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SID 5 Research Project Final Report

Department for Environment Food and Rural Affairs

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Project identification

1. Defra Project code: FO0412
2. Project title: Understanding the environmental impacts of consuming foods that are produced locally in season
3. Contractor organisation(s): ADAS UK Ltd; SERIO, University of Plymouth; EuGeos; CFI, Sheffield Hallam University
4. Total Defra project costs (agreed fixed price): £ 185,813
5. Project: start date 01/06/2009
   end date 01/02/2012

6. It is Defra's intention to publish this form.
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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Introduction

Defra identified the need for further research in order to determine the environmental impacts of seasonal food consumption. The aim of this research was to clarify the extent to which consumption of locally in season food might reduce the negative impacts of food consumption and be a criterion for sustainable food purchasing. It provides evidence on the impacts of buying locally in season produce, and will be used to inform the continued development of governments' environmental behaviour goals.
The main objectives were:

- To identify the definitions and concepts of seasonality and how these have evolved over time.
- To assess how environmental impacts vary based upon different definitions and concepts.
- To undertake an analysis of the life-cycle impacts of selected commodities in different production scenarios to determine environmental impacts.
- To assess consumers' awareness and understanding of seasonality as well as their attitudes and current behaviour towards seasonal food to enable patterns of consumption to be identified.
- To understand both the promoters and barriers to consumption of seasonal produce in terms of current 'messages' around seasonal, fresh produce as opposed to imported or non-seasonal produce.
- To assess the likely environmental costs and benefits of an increase in seasonal consumption and assess to what extent should consumption of foods produced locally in season be used as a criterion of sustainable food purchasing.

This project was divided into two main parts;

Part 1 – A technical study comprising of a literature review of current evidence and further life-cycle assessments (LCAs) on a variety of produce.
Part 2 – Consumer research to explore current awareness, levels of understanding and attitudes towards seasonal foods.

Defra's starting point for the definition of locally in season food is food *that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown. (*This applies to seasonal foods produced both in the UK and overseas).

Methods

Seasonal Food Definitions

As there were very different possible definitions and perceptions of what is seasonal, the project used two definitions to ensure consistency in the design of both the consumer research and LCA research tools.

1. Produced in season (Global) - Defra original 'locally in season' definition: Food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown.
2. A definition that takes the consumers' perspective, by incorporating a local link between production and consumption, produced and consumed in the same climatic zone without high energy use for climate modification or storage.

Consumer Research Methods

The consumer aspect of the study incorporated both primary and secondary research methods. There were three distinct research phases, each of which built on the knowledge obtained in the previous stages:

1. Literature review of consumer research - a desk based investigation of secondary sources in order to contextualise the study.

2. Consumer focus groups - fourteen focus groups were held with consumers across the UK. The focus groups covered seven broad localities in the UK and were equally split between rural and urban locations to ensure that geographical differences in seasonal food consumption could be identified. The focus groups was recruited to represent Defra's seven environmental consumer segments.

3. Online survey - the quantitative consumer survey collected data from a stratified sample of 1,200 grocery buyers using quota sampling criteria including regional location, age and gender to reflect the distribution of population and participation in food and drink buying behaviour.

Life Cycle Assessment (LCA) Method

The LCA work effectively comprised six separate LCA studies, one for each of the following foods - lamb, potatoes, raspberries, strawberries, melon and pineapple. Melon and pineapple were combined into one case study called exotic fruit. The food products were chosen to allow exploration of particular aspects of the environmental impact of seasonal and non-seasonal food production and supply - such as duration of storage and differences in production system. The literature review highlighted how other factors driving LCA results, such as the data used to characterise refrigerated sea freight or operation of a refrigerated storage facility, can confound efforts to draw comparative conclusions about these aspects. To avoid this, we used generic data to characterise activities that were common to all case studies and/or not relevant to the aspects under study. For example, a generic dataset was compiled to characterise operation of a typical refrigerated storage facility of specified volume for unit time, because this study was not concerned with variation in performance between different cold stores; this dataset was then used in all the case studies, with duration of storage and the volume occupied by a unit weight of foodstuff changed as necessary. Where different production systems or locations normally provide food for supply at a particular time of year, data representing the particular production system was used. Average data of comparable quality is not available for all production systems, and so data from individual producers operating appropriate systems was used to elaborate the case studies. For each case energy use for growing or storage, the goal was the same – to compare the scenarios and provide some commentary on the differences between them in terms of their impacts on the environment. The boundaries of the assessments were from primary production, including raw materials, to delivery of the food to a notional retailer's distribution centre in the UK. Impacts of capital equipment have been excluded, following the requirements of PAS2050. The environmental impact categories assessed were as follows: carbon footprint, water footprint, abiotic resource depletion, acidification, eutrophication, photochemical oxidant creation and ecotoxicity.

Findings

'Locally in season' definition and the consumer perspective

The consumer research highlighted that consumers do not have one universally accepted definition of seasonality. Consumers predominantly defined seasonal foods as food which is grown, and possibly consumed, during a product's natural growing season (without artificial heat and/or light). Close to half of consumers (49%) associated seasonal foods with UK-grown produce, although a substantial proportion thought that it could be grown anywhere in the world (31%).

The focus groups showed that consumers' understanding of seasonality varied between different types of food. Broadly speaking fruit and vegetables were more likely to be identified as seasonal compared with meat and fish, reflecting the findings of prior research. On the whole consumers did not consider meat to be seasonal.

The online survey highlighted that over two thirds of respondents reported consuming seasonal foods, with around 40% saying that they supplemented certain staple foods with seasonal foods, and over 30% that they consumed as much seasonal foods as possible. Nearly 30% of respondents were interested in increasing their consumption of seasonal foods a little and one in eight said they wanted to increase this by a lot.

However, respondents perceived knowledge of growing seasons for different foods was fairly limited, with half of respondents indicating that they had 'a little' knowledge. Remaining respondents were equally split between those feeling they had 'a lot' or 'a great deal' of knowledge (26%) and those feeling they had 'very little' or 'no knowledge' of natural growing seasons (24%).This is important, both in terms of consumers being able to make informed choices about consumption and in the promotion of seasonal foods.

The results indicated that a large number of factors influence consumers' decision to eat seasonal foods with the principal reasons for consuming seasonal foods being taste and freshness, while the main barrier was perceived cost. Consumers' positive attitudes to seasonal foods were often intrinsically linked to the fact that they were perceived to be locally sourced. Interestingly, environmental concerns were more peripheral in terms of influencing consumers' decision to eat seasonal foods, as were provenance and any price benefits. Where environmental concerns were raised the research revealed that consumers tended to focus on aspects of energy input during delivery, such as food miles etc. when discussing the benefits of seasonal food, rather than energy inputs during production. This view is contrary to the 'real' picture as carbon emissions associated with energy use in transport is only one component of environmental sustainability and the main burden of environmental impact falls on production rather than transport.

A classification of seasonal food consumers was developed to facilitate understanding of the differences in buying and consuming behaviours of seasonal foods. Of the four customer segments identified, Growing Enthusiasts account for 13.9% of consumers and are distinctive as they are the only segment that generally intends to increase their consumption of seasonal foods in future. In addition, they are already more likely to consume seasonal foods. In relation to the clarity of message, the Growing Enthusiasts are more likely to consider food grown in the region where they live to be seasonal and less likely to consider food grown anywhere in the world to be seasonal.

Lifecycle Assessment: Environmental impact of consuming foods 'locally in season'

There is not one consistent definition of seasonal food that, if applied, would consistently select foodstuffs of various kinds with lower environmental impact across the board. One of the main reasons is the impossibility of untangling shifts in the place of production from the production systems used and the effects of location on the environmental impacts of those systems. Therefore two products produced using identical systems will have different impacts depending upon the local environment in which they are produced. The local influences occur at both small scale and larger scale. At the small scale differences in soil type, orientation and so on are influences. At the larger scale the availability of both water and sunlight vary from region to region and these differences clearly influence the impacts associated with production in different places, especially when regional resource availability is taken into account as it is in the weighted water-footprint assessment method. Very detailed work would be necessary to understand the extent to which the small-scale differences rather than differences in practice contribute to the range of environmental impacts associated with any particular production system. The large scale differences are the source of the "ecological comparative advantage" postulated by Foster *et al*[1] Defra project SCP007 and also noted by Williams *et al*[2] Defra project FO0103. Trade-offs between environmental impacts are also observed, for example between GHG emissions and water, or between abiotic resources (fossil fuels) and land occupation (to capture solar energy). To untangle the influences on LCA outcomes of locality and operational characteristics, some LCA studies are being conducted with a large sample of farms producing and supplying the same specification of product. Examples include retailers' carbon footprinting programmes, some of which span several years and many supplier farms, and the Swiss agricultural LCA research programme. Such exercises will help to develop an understanding of the variability in life cycle inventories for individual products and the forces driving this. Further, the development of regionally-sensitive life cycle impact assessment methods, now endorsed by the EC-led International Life Cycle Data Handbook, and exemplified by the weighted water footprint used in this study, will also help to build a more accurate picture of the effects of this variation in inputs and outputs on the natural environment itself.

Even if the environmental assessment is based solely on the carbon footprint then there is still not a seasonal food definition that will consistently result in reduced GHG emissions across different products. Applying yield sensitivity analysis to the illustrative case studies show that yields have a strong effect on the differences in environmental impacts between the case study scenarios. The LCA literature review also found that the strong influence of yield on calculated impacts prevents a generalised resolution of the local vs. global debate. For example, differences in production yield can have such a strong effect on the carbon footprint of a product grown in two places that in some instances it can override the effect of transporting food long distances.

