not been exploited fully. For example, the project team did not find any evidence that products are being labelled as 'intended for home processing', a derogation from the specific market standards and which may help to reduce waste and economic loss. Products such as apples and strawberries, for example, could benefit from specific trials of this newly agreed relaxation without any detriment to overall quality. The new category of produce that may be marketed has to meet less exacting standards and be clearly labelled as 'product intended for processing'. As an example of this, strawberries, which have colour defects, could be offered for sale in line with the Regulation as 'strawberries for home jam making' or similar wording.

It is evident from this research that one of the main criticisms raised by suppliers is the inflexibility of some retailer specifications to take into account natural variability. This is particularly the case at the transition between seasons and storage regimes. If natural variability and differences in product quality at key periods in the calendar are not taken into account, there can be greater waste/loss in the field and at grading.

■ Work to optimise packaging

Packaging plays a dual role in terms of waste; on the one hand it protects the product from damage and can help to extend shelf-life, having a positive effect on waste reduction. On the other hand, the amount of packaging on a product has a direct impact on household waste and to some degree on waste generated at other stages in the chain. Further, once a product is packaged the costs of separation on disposal can be regarded as significant relative to the cost of other disposal routes e.g. landfill. This can inhibit the processing of food through composting and anaerobic digestion, although approaches to removing packaging at plant are available[42].

In recent years, packaging suppliers have developed optimised packs for the category, for example, reducing the pack weight, using recycled content materials and implementing technologies, such as modified atmosphere packaging (MAP) or new sealing techniques, to increase shelf life. Although for some products, interviewees believed that light-weighting had gone as far as possible, some examples of novel approaches were still being found to further optimise packaging; both to optimise the pack throughout the supply chain and to increase shelf-life.

It was evident that increasing shelf-life was a priority for many of the retailers interviewed. This is understandable as it would be assumed that greater shelf-life would, by increasing the window for sale, reduce the risk of producing waste where forecasting or promotions were not accurate or did not work as planned. However, a balance needs to be struck between greater shelf-life and residency time in-store, which can lead to product damage as a result of increased consumer handling.

To achieve shelf-life extension, in many cases, new technology will be required, which means any commercial benefit has to be robust. Retailers expressed concerns that consumers may not feel a 'longer-life' product is

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[42] *http://www.wrap.org.uk/recycling_industry/information_by_material/organics/depackaging.html*

'fresh' even though many products are stored for considerable periods without a deleterious effect on quality. There were also concerns about any impact shelf-life extension may have on taste and flavour and that possible trade-offs between shelf life and taste should be recognised. What might be appropriate is to encourage good storage in-store and in-home to ensure products reach their current optimum shelf-life. In many cases adequate temperature control is key.

Several retailers now provide advice on how best to store products at home. This can take the form of, for example, 'best kept' stickers advising on whether food is best kept in the fridge, in a cool dark place or at room temperature. The Co-operative Group became the first retailer to include storage instructions for fruit and vegetables on its fresh produce bags. The storage instructions indicate the optimum conditions under which products should be kept to maintain freshness. The instructions are printed on the bags themselves (Figure 25).

Figure 25 Co-operative fresh produce bag

■ Promote technology development and knowledge transfer

The use of appropriate technology has a major role to play in reducing fruit and vegetable waste and some novel techniques were identified through this research. In general, however, it is thought that the technological and research base within the UK and wider EU is underutilised by the industry. It is evident more could be done to explore cost effective solutions that either transfer good practice from one product to another or are truly novel.

Two examples where knowledge transfer could work better are the wider use of vacuum cooling and ethylene control. Vacuum cooling is a rapid evaporative cooling technique that can reduce processing times with consequent energy savings, improved product shelf life, quality and safety. Traditionally, products such as lettuce and mushrooms have been cooled under vacuum. Recent research has highlighted the possible applications of vacuum cooling for cooling vegetables (and other products). Ethylene is critical for apple storage and for stone fruit, kiwifruit and some pears, but is not really controlled for the other products (e.g., tomatoes - although this might extend storage life depending on efficacy and timing). Continuous ethylene supplementation of onions and potatoes through storage will extend storage life even though they are low ethylene producers. Ethylene is not generally used to ripen avocados in the UK but some trials are on-going.