Within the majority of the case studies the on-farm production stage of the product lifecycle dominates the environmental impact, although the exotic fruit case study does show that post-harvest activities (product chilling, cold storage, packing and transportation) can all contribute significantly to the LCA results. Post harvest activity will be particularly significant for commodities with relatively low impacts in primary production including some exotic fruits that are also bulky items and require significant energy for storage, packing and transportation. The literature suggests that top fruits as well as exotic fruits will fall into this group.

Conclusions

The definition of environmentally sustainable food is multidimensional, complicated by resource availability at point of production. There is not one consistent seasonal food definition that results in a reduced environmental impact across different products as neither production season nor distance of travel provide good proxies for environmental impacts; furthermore, there are often trade-offs between environmental impacts. Used in isolation, defining food as 'in season' does not provide a good blanket criterion for environmentally sustainable food purchasing.

Based solely upon the case studies investigated in this project, a definition of seasonal food based on the consumer viewpoint and therefore incorporating a local link between production and consumption (e.g.

produced and consumed in the same climatic zone without high energy use for growing or storage) provided a better indicator than the “global” definition of production-supply systems with lower environmental impacts. That is to say that in more case studies it pointed to the system with lower impacts for more categories of environmental impact, without making any allowance for the relative importance to society of the different impact categories. There may be several reasons for why a more local definition of seasonal pointed to more lower impact products:

- Firstly, while transport-derived emissions are not significant drivers of carbon footprint or water footprint, they are significant drivers of acidification and photochemical oxidant creation potential; emissions from the generation of electricity to power cold stores also contribute to these impact categories.
- Secondly, true out-of-season production (i.e. out-of-season at the place of production) requires the input of artificial energy – either directly or (in the case of livestock) as embedded energy used to produce supplemental feed to support out of season production these inputs drive abiotic resource depletion (in these cases essentially an indicator of fossil fuel use) and carbon footprint. Out-of-season supply to the UK from Southern Europe may avoid higher energy use in primary production to some extent, but brings the pressure experienced by some Southern European water resources into the picture.

These general drivers might be the same in many cases. Pesticide use, on the other hand, may well reflect the practice of individual producers and the demands of individual products to a much greater extent. Differences in yield may well tip the balance toward one production-supply system or another in individual cases.

Throughout all the case studies the variability between the environmental impacts was typically of a low to medium magnitude, so any benefits derived from a shift in procurement would be of a similar nature. However, the trade data shows that the majority of the food production scenarios assessed are complimentary supply scenarios evolved to fill gaps in availability. Contrary to popular belief, within the current food system the opportunity to source a commodity from different production systems or regions at the same time is limited. Therefore at any time the choice available will primarily be between different commodities rather than between one commodity produced in different regions or production systems.

Attempts to support a seasonal food definition when claiming environmental benefits of seasonal food would require additional procurement criteria which take into account a range of performance indicators such as resource efficiency and good agricultural practices; importantly, resource availability, specifically water resources at the point of production should also be considered.

There is a conflict between the need to provide the consumer with a clear and simple message and the need to conduct a complex environmental assessment if trying to convey a positive message on seasonal food consumption. These environmental impacts should be considered by the supply chain but any messages to consumers need to be clear and simple.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

Understanding the environmental impacts of consuming foods that are produced locally in season

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Introduction

At the time this project was commissioned, one of Defra's high level environmental behaviour goals for consumers to eat more food that is locally in season. The Defra Pro-environmental Behaviours report[3] highlighted that the consumption of locally in season food had a modest environmental impact and was tentative about whether or not this behaviour should remain a high level goal. Defra identified the need for further research in order to determine the environmental impacts of seasonal food consumption. Defra's starting point for the definition of locally in season food is food *that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown. (*This applies to seasonal foods produced both in the UK and overseas).

This project was divided into two main parts;

Part 1 – A technical study comprising of a literature review of current evidence and further life cycle assessments (LCAs) on a variety of produce.

Part 2 – Consumer research to explore current awareness, levels of understanding and attitudes towards seasonal foods.

The aim of this research was to clarify the extent to which consumption of locally in season food results in reduced negative impacts of food consumption and could provide a criteria for sustainable food purchasing. It provides evidence on the impacts of buying locally in season produce, and will be used to inform the continued development of governments' environmental behaviour goals.

The approach to the LCAs in this project has been to develop a number of case studies comparing products produced in relevant agricultural systems delivered to a Supermarket Regional Distribution Centre (RDC) at a specified time of year. The LCAs are illustrative case studies based on individual farms to identify specific issues of seasonal and non-seasonal production, such as storage or protected cropping. The production data used in the case studies are not industry average data for particular foods produced in particular regions or countries; background data have been drawn from a single, generic database (the ecoinvent database v2.1), while a consistent set of data for post-farm gate activities, such as cold storage and transportation has been developed and applied. This allowed the LCAs specifically to investigate the differences in environmental impacts between supply scenarios based on production systems in defined locations (in some cases a specific region of a country) and for defined times of consumption. The chosen scenarios involved production systems, locations and consumption times typical of the UK consumption pattern for that food. The project required the investigation of 'in season' and 'out of season' production-supply scenarios' based on real producers. At this level, where individual production systems for particular crops are being compared, average data of comparable quality, covering many producers in particular locations, is not generally available, so data from single farms was used. In some instances, even this was found to be incomplete and experts were consulted to fill gaps to ensure the coverage of compared production scenarios was equivalent.

Experts from the project team and other stakeholders helped to define the scenarios, and case studies were carefully selected to allow reasonable representation of the scenarios. Expert knowledge of industry partners was used to ensure that the LCAs were consistent in coverage. The LCAs assessed a range of environmental impact categories including both the carbon and water footprints. The illustrative case studies are based on scenarios for the following products: lamb, maincrop potatoes, strawberries, raspberries, pineapple and melons.

The consumer research approach comprised of a literature review of the policy context and previous research, fourteen consumer focus groups held across seven localities in the UK, two groups within each locality. Focus groups were equally split between rural and urban locations. This approach was supplemented with a quantitative consumer survey following the qualitative research. This collected data from 1,200 consumers administered using an online consumer panel.

Scientific Objectives

The research will support the key intermediate objectives of Defra's Food Chain Programme which are to reduce the negative environmental impacts of the food chain, to reduce the amount of food waste generated and to increase the socio-economic benefits of food production and consumption.

In order to achieve the main aims of understanding the environmental impacts of consuming foods that are produced locally in season the project had the following scientific objectives:

There were twelve objectives:

1. To identify the definitions and concepts of seasonality and how these have evolved over time.
2. To establish the significance of seasonal effects in existing life-cycle analysis research.
3. To assess how environmental impacts vary based upon different definitions and concepts.
4. To undertake an analysis of the life-cycle impacts of selected commodities in different production scenarios to determine environmental impacts.
5. To produce case studies demonstrating produce available at different times throughout the year and their environmental impacts.
6. To assess consumers' awareness and understanding of seasonality as well as their attitudes and current behaviour towards seasonal food to enable patterns of consumption to be identified.
7. To understand both the promoters and barriers to consumption of seasonal produce in terms of current 'messages' around seasonal, fresh produce as opposed to imported or non-seasonal produce.
8. To understand the wider determinants of seasonal food consumption – for example, social norms, availability etc. This aspect will also consider consumer perceptions of the role of supermarkets and the media in influencing demand.
9. To identify the type of information, and its means of delivery, that is likely to influence consumers' purchasing behaviour in order to inform messages about seasonality.
10. To assess the likely environmental costs and benefits of an increase in seasonal consumption and assess to what extent should consumption of foods produced locally in season be used as a criterion of sustainable food purchasing.
11. To design and implement a knowledge transfer programme to exploit the outcomes/outputs of this project.
12. To provide recommendations on how outcomes from the project could be used in a practical way by policy makers and the food sector.

Methods

Seasonal Food Definitions Method Design

A fundamental component of the study was to explore the ‘in season’ definitions which will influence both the LCA and consumer research. The starting point was the Defra definition for ‘locally in season’ which is *food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown. (*This applies to seasonal foods produced both in the UK and overseas).

As there were very different possible definitions and perceptions of what is seasonal, the project used two definitions. The two definitions have been used to ensure consistency in the design of both the consumer research and LCA research tools.

1. Produced in season (Global) – Defra’s original ‘locally in season’ definition:
   Food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown.
2. A definition that takes the consumers’ perspective, by incorporating a local link between production and consumption*:*
   Food that is produced and consumed in the same climatic zone without high energy use for climate modification or storage.

Consumer Research Methods

The consumer aspect of the study was based upon a pluralistic approach, incorporating both primary and secondary research methods. There were three distinct research phases, each of which built on the knowledge obtained in the previous stages:

- Literature review of consumer research
- Consumer focus groups
- Online survey

Literature Review of Consumer Research

The first phase of research involved a desk based investigation of secondary sources in order to contextualise the study. This incorporated an examination of the consumer research that has already been undertaken in this area, including a comprehensive literature review of academic research that has investigated the demand for seasonal foods and the market more generally.

Consumer Focus Groups

Fourteen focus groups were held with consumers across the UK. The focus groups were conducted in two stages, with seven groups being held between October and December 2009 and seven between January and February 2010, to identify whether attitudes and consumption of seasonal food differed depending on the time of the year. The focus groups covered seven broad localities in the UK and were equally split between rural and urban locations to ensure that geographical differences in seasonal food consumption could be identified. Each of the focus groups was recruited to represent one of Defra’s seven environmental consumer segments[3] which divide the public into clusters, each sharing a distinct set of attitudes and beliefs towards the environment, environmental issues and behaviours. Each segment was represented by two focus groups, one in an urban area and the other in a rural area.

Online Survey

Reflecting the sequential approach, the findings from the preceding phases informed the design of quantitative research. The quantitative consumer survey collected data from a stratified sample of 1,200 grocery buyers using quota sampling criteria including regional location, age and gender to reflect the distribution of population and participation in food and drink buying behaviour. The survey was administered using an online consumer panel with over 130,000 potential respondents. This method was adopted in order to achieve the required number of responses within the quota bandings, and to attain coverage of all geographical areas. Findings from this survey can be generalised to the population as a whole.

Life Cycle Assessment Method

The LCA work effectively comprised six separate comparative LCA studies, one for each of the case studies (Table 1). For each of these the goal was the same – to compare the scenarios and provide some commentary on the difference between them in terms of their impacts on the environment. The methods and data used in each case have much in common, and these common elements are set out below. For each food, it has been necessary to make assumptions specific to the production of that food or to make the data collected useable in a LCA with the goal just described; such assumptions are summarised in the case studies themselves.

The boundaries of the assessments were from primary production, including raw materials, to delivery of the food to a notional retailer's distribution centre in the UK. Capital equipment has been excluded, following the requirements of PAS2050[4] specified in the bid. This exclusion does affect the outcomes and limits the comparability of the results of these studies with other LCAs of food products, in which at least capital equipment used on-farm is accounted for. The specific details of the system boundaries for each scenario are provided in the case studies.

For agricultural production and use of raw materials such as fertilisers, activity data were collected from real businesses representing the scenarios that were chosen. Secondary data were used to assess processing and transport emissions after the farm gate; datasets were developed using both data submitted by participating businesses and generic data characterising specific activities such as vehicle operation. This approach allowed a consistent treatment of post farm gate processing and transport.

General background data for the LCAs has been drawn from the Ecoinvent database v.2.1. Data for agricultural commodity crops used as inputs has been drawn from Cranfield University's AgriLCA model (v.3) to retain as much consistency as possible with previous LCAs commissioned by Defra.

Data collection

The data used for each of the case studies was collected from a single farm, providing a snapshot of how production of that product occurs in that country, under that production system. These example farms may not necessarily be representative of the whole range of production systems that are present, even within a single location.

Data collection forms were supplied to farmers or producers. These forms requested data on:

- Crop type and production method
- Yield
- Location of farm and time of year when product is available
- Raw material inputs (fertilisers, pesticides, plastics, feeds)
- Land area required for production (especially for the lamb)
- Average rainfall plus any additional water use for drinking or irrigation
- Soil type
- Fuel use (diesel, electricity, other fossil fuels) and breakdown of field operations
- Storage conditions (time spent in storage, type of storage, losses in storage)
- Transport (type of transport used, distance travelled, period spent in transit)

These forms were returned by the farmers and producers and the information was used to construct the LCA models. The data provided was not comprehensive in all cases; in some cases further queries elicited the missing information, while in others expert judgement was used to ensure consistent treatment of production, processing and transport in all scenarios relating to any particular food.

Environmental impact categories

Fossil fuel and mineral resource depletion

The extent to which the activities in the product's life cycle contribute to the depletion of non-living resources – essentially fossil and mineral resources – is assessed using the CML (CML is the Centre for Environmental Sciences, Leiden University) method for the impact category "abiotic resource depletion"[5].

Carbon Footprint

The extent to which the scenario contributes to greenhouse gas formation and hence climate change is assessed by calculating a carbon footprint (also referred to as global warming potential, GWP). The method followed is that given in PAS2050.

Acidification

Acidification impact assessment quantifies acid-gas releases from the system and/or the subsequent damage they cause. We have applied the CML method[5], which converts all acidifying gases released into quantities of a reference substance, SO_2; no distinction is made between the impacts of emissions occurring at different locations.

Eutrophication

Water pollution from release of excess nutrients is a significant environmental problem. Agricultural sources of excess nutrients include nitrate (NO_3) and phosphate (PO_4) leaching to water, and ammonia (NH_3) emissions to air. For each scenario nutrient inputs to and nutrient losses from soil and crop have been estimated. These, together with other eutrophying substances in the life cycle inventory of each scenario (for example NH_3 releases from the fertiliser production chain), have been converted into eutrophication potentials using the CML baseline method[5]. Estimates of diffuse nitrate and phosphorus loss to water courses from crop production were calculated using the ADAS Nitcat (Lord, 1992 and subsequent revisions) and PSYCHIC (Davison et al. 2008) field scale leaching models. These models were used to calculate nutrient losses for grass and feed crops for lamb production in the UK and New Zealand and for potatoes grown in the UK. It was felt that the assumptions used in these models were not suitable to estimate nutrient losses for the other cropping scenarios. For these scenarios a very simplistic approach has been used to provide nutrient loss estimates. Nitrate-N loss is calculated from an estimate of the potential nitrogen at risk of leaching which is then multiplied by a coefficient describing the proportion of this nitrogen that is leached. For phosphorus, the losses from fertiliser and soil are estimated independently and are dependent upon soil type and hydrologically effective rainfall. It is recognised that this approach can be improved and is an area for further work, but provides indicative losses for the project.

Photochemical oxidant creation

Photochemical Ozone Creation Potential (POCP) provides a measure of the extent to which substances contributing to smog are produced in the system under study. The CML method, which expresses releases of smog precursors in terms of the reference substance ethene (C_2H_4), has been used.

Ecotoxicity from pesticide use

The impact of production-consumption systems on eco-systems, whether characterised as ecotoxicity impact or biodiversity impact, is of keen interest to stakeholders. It was decided to use the Environmental Impact Quotient (EIQ) developed at Cornell University[6] as an indicator of the relative toxicity of pesticide application in the various scenarios.

Water Use Indicators

This project has used the water footprint[7] approach to provide an assessment of the impact of water use associated with each of the products. In common with the LCA methodology outlined above, a separate water footprint study was undertaken for each of the products. A volumetric water footprint does not reflect the impact of water use at the specific location(s) where it occurs. In order to address this, a water stress index weighted water footprint approach was taken, similar to that outlined by Ridoutt and Pfister[8], whereby a water stress characterisation factor for each location was introduced through the use of a water stress index (WSI) developed by Pfister *et al*[9]*.* to "weight" the water use according to the degree of water stress at the place of use. This provides an indication of both the amount of water used and the significance of that water use with reference to the regional availability of water.

In these (and almost all other) life cycle impact assessments, there is no differentiation between emissions or resource consumptions occurring at different times of the year. So, for example, nutrients released to the aqueous environment in January are treated in the same way as nutrients released in July. Seasonal differences therefore show up because production at different seasons involves different quantities or types of inputs or outputs, not because the LCA method discerns any difference between the effects of unit quantities emitted or used in different places at different times.

LCA product choice

The approach to the LCAs has been to develop a number of illustrative case studies in order to better understand role of seasonality comparing products from production through to delivery to a Supermarket Regional Distribution Centre (RDC) at a specified time of year. The food products were chosen on the ability to explore a specific aspect of the environmental impact of seasonal and non-seasonal food production such as storage. The project team initially identified a list of products which were then refined based upon discussion with food retailers to ensure that they were founded in real purchasing practice. The following product case studies were chosen:

Table 1 Food product and scenario choice for comparative lifecycle assessments

Case study	Case study scenarios	Rationale

Lamb	• UK early lambing consumed in April • Chilled NZ consumed in April • UK spring lambing consumed in September • Frozen NZ consumed in September	Lamb is one of the few meat products that has a strong seasonal production association.
Raspberries	• UK fresh consumed in June • UK frozen consumed in November • Spanish fresh consumed in May	Raspberries are one of the quintessential UK seasonal fruits. Consumption within the UK throughout the whole year has increased in the past 10 years. Technology has enabled the extension of the UK growing season.
Strawberries	• UK outdoors in un-heated tunnels consumed in July • UK heated glasshouse consumed in October • Spanish, un-heated in tunnels consumed in May	Strawberry consumption within the UK throughout the whole year has increased in the past 10 years. Technology has enabled the extension of the UK growing season with an increased trend of production in heated glasshouses.
Maincrop potatoes	• UK fresh maincrop consumed in September • Israeli fresh maincrop consumed April • UK long-term stored maincrop consumed April	This case study investigated the role of storage which is an important part of many product lifecycles.
Exotic fruit Honeydew Melon Pineapple	• Spanish melon consumed in June • Costa Rican melon consumed in January • Ghanaian pineapple throughout the year	This case study explored melon imported from different continents at different times of year in order to explore seasonality of imported products that are consumed in the UK throughout the year. Some products are always in season at the place of production. This case study used pineapple produced in West Africa to explore the impacts of consuming throughout the year in the UK.

Summary of Results

A review of literature and seasonal food websites revealed that while the term “seasonal food” is widely used, few users define what is meant by the term. A variety of meanings are presented so the term seasonal has come to mean different things to different groups of people. The consumer literature review also found that many consumers seem to be unclear about what constitutes seasonal produce. The available consumer research indicates that respondents to questionnaires associated “seasonal” with UK seasonal produce. The most referred to or assumed meaning of seasonal food is: *Food that is produced locally (e.g. UK produced) and is produced and consumed within the products’ natural growing season*. The term “local” is also interpreted somewhat differently by different people.