An example of an alternative approach is the investigation of prolonging shelf-life and reducing waste by using low doses of ultraviolet light to stimulate natural plant defences (a process known as hormesis). The effect of low dose UV-C treatment is not restricted to the surface of the treated commodities (e.g. germicidal effect), but is also manifested through the plant tissues. This, and other similar physical control methods, offer possibilities for reducing post-harvest losses of perishable fruits and vegetables if the technology can be harnessed under commercial conditions. If successful, initial trials could be extended to a wider range of produce.

Storage is necessary because without it UK growers could not sustain supply beyond the immediate harvest. Storage reduces the rate of biochemical change (respiration and senescence) and also slows down the rate of growth of contaminating micro-organisms. Storage is expensive both in terms of buying and operating the store and in dealing with the loss (primarily in terms of product weight), therefore an economic consideration is paramount. Some fruits undergo 'climacteric' ripening, which is linked to the production of the plant hormone, ethylene and this requires careful management.

Fresh fruits and vegetables are living, although they are no longer attached to the plant. They respire and their composition, texture and physiology continue to change after harvest. They continue to ripen or deteriorate with age (senesce), depending on species, and, finally, they begin to die. Cellular breakdown and death (senescence) are inevitable, but can be slowed with optimal storage conditions. Most temperate fresh fruits and vegetables need to be held at low temperatures (0 to 8°C) and high relative humidity (80 to 95 percent) to lower respiration and to slow metabolic changes and water loss. Products of tropical origin, e.g. bananas, should not be stored at low temperature due to their propensity to succumb to chilling injury. Temperature and relative humidity regimes are product specific. By slowing these processes, water loss is reduced and food value, quality and energy reserves are better maintained.

It is too simplistic to state that the longer a product is stored the greater the risk of waste or loss. Investment in long-term storage techniques copes with peaks in production (e.g. onions, potatoes and apples). Products that are stored for long periods tend to have inherently low respiration rates (lower metabolic activity), but storage regimes may be put in place to reduce respiration of both the product and potential pathogens. Although the longer a product is stored under a particular storage regime the greater the potential is for loss (especially water loss and loss caused by post-harvest disease and disorders), it is the combination of pre-harvest factors, storage regime (e.g. ambient, cold storage, controlled atmosphere, and ethylene control/suppression) and management, which is important, not just the duration of storage.

Although storage can extend the availability of a product, specific storage regimes, e.g. the heating and cooling that are required for curing onions, can increase energy use resulting in increased GHG emissions thereby having a negative environmental impact. Moreover such regimes may not be feasible from a cost/benefit perspective, for example, where the 'cost' (financial and environmental) required for long-term storage is weighed against and exceeds the cost of importing similar produce from elsewhere.

■ Increase use of production planning systems

Retailers' replenishment systems have become very sophisticated and are shown to good effect by the high levels of on-shelf availability achieved. In turn sophisticated production planning systems have been introduced by suppliers to cope and deal with the diversity of product that has been introduced by retailers to provide 'a point of difference'. Generally such enterprise resource planning software (ERP) technology has had a positive impact on reducing waste.

Many fresh produce businesses have invested considerably in this technology to manage large volumes of produce through the production process, whilst meeting the demands of quality, packaging, delivery and traceability standards. For example, by rapidly sharing the quality control results with the grower, the packer can pinpoint quickly any issues regarding quality, enabling the grower to take action to rectify the problem. Sometimes it can be more cost effective for a company to dispose of produce rather than repack it, and the labour costs of over-packing, as well as the waste packaging itself, can represent a substantial cost to a business. By integrating order intake and production through the use of ERP technology, over-packing can be reduced. In addition, by receiving advance notification of the work schedule, packhouses can avoid losing products in the supply chain and reduce the potential for wastage of short shelf-life products that become unfit for sale to the intended customer. With real time systems, date related alerts can be sent out pinpointing product that needs moving for dispatch. The benefits of such systems are best realised when the whole chain is involved rather than using them to 'optimise' just one stage in the replenishment process.