Discussions with food industry stakeholders as to their understanding of a ‘seasonal food’ definition support the original Defra ‘locally in season’ definition with the view that it would benefit from more guidance on production systems such as the use of unheated polytunnels. It was pointed out that in reality the term ‘in season’ is often used by the industry in association with provenance, e.g. British.

Literature and website review ‘Understanding of seasonal food past and present’

The importance of the seasonality of foods to society has altered over time. This has been influenced by food security concerns, politics, religious influences and consumer preference. All these factors have affected how food is produced and consumed.

How the seasonality of food has altered over time is discussed by Paul Waddington[10]. He states that before the 1500’s, people’s lives were entwined with the seasons and even religious ceremonies were influenced by seasonal food production. From the 1500’s onwards the enclosure of land saw the beginning of disengagement with food production and a loss of knowledge of natural growing seasons. By the 18th Century people had begun to move to towns and cities and were increasingly separated from food production. The Second World War and the Dig for Victory campaign saw a brief reconnection with food production to ensure food supply, but following this, as a result of the intensification and mechanisation of agriculture, the rise in technologies such as heating and refrigeration, and the move to a global market, the disconnection with food production and seasonality has intensified.

Many articles and websites take the meaning of what is seasonal as given and do not provide a clear definition. When exploring the narrative others have produced around seasonal foods it is clear that there are varied understandings. For some seasonal is not limited by geography but is any produce that is in its natural season anywhere in the world[11]. For others seasonality is closely connected to locality, whereby produce in season must also be local produce[12].

In addition to definitions of seasonal food relating to growing seasons and locality there are also references to seasonal foods that are culturally influenced, for example Turkey at Christmas and Haggis in the New Year. These are regarded by some as seasonal foods, but in these cases culture is more important than the growing season.

Of eight seasonal food calendars reviewed on the web, six provide details solely on produce that is local to the UK. One of the online calendars lists all produce that is available globally, while another lists the seasons of non-native UK produce which is produced near the UK, predominantly in Europe[13]. For example oranges from the Mediterranean are listed when they are in season but oranges from further afield are not included. A number of the calendars produced list culturally seasonal foods. The contents of seasonal calendars seem to be influenced by the objectives of the organisation producing the calendar, for example the Love British Foods website only discusses British produced foods[14].

Of the 28 articles and websites explored all promote the benefits of consuming seasonal foods. Of the perceived benefits of consuming seasonal foods the most commonly mentioned benefits are perceived taste, freshness and quality. The articles and websites also identify other benefits of consuming seasonal food that support the three pillars of sustainability (economic, social and environmental), and a number of websites argue that the environmental benefits of seasonal foods will only be realised if food is also local. Supporting this, Dibb and colleagues[15] argue that a positive response to climate change would be for consumers to opt for more seasonal UK produce, as it cuts out the bulk of greenhouse gas emissions associated with long distance food transport and avoids the need for heated greenhouses.

Consuming seasonal food is seen to have environmental benefits as it is thought that it will lead to a reduction in the inputs required to grow foods[16]. Consuming in season food is also seen to reduce the requirements for extended storage of produce which can be energy intensive.

The consumption and production of seasonal food is also thought to help protect the natural heritage of an area, and will help preserve local varieties of produce. For example the National Trust suggests that consumption of seasonal fruits will help protect the UK's declining orchards[17].

Literature review 'Overview of the policy context and previous consumer research'

'Eating seasonally' has increasingly been encouraged by government initiatives and supported by other agencies and organisations, such as Defra (particularly the *Eat Seasonably* campaign, the Food Standards Agency, the BBC and the Soil Association).The profile of seasonal foods has also been raised and information about "in-season" produce made available through a variety of channels, including television programmes, magazine articles and websites.

Numerous influences operate upon food choice and preferences and it is recognised that what we eat is embedded in emotional, as well as cultural and sub-cultural meanings, social norms, habits and experiences. The effects of messages about food are also mediated by the immediate social context, including family and peer group influences.

The different attitudes and behaviour among consumers will make them more or less receptive to messaging about food, and more or less interested in pricing, or other issues such as those relating to the seasonality and provenance of produce. Various segmentation models – such as those developed by SERIO[18] and the FSA[19] for food preference have been identified which might assist in influencing consumers more effectively.

The cultural and social norms, learned habits and the emotional aspects of food that lie behind these attitudinal and behavioural typologies, mean that individuals often find food preference habits, and therefore purchasing practices, hard to change, even when the benefits of making changes are known; rational choice is only one part of behavioural choice.

In attempting to influence behaviour related to food there is no 'one size fits all' solution, and, indeed, a number of factors may prove unhelpful, for example, difficult, unclear and complicated messages, or seeming to issue instructions about behaviour.

Successive surveys have found that price is one of the major issues influencing shopping priorities. Many other factors are also of importance to consumers, including the quality of the food, brand names, special offers and the healthiness of the food. Smaller proportions of respondents tend to mention specific health or environmental and ethical issues. When prompted, however, greater numbers of respondents indicate that seasonality and buying local produce, as well as specific ethical and health issues, are important to them.

Little of the available consumer research concentrates solely on seasonality. It is, however, apparent that respondents to surveys which do ask questions about seasonal foods tend to have UK, not global, seasonality in mind. In spite of this, the majority of people are unaware of the cropping seasons for common British fruit and vegetables, with older people being the most knowledgeable and the younger age groups being both less knowledgeable and less interested. Indeed age, gender, rural or urban residence and socio-economic status all have a crucial effect upon seasonal food choices and purchases.

Studies concerned with local or regional food also frequently contain references to seasonal produce, and while seasonal foods are not necessarily produced locally and local food may be grown out of season, there is overlap between the two, with shoppers seeing seasonality as one of the characteristics of local food and one of the reasons why they shop locally[18].The main motivations for buying local and seasonal foods are also similar, with those for seasonal foods being the freshness, quality and taste of the produce, supporting local growers and farmers, the farming and growing standards employed, sustainability and maintaining the local economy.

The major barriers to buying seasonal produce relate to price, choice, awareness and knowledge, availability and accessibility. For the majority of consumers, who shop mainly in supermarkets, these issues, as well as established purchasing habits and food preferences, will all present barriers to in season food purchases[20] even when seasonal foods are available in store.

Given their market dominance, the supermarkets and other chains are of key importance to influence consumption. While specialist and alternative outlets are being used for at least part of the shop by a number of customers, many consumers, including those shopping for organic produce, still prefer ‘one stop’ or ‘under one roof’ shopping and to inform consumers, information about in season produce should be made available in a variety of forms and at point of sale in the majority of outlets.

Literature review ‘Environmental impact of food production and role of seasonality’

There are a wide range of potential environmental impacts that can come about as a result of food production. In the literature there is little direct linkage between the seasonality of a food product and its environmental impact. However, there is a wide body of research on the environmental impacts of different aspects of food production. From these different papers it is possible to extrapolate what impacts in season production might have compared to out of season production.

For the purposes of this literature review a general look at the environmental impacts of agriculture was used, followed by a more in depth look at a number of products. Many environmental impacts are interlinked, with pesticides and fertilisers, for example, having a number of potential environmental impacts.

Potential environmental impacts of food production include:

- Greenhouse gas emissions (global warming) – as a result of fuel use (CO_2), application of artificial fertilisers and manures (N_2O), enteric fermentation in cattle and sheep (CH_4).

- Bio-diversity – reductions in bio-diversity can arise through the use of pesticides directly or indirectly through leaching into water, leaching of nitrate and phosphorus into water causing eutrophication, or through land use change and habitat destruction.

- Water quality and availability – soil erosion and leaching of pesticides and nutrients can all lead to a reduction in water quality for drinking and aquatic ecosystems. Where water quality has been particularly badly affected it can reduce the availability of water for other purposes and irrigation can also reduce the availability of water for other purposes.

- Soil erosion – through land use and cultivation practices. This can contribute to bio-diversity problems as soil particles can cause sedimentation of water courses. Nutrients and pesticides can bind to the soil particles causing eutrophication.

- Visual impacts - land use change such as arable crops or grassland potentially replacing woodland.

Seasonality can affect the severity of these environmental impacts through:

- Storage requirements (increased storage increases fuel requirements and therefore carbon emissions).
- Timing and type of cultivations.
- Amount, timing and type of pesticide and fertiliser applications.
- Water requirement of the crop (balance of available natural rainfall with irrigation).
- Soil protection - the presence or absence of crop canopy during vulnerable periods (over winter).
- Need for crop covers or mulches to extend season.
- Visual impacts resulting from techniques to extend the growing season in the UK – through the use of polytunnels or glass to extend the season or improve quality.

Literature review 'Seasonality and seasonal effects in LCA studies of foods'

The literature review 'Seasonality and seasonal effects in LCA studies of foods' finds that seasonality is addressed within the LCA literature to a very limited extent. This coverage is almost exclusively in the context of cases of fresh produce supplied to consumers in Northern Europe all year round either from the Southern Hemisphere or from the Mediterranean region. Reporting concentrates on the impact categories of global warming potential (GWP, carbon footprint) and primary energy use that have been the focus of most public debate. Few of the other types of impact listed in the previous section have received any significant attention. Reviewing this literature highlighted the difficulty of comparing the potential impacts associated with fresh produce from different sources arriving at the point of sale at a particular time in the year. For the items of fresh produce covered by published LCA studies that consider "seasonality" in some way, the reported impacts are seen to be all of the same order of magnitude for the different stages of the life cycle; robust comparisons therefore require careful assessment of each stage - cultivation, transport and storage. Even so, capturing the effects of some of the seasonal factors identified in the previous section as having the potential to influence the environmental impacts of production is probably beyond the scope of the LCA technique in its current form; it would certainly require a level of refinement in data capture and collection some way beyond that normally encountered in practice.