This research has highlighted the extent to which fresh fruit and vegetables are wasted or lost in the UK's food supply chain. By identifying how, where and why the products are wasted, these resource maps have enabled the identification of where science and better management practices can be used to develop more resource efficient strategies within the fresh fruit and vegetable sector. The project team estimates that about £400-£500 million can be realised through commercial improvements based on the recommendations outlined in this report.

Appendix 1 Template used for structured interviews

Data Collection Protocol

The following table presents the stages of the interview process and has been designed by the project team as a guide to ensure that all interviews are conducted in a consistent and systematic way.

Before	■ Interviews should ideally be conducted face-to-face ■ Arrange suitable time (interviews should last around 1h) ■ Arrange suitable place (make sure there will be a private area to conduct the interviews) ■ Make sure participants are aware of the purpose and benefits of the interview and are comfortable with providing data. Data will be confidential ■ Define waste as "Any substance or object the holder discards, intends to discard or is required to discard" based on Waste Framework Directive (European Directive 2006/12/EC) but will include downgraded product ■ Send interview protocol (if requested) in advance of interview ■ Two researchers should attend each interview for triangulation purposes
During	■ Introduce project and researchers ■ Outline purpose of the interview and clarify scope, objectives and benefits ■ Ensure anonymity and confidentiality of information if required ■ Complete cover sheet (Section 1) ■ Go through questions in sections 2 and 3 and take notes as appropriate. Questions should serve as a guide and can be adapted or omitted depending on the circumstances. It is also possible to ask additional questions if necessary. ■ Summarize main points ■ Ask if there are any additional leads or sources of information ■ Ask if there are any additional questions and thank for time
After	■ Complete interview summary form (Section 4). Discussed by both researchers ■ Follow any additional leads ■ Prepare an interview report to be signed off by company ■ Incorporate data into secure database ■ Archive interview notes in secure location

1. COVER SHEET

<table>
<tr><td colspan="2">Company (optional) and location</td><td>Date</td><td>Time</td><td>Interviewer</td></tr>
<tr><td>Name (optional)</td><td colspan="3">E-mail (optional)</td><td>Telephone (optional)</td></tr>
<tr><td colspan="5">Title and responsibilities (optional)</td></tr>
<tr><td colspan="5">1.0 How would you define waste?</td></tr>
<tr><td colspan="5">1.1. Product Type

· Salads · Vegetables · Fruits</td></tr>
<tr><td colspan="5">1.2. Product Category

■ Short storage life, short shelf life product – e.g. strawberries, raspberries tomatoes and lettuce (Romaine)

■ Long storage life, medium shelf life product – e.g. apples, onions, potatoes, brassica (cabbage)

■ Long/medium storage life, medium/short shelf life product (e.g. citrus, avocado)

■ Tropical(s) (unable to store at low temperature due to increased risk of physiological damage) – e.g. bananas</td></tr>
<tr><td colspan="5">1.3. Principle Product Varieties
· Potatoes · apple · Soft fruit · onions · Imported · Home-grown</td></tr>
<tr><td colspan="5">1.4. What is the effect of varietal selection on waste?</td></tr>
<tr><td colspan="5">1.5. Role in the Fresh Food Supply Chain:

· Grower/Packer · Importer/packer · Food Manufacturer · Logistics/Storage Provider