The three published comparative studies identified concern broccoli[21] apples[22, 23] and a basket of products for the Belgian market[24]. The overall picture that emerges from these is that open-field produce items, grown in season in Northern Europe and consumed in season in the same country or region generally have lower energy requirements and carbon footprints per functional unit than equivalent items grown under protection, imported or stored; but this general finding does not always extend to other environmental impacts such as acidification, eutrophication, water and land use.

Detailed examination of the results of four published LCA studies of apples, and the comparisons of several commodities (including apples, tomatoes and potatoes) presented by Williams *et al*[2] in Defra project FO0103 show that the absence of one single "dominant" stage in the life cycle makes comparing the potential impacts associated with fresh produce from different sources arriving at the point of sale at a given time in the year particularly difficult, because all stages need to be studied in some depth. Furthermore, the wide range of yields noted by different authors for different items of produce, and the strong influence of yield (and, of course, of wastage through the transport - storage chain) on calculated impacts, casts doubt on the potential for a generalised resolution of the local vs. global debate to be easily reached.

Findings from Consumer Research

- Both the focus groups and surveys highlighted that consumers have only a vague definition of seasonal food. When pushed, consumers define seasonal food predominantly as food which is grown, and possibly consumed, during a product's natural growing season (without artificial heat and/or light). Focus group participants were divided as to whether frozen or stored food could be described as seasonal.

- In terms of location, nearly half of respondents to the online survey associated seasonal foods with UK-grown produce, although substantial numbers (30.7%) thought that it could be grown anywhere in the world, suggesting that a sizeable proportion of consumers have a broader definition of seasonal foods, similar to Defra's definition.

- The online survey highlighted that over two thirds of respondents reported consuming seasonal foods, with around 40% saying that they supplemented certain staple foods with seasonal foods, and over 30% that they consumed as much seasonal food as possible. Just over half of respondents did not intend to change their consumption of seasonal foods in the future. On the other hand, nearly 30% were interested in increasing their consumption a little and one in eight said they wanted to increase this by a lot.

- Seasonal food shopping patterns were very similar to those for general fresh food shopping, demonstrating a heavy reliance on supermarkets with nearly all respondents to the online survey using these, generally on a weekly basis. This was followed by local specialist shops (68.0%), street markets (55.0%) and convenience stores (54.8%) which were all used less frequently. On average consumers used local specialist shops once a month, and street markets and convenience stores less than once a month, compared with supermarkets which were used once a week. This suggests that seasonal foods are purchased as part of consumers' general shopping.

- Respondents perceived knowledge of growing seasons for different foods was fairly limited, with half of respondents to the online survey indicating that they had 'a little' knowledge and around a quarter feeling they had either more or less knowledge. Actual knowledge varied for different food types. When survey respondents were tested across five products, the mean percentage of correct answers was 49.2%, indicating that a large number of respondents were unable to identify when produce was in season in the UK.

- The online survey highlighted that consumers' choice to eat seasonal foods was complex, based on a large number of considerations. Consumers' primary reasons for consuming seasonal foods were due to its freshness and taste, while the main barrier identified by consumers was cost. However, these are common to most types of food and more marginal concerns determine those who actually buy seasonal foods.

- When looking at relationships between current consumption and reasons for buying and not buying, the main positive determinants of consumers' buying behaviour were beliefs that seasonal foods are healthy, better for the environment and of known provenance, with the main negative influences being a lack of knowledge of seasonality and the belief that it offers limited food choices.

- Analysis of the online survey findings indicated that intentions to increase consumption of seasonal foods in the future were positively associated only with the beliefs that seasonal foods are better for the environment and of known provenance. The perception that seasonal foods were expensive was associated with a lower intention to consume seasonal foods in the future, as was a lack of knowledge of what is in season.

- Due to the ubiquity of supermarkets any endeavour to encourage consumption of seasonal foods would have to include efforts in these shops. Based on our research, clear, easy to see point-of-purchase information and leaflets to take away would be the best way to reach shoppers. Product layout and shop layout are also influential factors, with focus group participants highlighting the potential benefit of a seasonal foods section, like the current organic section, in supermarkets.

- The online survey revealed that the strategies that consumers perceived as most likely to increase their consumption of seasonal foods were lowering the price, increasing availability and putting more information in shops. However, given the principal perceived barriers of price, accessibility and lack of knowledge of what is in season, information alone may not be adequate for changing behaviour with regards to seasonal foods - a number of focus group participants suggested more forceful strategies might be required to increase consumption, such as obliging shops to stock seasonal foods by means of choice editing or reducing the availability of imported foods.

- Analysis of the online survey findings indicated that major differences exist between rural and urban consumers, with rural consumers demonstrating a better knowledge of seasonal foods and being more inclined to eat them, while urban consumers were more affected by the barriers associated with consuming seasonal foods. In terms of purchasing behaviour, rural consumers were more likely to shop locally than their urban counterparts. Urban consumers felt that they would be encouraged to buy more seasonal foods as a result of general informational strategies.

- Furthermore, older consumers were generally more knowledgeable about seasonal foods and more likely to consume them compared with younger consumers. The key motivations to consume seasonal foods generally became stronger with age, while younger consumers were more influenced by the identified barriers to consumption. Interestingly, consumers aged between 18 and 55 were more likely to intend to increase their consumption of seasonal foods in the future compared to those aged over 55 years. Younger consumers felt that they would be encouraged to buy more seasonal foods as a result of general informational strategies.

- Women were more likely to eat seasonal foods and intend to increase their future consumption. Women scored significantly higher than men on the factors related to positive reasons for consuming seasonal foods, whereas men scored higher on the barriers to consumption. Women were more likely to think that both general informational and practical interventions would be successful in persuading them to consume more seasonal foods.

- Differences existed in attitudes and behaviour between single consumers compared with all other groups. Single consumers were significantly less inclined to include seasonal foods in their regular diet, recognising the barriers to consumption as being a relevant issue when making their purchasing decisions.

- Eating behaviour and attitudes tended to vary significantly across Defra's environmental segments[3] with positive greens and waste watchers more likely to eat seasonal foods and more motivated to consume them by the perceived benefits compared to other groups. Positive greens were more knowledgeable about seasonal foods and were more inclined to consume seasonal food in the future. Amongst other groups, stalled starters showed a more positive attitude to future consumption, compared to others, even though they appeared to be the most affected by the barriers associated with consuming seasonal foods.

- Analysis of the online survey findings indicated that there were no differences in behaviours or attitudes towards seasonal foods between Scotland, Wales and Northern Ireland, or between the regions of England.

- The number of children in a household does not appear to be a significant factor in current or future intended consumption of seasonal foods.

- The socio-economic groups did not differ significantly from each other in terms of propensity to eat seasonal foods currently or in the future.

- Despite consumers citing price as a major barrier to buying seasonal food, there were no significant differences between the perception of price and inconvenience between the socio-economic groups. Nor did they differ substantially in terms of knowledge of seasonal food.

- A classification of seasonal food consumers was developed to facilitate understanding of the differences in buying and consuming behaviours of seasonal foods. Figure one shows that four customer segments were identified: Growing Enthusiasts (13.9%) Satisfied Enthusiasts (25.9%), Mixed Consumers (39.4%) and Uninterested (21.3%).

- Growing Enthusiasts are distinctive as they are the only segment that generally intends to increase their consumption of seasonal foods in the future. In addition, they are already more likely to consume seasonal foods. The other three segments either do not intend to increase their consumption of seasonal foods or only intend to by a little. Mixed Consumers, who represent the majority of the population, tend to consume certain staple foods, supplemented with some seasonal produce. They recognise both the benefits and barriers to consuming seasonal foods. The last two groups generally have no intention to change their behaviour. They differ in the fact that Satisfied Enthusiasts already consume seasonal foods frequently, while Uninterested consume very little and are heavily influenced by the barriers.

Figure 1: Seasonal Food Consumer Segments

Satisfied Enthusiasts (25.4%)

- More women
- More 45+
- More retired
- Fewer degrees
- More rural (countryside/village or

Growing Enthusiasts (13.9%)

- More women
- More 55-64 and 25-34
- More A levels and degrees
- More major town centre
- More positive greens and stalled starters,

country/market town)
- More positive greens and waste watchers, fewer stalled starters
- Less consider food grown anywhere in the world to be seasonal
- More would not look for information about seasonal food

fewer concerned consumers
- More consider food grown in the region where they live to be seasonal
- Less consider food grown anywhere in the world to be seasonal
- More would look for information about seasonal foods in the media and in supermarkets
- More perceive they have quite a lot or a great deal of knowledge about seasonal food

Mixed Consumers (39.4%)
- More men
- More urban (suburban area)
- More A levels and foundation degrees or equivalent
- More consider food grown in the UK to be seasonal

Uninterested (21.3%)
- More men
- More 18-44
- More singles
- More A levels and degrees
- More administrative /clerical/secretarial occupations
- More urban (inner city and suburban area)
- More honestly disengaged, stalled starters and cautious participants
- More consider food grown anywhere in the world to be seasonal
- Less consider food grown in the region where they live to be seasonal
- More would not look for information about seasonal food
- More perceive they have little knowledge about seasonal food

- Using this research to target different consumer groups with messages which are relevant to their own particular needs and constraints, it may be possible to influence consumption of seasonal foods.

Life Cycle Assessment Illustrative Case Studies

Case Study 1: UK Lamb Purchasing Scenarios - UK & NZ produced

Lamb was chosen as a case study because of the strong seasonal marketing programmes used to promote ‘new season’ lamb in the UK. The case study uses LCAs of lamb from individual farms in the UK and NZ to explore the environmental impact of consuming lamb in the UK at different times of year.

The notion and customer preference for 'spring lamb' and seasonal lamb was evident in the consumer research carried out for this project. The customer definition of seasonal food is culturally defined (e.g. Christmas) or time defined (e.g. spring lamb). The research also found that consumers often associate seasonal foods with the UK natural growing season. Consumers' associate spring (April) as the time that UK produced lamb is in season, although in fact this is the time when the UK 'maincrop' of lamb is born rather than when it is at slaughter weight, which is later in the year, e.g. July. The production of UK lambs for sale in April is small in comparison to the 'maincrop' for sale in summer and autumn.

This case study describes the outputs of four LCAs of differing UK lamb purchasing scenarios supplied by farm production in the UK or New Zealand (NZ). NZ was chosen as it is the main exporter of lamb to the UK. The import of NZ lamb to the UK peaks in April and then gradually declines throughout summer and autumn as the volume of UK new season lambs for sale peaks.

Scenario	**Production summary**	**Defra 'Locally in Season' definition ***	**Consumer definition 'Local link production & consumption****
Scenario 1: UK produced early lamb consumed fresh in April	Location: East Midlands, UK Lambs born: January Lambs ready for sale: April onwards Housed indoors	☒	☑
Scenario 2: NZ produced lamb transported chilled and consumed fresh in the UK in April	Location: (southern part of South Island) New Zealand Lambs born: September Lambs ready for sale: January - April Grazed outside	☑	☒
Scenario 3: UK produced lamb consumed fresh in July	Location: East Midlands, UK Lambs born: March Lambs ready for sale: late June onwards Grazed outside	☑	☑
Scenario 4: NZ produced lamb transported frozen and consumed in the UK in July	Location: (northern part of South Island) NZ Lambs born: August Lambs ready for sale: November-January Grazed outside	☒ ? Definition does not provide guidance on frozen	☒

* Defra original 'locally in season' definition: Food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown.
** Takes the consumers' perspective, by incorporating a local link between production and consumption, produced and consumed in the same climatic zone without high energy use for growing or storage.

The results are summarised below. For a discussion of the various impact potentials, their significance in relation to food systems and the units used, refer to the separate Annex 3, Method, and p.10 - 11 of this SID 5.

Impact potential per kg of product	Scenario			
	1. UK Lamb, chilled consumed in April	2. NZ Lamb, chilled consumed in April	3. UK Lamb, chilled consumed in July	4. NZ Lamb, frozen consumed July

Carbon footprint (GWP100, kg CO_2 eq)	21	28	18	34
Water footprint (WF) (m^3 Virtual water)	8.2	11	9	10
Weighted WF (m^3 Virtual water)	1.1	0.2	1.3	0.1
Agricultural land occupation (m^2.yr)	26	25	35	41
Pesticide hazard indicator E.I.Q., direct	0.02	0	0.07	0.02
abiotic depletion (kg antimony eq.)	0.04	0.01	0.02	0.02
photochemical oxidation -high NO_x (kg ethylene eq.)	0.003	0.006	0.003	0.006
acidification - (kg SO_2 eq.)	0.03	0.02	0.02	0.02
eutrophication (kg PO_4^{---} eq.)	0.05	0.04	0.05	0.03

The four scenarios represent four quite different types of farm raising lamb. There is a marked difference between the carbon footprints obtained for the NZ lamb products and those obtained for the UK examples. Transport, refrigeration and storage do not contribute significantly to the overall carbon footprint in any of the examples. Livestock emissions on the farm are the main contributor to these totals, and the emission rates from lambs used in the calculations strongly influence the values obtained. Following PAS2050, emissions factors reported to the IPCC by the UK and New Zealand were used to calculate the relevant emissions from animals. However, the reported emission factors are very different in the two cases. If one assumes that sheep in the two locations are very similar in terms of their metabolic function and the UK emission factors are applied to the NZ frozen lamb scenario, the carbon footprint is found to be 23.5 kg CO_2eq per kg lamb rather than 34, i.e. 29% greater than the scenario for July-supplied lamb from the UK rather than 88% greater. Setting these differences aside, the examples show that a low input extensive system, in this case operated in New Zealand, can have a higher carbon footprint per kg of lamb than a higher-input system, in this case operated in the UK; lower efficiency in the conversion of inputs to meat in the lower-input system may be responsible for this, although large differences between the farm types make it difficult to draw strong conclusions. Comparing the UK results with each other shows that the type of production system influences the carbon footprint but that an outdoor production system does not necessarily have a lower carbon footprint than an indoor one.

The volumetric water footprint of New Zealand lamb is similar to that of UK lamb. A water footprint of a product considers the freshwater volume required to produce it, summed over all steps in the production chain. However, it does not reflect the impact of water use at the specific location(s) where it occurs. This limits the extent to which comparison of water footprints leads to good environmental decisions. For example, a product with a lower water footprint could be more damaging to the environment than one with a higher water footprint if the water use in the first case occurs in a place where water resources are already highly stressed. Clearly this holds true for the extraction of water used for drinking or for servicing animals or for irrigation required for crop growth used for feed, which could stress local water resources, both classed as the 'blue' component of the water footprint. The blue water component was c2% of the total water footprint for UK lamb and less than 1% for New Zealand lamb. This is also the case for the 'grey' components of the water footprint, whereby the pollution losses would impact negatively on the overall water quality of the water resources, and would have a higher impact in water stressed areas where flows would be lower. The weighted water footprint is adjusted using the "Water Stress Index" (WSI). The WSI is used as a weighting factor to account for the different levels of "stress" to which water resources in different places are exposed. The weighted water footprint, which takes water availability into account, is much lower for the New Zealand examples, reflecting the lower stress that water resources in New Zealand are under.

The results for land occupancy reflect the extent to which the different source farms are intensive or extensive. The indoor-housing of livestock in the system preparing UK produced lambs for consumption in April is reflected in lower land occupancy for this than for lamb prepared for July which involves outdoor grazing. The New Zealand production system providing lamb for freezing and July consumption has very extensive grazing, whereas that supplying the April consumption scenario uses intensive rotational grazing management. This partly explains the differences in land occupancy between these two examples, although there are also other differences in the way land is used between the former (a livestock-only system) and the latter (a mixed arable and livestock system).

Both New Zealand production systems for which data was collected use few chemical inputs, and one (supplying the April consumption scenario) is fully organic. This explains the lower Environmental Impact Quotient results obtained for the examples involving New Zealand sourced lamb.

Transportation is a more significant driver of impacts for the other environmental categories. For example, sea freight accounts for around half of the acidification impacts for the two scenarios involving New Zealand production, but no more than 3% of these for either of the scenarios involving UK production.

For this case study, the products that meet the original Defra definition of seasonal do not have lower environmental impacts; while those that meet "the most common consumer definition" appear to have a lower carbon footprint. These assessments are based upon single farm case studies there will be differences from farm to farm. These case studies are representative as typically NZ farms are lower input in terms of nitrogen fertiliser use and supplemental feed as NZ grassland management is generally better that that in the UK and farms have less need for additional inputs.

Case Study 2: UK Potato (maincrop) Purchasing Scenarios - UK & Israel produced

This case study describes the outputs of three LCAs representing different UK maincrop potato purchasing scenarios based on farm production in the UK or Israel. The LCAs were for production on individual farms producing maincrop potatoes, and explored the environmental impact of consuming maincrop potatoes in the UK at differing times of year sourced from differing locations.

Although new potatoes have a stronger seasonal association than maincrop potatoes, the latter were chosen to better understand the role of storage or importing within the overall impact of a product lifecycle. They also represent the majority of consumption. Israel was chosen as the source of imported potatoes because it does export a significant quantity of maincrop potatoes to the UK. The majority of imports occur between April and August, peaking in June to coincide with the dip in UK maincrop availability, which is reliant on potatoes that have been stored from the previous year.

Scenario	**Production summary**	**Defra 'Locally in Season' definition ***	**Consumer definition 'Local link production & consumption****
Scenario 1: UK maincrop potatoes consumed fresh in the UK in September	Location: Yorkshire Planting date: April Harvest date: September No storage	☑	☑
Scenario 2: UK maincrop potatoes stored and consumed in the UK in April	Location: Yorkshire Planting date: April Harvest date: September Storage: Chilled Store	☒	☒
Scenario 3: Israeli maincrop potatoes consumed fresh in the UK in April	Location: Northern Negev Desert, Israel Harvest date: April No storage	☑	☒

* Defra original 'locally in season' definition: Food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown.
** Takes the consumers' perspective, by incorporating a local link between production and consumption, e.g. produced and consumed in the same climatic zone without high energy use for growing or storage.

The results are summarised below. For a discussion of the various impact potentials, their significance in relation to food systems and the units used, refer to the separate Annex 3, Method, and p.10 - 11 of this SID 5.