· Wholesaler · Retailer</td></tr>
<tr><td colspan="5">1.6. How is your product transported (road, air, sea freight, combination)?</td></tr>
<tr><td colspan="5">1.7. What is the amount of your sales per year (roughly) for this product?</td></tr>
<tr><td colspan="5">1.8. What is your market share in UK for this product?</td></tr>
<tr><td colspan="5">1.9. Who are your major customers for this product?</td></tr>
<tr><td colspan="5">1.10. Are you the sole supplier of your customer for this product?</td></tr>
<tr><td colspan="5">1.11. Product shelf-life (days) (total and from RDC) for this product</td></tr>
<tr><td colspan="5">1.12. Lead time (hours from order to delivery)</td></tr>
<tr><td colspan="5">1.13. What is the typical packaging units/case counts/pack size used?</td></tr>
<tr><td colspan="5">1.14. What is the storage life and stock rotation of your product(s)?</td></tr>
<tr><td colspan="5">1.15. Which product storage technologies are being used in your company?</td></tr>
<tr><td colspan="5">1.16 What are the effects of transition between seasons on your product?</td></tr>
<tr><td colspan="5">1.17. Demand variability (comments on seasonality, cyclicality and promotions)</td></tr>
</table>

1.18. Average stock cover (days):
1.19. Total production volume of the product (per year):
1.20. Percentage of wasted product (over a year) [typical min/max values and range]:
1.21. What is the pattern of your products' waste during the year? Are there any specific cycle periods or effects on shelf life
1.22. Tonnage of wasted product (per year):
1.23. Tonnage of wasted primary and secondary packaging waste (including back of store):
1.24. Do you believe there is a trade off between shelf life of the product and waste (e.g. ripe and ready, ripening, minimal processing)?
1.25. How does storage life affect waste?
1.26. Do you believe the technology used to extend storage life and/or the period of storage affects waste? **1.26.1 What is technology is lacking/needed?**

2. CAUSES OF WASTE

2.1 What are the main causes of waste for this product and where does it occur?
2.2 Which of the following reasons play most significant role in waste generation? (Please rank) **Temperature Disease/Insect infestation Ethylene Management Horticultural Maturity** **Gaseous Composition Packaging and Date Coding Handling Other__________**
2.3 What is the impact of forecasting practices on waste?
2.4. What are the positive and negative impacts of promotions on waste for this product?
2.5 What is the impact of lead-times on waste?
2.6 What is the impact of shelf-life policies on waste?
2.7. Are there any specific stacking and shelving polices for this product? **2.7.1 What is the impact of these polices on waste?**
2.8. What are the penalties for not delivering on-time in-full (OTIF)? **2.8.1 What is the impact of such policies on waste?**
2.9. Are there any specific characteristics of this product that make it more susceptible to creating waste?
2.10. What is the impact of product damage on waste for this product?

2.11. What is the impact of packaging technology on waste? **2.11.1. What kind of intermediate packaging is used for this product?** **2.11.2. What is the impact of "ready for shelf" packaging on waste?** **2.11.3 What is the effect of changing packaging design on waste?**
2.12. What happens to products following a product recall or emergency product withdrawals (EPWs) on wasted product?
2.13. What is the impact of weather changes on waste for this product?
2.14 What is the impact of quality control and product specifications on waste for this product?
2.15 Have we missed any other important cause of waste for this product (e.g. lessons from the wider world, field waste etc.)?

3. DESTINATION OF WASTE

3.1 What happens to waste of downgraded and damaged product (secondary usage)?
3.2 What happens to waste of product that exceeds its shelf life?
3.3 What happens to product that exceeds the proportion of shelf-life demanded by retailers but it is still safe to eat?
3.4 What happens to packaging waste (i.e. intermediate packaging or waste packaging resulting from re-packing)?

4. SUMMARY FORM

4.1 Interview Summary: *A brief summary of the interview and impressions*
4.2 Supporting documents collected: *A list of the documents collected in the interview*
4.3 Pending documents: *A list of documents pending collection*
4.4 Additional sources of information: *Reference to other sources of information (people, documents, computer systems)*

Appendix 2 Greenhouse gas (GHG) emissions calculations

Calculating carbon emissions

It must be remembered that GHG data include both the embedded emissions and the ones from waste management itself. So, the emissions inevitably increase per unit weight loss as a product progresses from farms to use in the home. The emissions from landfill per unit weight do not intrinsically change with position in the chain.

The emissions were all modelled on the basis of non-organic production and proxies were used in some cases, e.g. all citrus fruits were based on oranges from Spain as good data were only available for these. Bananas are a major commodity that has not apparently been subject to a Life Cycle Assessment or a carbon footprint analysis, so the error could be substantial by using the proxy crop of New Zealand apples (which was used by Wallen *et al.*, 2004). Nevertheless, these are the best estimates available. Detail on this and the results are given in Appendix 2.

Methodology

For each commodity, the GHG emissions fall into three general parts:

1. Those from primary production that are embedded in the freshly harvested product.
2. Those from the additional embedded emissions in products as they pass through the supply chain, e.g. from transport energy, refrigeration energy.
3. Those from the proportions of product entering waste management at any stage in the supply chain.

A model was constructed to calculate the losses of product at each stage and hence to calculate the primary production needed to supply each kg of product bought by consumers at retail. A further estimate of the losses in the model was applied. Hence, the amount of product sent to waste management (landfill assumed by default, unless composting was recorded in the interviews) is also calculated per kg product produced (or purchased). The emissions associated with a whole commodity were evaluated from the whole supply chain using national statistics of primary production (as marketed) and/or imports. Coefficients for GHG emissions per unit mass sent to landfill and for the production of most commodities were provided by WRAP. These were supplemented by data on primary production from previous studies by Cranfield University (Williams *et al.*, 2009) or from the literature. Some data were also provided by WRAP. Where no studied data were available, the nearest proxy values were used, e.g. bananas were substituted by New Zealand apples, following Wallen *et al.* (2004).

Data on GHG emissions from the RDC through to retail were taken from Tassou *et al.* (2009). The values from retail to home use were taken from Audsley *et al.* (2009). Vegetables are routinely cooked and an increment for cooking was included in the analysis. It was taken that the proportions cooked before wastage occurred were 49% for potato and 30% of brassica and onions.

The nature of the data is that all mass flows and emission factors are uncertain. In some cases formal estimates have been made and reported. Most of the mass flow data were reported as ranges, but without the nature and range of distribution being fully defined. In these cases it was assumed that the distribution was triangular and hence the reported ranges were the extreme values. Mid-points of the ranges supplied from resource maps where used assuming it was the mean of a triangular distribution.

Table A1: Data Sources used for GHG emissions from primary production (and storage for crops like potatoes and apples) to the RDC

Item	Origin of crop if not UK	Data reference	Comment
Apple	NZ	Williams *et al.*, 2009	
Avocado			As citrus
Banana			Assumed NZ apples, following Wallen *et al.* (2004)
Broccoli	Es	Mila i Canals *et al.* (2008)	All imports assumed Spanish
Citrus		Sanjuán *et al.* 2005	Primary production from Sanjuán *et al.* (2003) rest of chain as if Israeli potatoes.
Lettuce	Es	Mila i Canals *et al.* (2008) and Enviros (2009)	
Onion	NZ	Wiltshire *et al.* (2009)	All imports assumed from NZ
Potato	Is	Williams *et al.* 2009	All imports assumed from Israel and all potatoes assumed to be main crop
Raspberry	Es		Assumed same as strawberries
Strawberry	Es	Williams *et al.* (2009)	All imports assumed Spanish
Tomato	Es	Williams *et al.* (2009)	Assumed all loose classic

(NZ = New Zealand, Es = Spain, Is = Israel)

In some cases only a single value was obtainable, but the reality must have been a range. Where no range was available, it was assumed that the range of the nearest analogue would apply. National production and import weights were assumed to have a coefficient of variation (CV = standard deviation divided by mean) of 2%.

A Monte-Carlo simulation was applied to the model to obtain an overall estimate of uncertainty for each commodity and for the commodity at each stage in the chain.