Impact potential per kg of product	Scenario		
	1. UK maincrop potatoes consumed fresh in the UK in September	2. UK maincrop potatoes stored and consumed in the UK in April	3. Israeli maincrop potatoes consumed fresh in the UK in April
Carbon footprint (GWP100, kg CO_2 eq)	0.2	0.3	0.3
Water footprint (WF) (m^3 Virtual water)	0.2	0.3	0.1
Weighted WF (m^3 Virtual water)	0.03	0.04	0.1
Agricultural land occupation (m^2 .yr)	0.3	0.3	0.3
Pesticide hazard indicator E.I.Q., direct	0.006	0.008	0.007
abiotic depletion (kg antimony eq.)	0.0007	0.002	0.002
photochemical oxidation -high NO_x (kg ethylene eq.)	0.00004	0.00007	0.0002
acidification - (kg SO_2 eq.)	0.0009	0.001	0.004
eutrophication (kg PO_4--- eq.)	0.001	0.001	0.0007

UK stored potatoes consumed in April have generally greater environmental impact than UK fresh potatoes consumed in September, and impacts on global warming potential and abiotic resource depletion are approximately twice the value for UK fresh potatoes. This reflects losses and energy use during storage. The field production emissions from UK potatoes stored and consumed in April are the same as for the UK fresh scenario, but added to these emissions are emissions associated with cold storage. The emissions are further influenced by grading out of store: we assumed that 20% of the crop was down-graded and sold to a lower-value market. This introduces a co-product to which some emissions were allocated, according to market value. The effect of this is to increase emissions for quality, 'pre-pack' maincrop potatoes sold in a supermarket. This effect is further amplified by weight loss of tubers in store (through moisture loss), which has the effect of decreasing yield and increasing all contributions to total emissions per kg of produce.

For the impact categories of global warming potential, weighted water footprint, abiotic resource depletion and acidification, Israeli fresh potatoes consumed in April have impact values of at least double the values for UK fresh potatoes. The Israeli fresh potato impact values for weighted water footprint, photochemical oxidation and acidification were also large compared with UK stored potatoes consumed at the same time as the Israeli potatoes. However, values for all other impact categories (global warming potential, water footprint, land occupation, environmental impact quotient (EIQ), abiotic resource depletion and eutrophication) were similar or lower than for UK stored potatoes consumed at the same time as the Israeli potatoes.

Abiotic resource use captures the extent to which the activities in the product's life cycle contribute to the depletion of non-living resources – essentially fossil and mineral resources. For all three scenarios the main source of abiotic resource use is bought in fossil fuels, either directly or indirectly, through their use to produce agricultural inputs like fertilisers. For UK potatoes consumed fresh in September all abiotic resource use was associated with consumption of fossil hydrocarbons. Crude oil accounts for 60% of this impact. For UK potatoes consumed in April after storage, the higher value than UK fresh reflects the fuel use for electricity used in the cold store. For Israeli potatoes the use of PE mulch contributes about 20% of the additional impact over the fresh UK potatoes, but the main source of additional impact is extra crude oil extraction, reflecting the additional transport fuels for importing.

Acidification impact assessment quantifies acid-gas releases from the system and/or the subsequent damage they cause. For UK potatoes consumed fresh NO_x accounts for about 50% of the impact, from diesel combustion in field operations (~30%) and transport (~20%). The fertiliser production chain accounts for about one seventh of the total by direct emissions of NH_3 and SO_x. For UK potatoes consumed in April after storage, additional production and emissions from the electricity generation chain contribute similar additional burdens over the UK fresh scenario. For Israeli potatoes consumed fresh in April Scenario 3, SO_x and NO_x emissions from the shipping operation account for around 80% of the impact.

For Israeli potatoes consumed fresh in April Scenario 3, direct emissions (N_2O) from potato growing are almost double those for the fresh UK-produced potatoes, mainly because of differences in fertilisation regimes, but these emissions still make up only one fifth of the total. Emissions from sea freight account for more than one third of the total.

Israeli potatoes had the lowest water footprint value. Israeli potatoes are more highly reliant on irrigation during production, although UK potatoes are irrigated to supplement water supplied from rainfall. In the case studies, the Israeli potatoes were using more precise irrigation techniques to meet crop water requirements and therefore we anticipate less water being lost to either subsurface or runoff and, hence, reduced fertiliser losses to water courses which all contribute to a lower water footprint value. However, when the impact of production is considered in the context of local water stress the comparison with the other scenarios looks rather different. The weighted water footprint is adjusted using the “Water Stress Index” (WSI). The WSI is used as a weighting factor to account for the different levels of “stress” to which water resources in different places are exposed. Israeli potatoes had the greatest weighted water footprint value, reflecting a greater water stress index (WSI) in the Northern Negev desert compared with UK production in Yorkshire.

On the basis of this case study, UK potatoes produced ‘in season’ according to the original Defra definition would have a lower impact but ‘importing seasonality’ by procuring Israeli potatoes produced in season would lead to a higher impact than those stored. The “consumer definition” of UK ‘in season’ excludes Israeli potatoes. The impact of UK stored potatoes could be reduced by improving the energy efficiency of stores but also by increasing the use of renewable energy.

This case study did explore the extremes of the UK producer storage spectrum. In between the scenarios some potatoes will be stored for a few months in ambient stores using minimal energy for ventilation with lower weight and waste loss. These scenarios would have a higher carbon footprint then those sold off the field but with a lower differential between “fresh” and stored. This highlights the problem of making a black and white distinction between ‘in season’ and ‘out of season’ when that distinction depends on a variable attribute such as storage.

Case Study 3: UK Raspberry Purchasing Scenarios - UK & Spain produced

This case study describes the outputs of three LCAs of differing UK purchasing scenarios based on farm production in the UK and Spain. This case study investigates the purchase of UK and Spanish fresh raspberries as well as the purchase of raspberries that have been produced in the UK and frozen for use later in the year.

Raspberries were selected because they are one of the quintessential UK seasonal fruits associated with the summer months, and consumption of raspberries within the UK throughout the whole year has increased in the past 10 years. The majority of fresh raspberry imports are from Spain. These imports satisfy demand outside of the UK production season and the majority of imports occur during the spring and autumn months.

Scenario	**Production summary**	**Defra 'Locally in Season' definition ***	**Consumer definition 'Local link production & consumption****
Scenario 1: UK produced raspberries consumed fresh in the UK in July	Location: East of England, UK Planting date: April Harvest date: July	☑	☑
Scenario 2: UK produced raspberries frozen and consumed in the UK in November	Location: East of England, UK Planting date: April Harvest date: July	☒ ? Definition does not provide guidance on frozen	☒
Scenario 3:Spanish produced raspberries consumed fresh in the UK in May	Location: Southern Spain Planting date: November-January Harvest date: May	☑	☒

* Defra original 'locally in season' definition: Food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown.
** Takes the consumers' perspective, by incorporating a local link between production and consumption, e.g. produced and consumed in the same climatic zone without high energy use for growing or storage.

The results are summarised below. For a discussion of the various impact potentials, their significance in relation to food systems and the units used, refer to the separate Annex 3, Method, and p.10 - 11 of this SID 5.

Impact potential per kg of product	Scenario		
	1. UK produced raspberries consumed fresh in the UK in July	2. UK produced raspberries frozen and consumed in the UK in November	3. Spanish produced raspberries consumed fresh in the UK in May
Carbon footprint (GWP100, kg CO_2 eq)	7.4	7.7	7.3
Water footprint (WF) (m^3 Virtual water)	1.3	1.3	2.7
Weighted WF (m^3 Virtual water)	0.09	0.09	2.7
Agricultural land occupation (m^2 .yr)	1.2	1.2	1.5
Pesticide hazard indicator E.I.Q., direct	0.3	0.3	0.3
abiotic depletion (kg antimony eq.)	0.004	0.006	0.01
photochemical oxidation -high NO_x (kg ethylene eq.)	0.0001	0.0002	0.0004
acidification - (kg SO_2 eq.)	0.003	0.004	0.01
eutrophication (kg PO_4--- eq.)	0.004	0.004	0.005

UK produced raspberries consumed fresh in the UK in July Scenario 1 generally have the lowest impact in most impact categories, compared with Spanish fresh Scenario 2 and UK frozen Scenario 3. The difference is not apparent comparing the carbon footprints but is significant in other areas such as weighted water footprint and abiotic resource use.

The scenario for UK produced raspberries frozen and consumed in November Scenario 2 was developed from UK produced raspberries consumed fresh Scenario 1 plus the freezing process and cold storage. The freezing and cold storage account for an additional 0.34 kg CO_2e per kg, 4.5% of the UK produced fresh raspberry carbon footprint. Of course the magnitude of this additional burden is sensitive to cold-store technology and performance (for example volume utilisation over the year, loss rates).

Even though both scenarios 1 and 3 deliver fresh field-grown raspberries to the UK consumer they use different production methods due to the different growing conditions. The UK scenario involves planting canes that remain in the ground and bear fruit for several years whereas the Spanish example grown in a warmer and drier climate involves replacing canes each year which is the dominant production system for raspberries in Spain produced at that time of the year. Even though the carbon footprint of both scenarios is very similar the contribution to that footprint from inputs and processes is different. However yield is still a dominant factor in determining the carbon footprint in terms of both fruit production but also - in the case where canes are replaced annually - yield of juvenile canes for planting.