■ Discussion – the carbon impacts of loss

On a unit weight basis, the GHG emission from wastage ranged from 0.12 to 0.40 kg CO_2e/[kg commodity]. The lowest being broccoli and the highest were avocado and potato. These reasons behind differences are complex. With potatoes, there are relatively large losses at the packing stage and particularly in the home. Storage of main crop potatoes adds to the embedded emissions, which thus adds to the losses at both packing and domestic stages. In contrast, packing losses for broccoli are much lower and so is the waste in the home. Cooking potatoes uses more energy (and hence GHG emissions) than broccoli, so this, together with the other factors means that the overall emission from potatoes are high. It is beyond the scope of this project to determine what behavioural factors are involved.

Table A2: Summary of GHG emissions at each stage of the supply chain (g CO_2e [kg commodity] from eleven products studied. Numbers in brackets are the coefficients of variation (CV) for each estimate.

Product	Field loss Grading loss	Storage	Packing	Retail	Home	Total emisions[1]	Total emisions[2]
Strawberry	21 (12%)	---	24 (13%)	64 (16%)	26 (13%)	135 (9%)	20 (10%)
Lettuce	27 (15%)	5 (26%)	5 (8%)	35 (8%)	88 (13%)	160 (9%)	47 (9%)
Raspberry	19 (9%)	---	27 (12%)	57 (12%)	39 (13%)	141 (7%)	2.1 (8%)
Tomato	89 (9%)	---	32 (14%)	46 (9%)	83 (13%)	249 (7%)	126 (7%)
Apple	51 (29%)	9 (9%)	12 (21%)	19 (11%)	139 (12%)	230 (10%)	366 (10%)
Onion	55 (17%)	26 (25%)	9 (14%)	7 (16%)	37 (15%)	134 (9%)	99 (10%)
Potato	28 (25%)	13 (12%)	48 (9%)	14 (15%)	248 (13%)	351 (11%)	2664 (11%)
Broccoli	63 (8%)	---	---	37 (16%)	22 (17%)	121 (7%)	77 (7%)
Avocado	159 (10%)	15 (11%)	9 (11%)	24 (17%)	195 (14%)	403 (8%)	15 (8%)
Citrus	73 (26%)	---	1 (29%)	20 (11%)	90 (18%)	184 (12%)	126 (12%)
Banana	27 (12%)	---	5 (43%)	24 (14%)	143 (18%)	199 (13%)	187 (13%)

N.B. GHG emissions for field and grading loss have been combined.
1 = total g CO_2e [kg commodity].
2 = total GHG emissions (kt CO_2e) from waste for the national consumption of commodity.

- The total GHG emissions from waste for the national consumption of strawberries was 20 kt CO_2e (CV=10%). The largest stage was retail (including all embedded emissions).
- The total GHG emissions from waste for the national consumption of raspberries was 2.1 kt CO_2e (CV=8%). The largest stage was retail (including all embedded emissions).
- The total GHG emissions from waste for the national consumption of tomatoes was 126 kt CO_2e (CV=7%). The largest stage was grading.
- The total GHG emissions from waste for the national consumption of lettuce was 47 kt CO_2e (CV=9%). The largest stage was in the home (including all embedded emissions).
- The total GHG emissions from waste for the national consumption of apples was 366 kt CO_2e (CV=10%). The largest stage was in the home (including all embedded emissions).
- The total GHG emissions from waste for the national consumption of onions was 99 kt CO2e (CV=10%). The largest stage was grading.
- The total GHG emissions from waste for the national consumption of potatoes was 2664 kt CO2e (CV=11%). The largest stage was in the home (including all embedded emissions).
- The total GHG emissions from waste for the national consumption of brassicas was 77 kt CO_2e (CV=8%). The largest stage was grading (including all embedded emissions).
- The total GHG emissions from waste for the national consumption of avocados was 15 kt CO_2e (CV=8%). The largest stage was in the home (including all embedded emissions).
- The total GHG emissions from waste for the national consumption of citrus fruit was 126 kt CO_2e (CV=12%). The largest stage was in the home (including all embedded emissions).
- The total GHG emissions from waste for the national consumption of bananas was 187 kt CO_2e (CV=13%). The largest stage was in the home (including all embedded emissions).

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