The two UK produced scenarios had a lower water footprint value. However, when the impact of production is considered in the context of local water stress the difference between the UK and Spanish scenario is much greater. The weighted water footprint is adjusted using the “Water Stress Index” (WSI). The WSI is used as a weighting factor to account for the different levels of “stress” to which water resources in different places are exposed. The Spanish weighted water footprint reflects a greater WSI in Southern Spain compared with the East of England.

Both the UK and Spanish scenarios meet the Defra definition of ‘locally in season’ to guide food procurement. The frozen raspberry scenario has a higher carbon footprint but lower other environmental impacts in comparison to the Spanish scenario. Of course frozen raspberries are not necessarily substitutes for fresh raspberries.

The “consumer definition” of UK ‘in season’ applies only to UK raspberries produced ‘in season’ using un-heated tunnels consumed in July Scenario 1, which has the lowest impacts, although in terms of the carbon and water footprint UK fresh is only marginally better than UK frozen Scenario 3. Applying the “consumer definition” would, however, mean that raspberries would only be available within the UK production season and therefore would significantly reduce consumer choice. The UK fresh case study is based on an early fruiting variety, primocane varieties bear fruit into the autumn thus allowing the UK growing season to run from early summer through to autumn.

Case Study 4: UK Strawberry Purchasing Scenarios - UK & Spain produced

This case study describes the outputs of three LCAs of differing UK strawberry purchasing scenarios for production in both the UK and Spain. The case study uses the LCAs to explore the environmental impact of consuming strawberries in the UK at differing times of year sourced from differing locations using different production methods. Strawberries have a very strong seasonal association with summertime, for example strawberries during the Wimbledon tennis championships which take place at the end of June. The consumption of fresh soft fruit in the UK has increased over recent years and industry has responded to this demand through extending the UK growing season as well as through imports. Strawberries were chosen as a case study to better understand the role of production methods, in particular glasshouse production using artificial heat and outdoor produced using un-heated tunnels. Even though the case study assesses three systems there is an extremely wide variety of strawberry production systems which cater for all year round availability.

Scenario	**Production summary**	**Defra 'Locally in Season' definition ***	**Consumer definition 'Local link production & consumption****
Scenario 1: UK produced using un-heated tunnels (outdoors) consumed in July (summer-fruiting variety)	Location: UK, East of England Planting date: April Harvest date: July	☑	☑
Scenario 2: Spain produced using un-heated tunnels (outdoors) consumed in May	Location: Southern Spain Planting date: January Harvest date: May	☑	☒
Scenario 3: UK produced using heated glasshouse consumed in October	Location: South East England Planting date: July Harvest date: October	☒	☒

* Defra original 'locally in season' definition: Food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown.
** Takes the consumers' perspective, by incorporating a local link between production and consumption, e.g. produced and consumed in the same climatic zone without high energy use for growing or storage.

The results are summarised below. For a discussion of the various impact potentials, their significance in relation to food systems and the units used, refer to the separate Annex 3, Method, and p.10 - 11 of this SID 5.

Impact potential per kg of product	Scenario		
	1. Strawberries, UK produced using unheated tunnels consumed fresh in the UK in July	2. Strawberries, Spain produced Spain produced using unheated tunnels consumed fresh in the UK in May	3. Strawberries, UK glasshouse produced consumed fresh in the UK in October
Carbon footprint (GWP100, kg CO_2 eq)	0.7	1.5	6.5
Water footprint (WF) (m^3 Virtual water)	0.4	0.4	0.09
Weighted WF (m^3 Virtual water)	0.03	0.4	0.01
Agricultural land occupation (m^2 .yr)	0.5	0.4	0.3
Pesticide hazard indicator E.I.Q., direct	0.1	data unavailable	0.02
abiotic depletion (kg antimony eq.)	0.006	0.01	0.05
photochemical oxidation -high NO_x (kg ethylene eq.)	0.0001	0.0004	0.0007
acidification - (kg SO_2 eq.)	0.003	0.009	0.01
eutrophication (kg PO_4--- eq.)	0.001	0.001	0.001

The overall environmental impact is a mixed picture and priority of impact category dictates best and worst scenario. UK produced using un-heated tunnels consumed in July Scenario 1 has the lowest carbon footprint and resource depletion impact. However, the glasshouse scenario Scenario 3 performs better in the categories of water footprint, agricultural land occupation and pesticide hazard indicator.

UK produced strawberries using un-heated tunnels consumed in July Scenario 1 have less than half the carbon footprint of Spanish produced using un-heated tunnels consumed in May Scenario 2. There is not one dominant area contributing to the carbon footprint of strawberries in Scenario 1, as approximately 10% of the footprint is derived from N_2O emissions in the growing stages, 10% from peat production use and 15% from the fertiliser production chain. In the case of Scenario 2 long distance transport is significant and accounts for between 10% and 15% of the total carbon footprint for that scenario. Higher energy consumption associated with fruit production in the Spanish data accounts for much of the difference between the carbon footprints of Scenarios 1 and 2.

In the case of Scenario 3 UK glasshouse production, heating and lighting account for three quarters of the carbon footprint for that scenario. The carbon footprint is therefore very sensitive to the amount of energy used and assumptions about its source. So if consumption of UK grid electricity is half the level assumed, the carbon footprint reduces to 5.8 kgCO_2eq per kg, while if the heat used were “true” waste heat (i.e obtained in exchange for no payment so that it is free of burdens in a PAS2050-style calculation) the carbon footprint would be less than 2 kgCO_2eq per kg. The glasshouse production scenario used involves a medium temperature regime in order to maintain a minimum temperate climate and provide frost protection in warmer months; there is no heating for approx. 3 months in the winter.

UK glasshouse produced strawberries Scenario 3 had the lowest water footprint value. This is due to a combination of two factors: firstly the ability to use water very efficiently in a controlled environment and secondly due to the higher yield from glasshouse production which means the water footprint is allocated across a greater weight of end product. When the impact of production is considered in the context of local water stress the difference between the UK and Spanish scenario is much greater, as in the raspberry case study the Spanish weighted water footprint reflects a greater WSI in Southern Spain compared with the East of England.

On the basis of this case study, the original Defra definition of ‘locally in season’ to guide food procurement excludes “high-carbon” glasshouse-produced strawberries. However ‘importing seasonality’ by procuring Spanish strawberries produced in season appears to involve trading-off low-carbon for higher impacts in other categories, notably weighted water footprint and land occupancy.

The “consumer definition” of UK ‘in season’ applies only to Scenario 1 (UK strawberries produced ‘in season’ using un-heated tunnels consumed in July), which have a lower carbon footprint. But preferring this produce over glasshouse strawberries involves preferring low-carbon over more water- and pesticide-intensive produce. This case study illustrates clearly the trade-offs involved in produce-sourcing decisions. Local seasonal production in the UK may well be the lowest-carbon option, but requires more land and involves more chemical intervention to achieve commercial yields than glasshouse production. Produce imported from Southern Europe is lower-carbon than UK glasshouse produce but its production imposes higher burdens on stressed water resources.

Case Study 5: UK Exotic Fruit Purchasing Scenarios - Spanish & Costa Rican melon, Ghanaian pineapple

This case study describes the outputs of three LCAs of differing UK purchasing scenarios for melon and pineapple.

The case study uses two LCAs of individual farms producing honeydew melon in Spain and Costa Rica to explore the environmental impact of consuming melon in the UK at different times of year sourced from differing locations. Spain and Costa Rica were chosen as they are prime exporters of melon to the UK. The LCAs follow the same product being produced on different continents at different times of year. The purpose of this is to better understand the difference between the consumption at different times of year from different sources that are both consumed within their natural growing season.

A pineapple LCA scenario was chosen as to better understand the environmental impact of consuming tropical fruit produced as a plantation crop in a climate that allows for harvesting 12 months of the year. Therefore the natural growing season is continuous. Within a definition of seasonality that includes a sole prerequisite of having been grown in its natural growing season, then Ghanaian pineapples would always be in season.

Scenario	**Production summary**	**Defra 'Locally in Season' definition ***	**Consumer definition 'Local link production & consumption****
Scenario 1: Spanish honeydew melon consumed fresh in the UK in July	Location: Southern Spain Planting date: February-March Harvest date: June-August	☑	☒
Scenario 2: Costa Rican honeydew melon consumed fresh in the UK in April	Location: Northwest Costa Rica Planting date: November Harvest date: April	☑	☒
Scenario 3: Ghanaian pineapple consumed fresh in the UK year round (two points within the year chosen April and July)	Location: Southern Ghana Planting date: Year round Harvest date: Year round	☑	☒

* Defra original 'locally in season' definition: Food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown.
** Takes the consumers' perspective, by incorporating a local link between production and consumption, e.g. produced and consumed in the same climatic zone without high energy use for growing or storage.

The results are summarised below. For a discussion of the various impact potentials, their significance in relation to food systems and the units used, refer to the separate Annex 3, Method, and p.10 - 11 of this SID 5.

Impact potential per kg of product	Scenario			
	1: Spanish honeydew melon consumed fresh in the UK in July	2: Costa Rican honeydew melon consumed fresh in the UK in April	3: Ghanaian pineapple consumed fresh in the UK in July	4: Ghanaian pineapple consumed fresh in the UK in April
Carbon footprint (GWP100, kg CO_2 eq)	0.7	0.5	0.6	0.6
Water footprint (WF) (m^3 Virtual water)	0.1	0.3	0.6	0.6
Weighted WF (m^3 Virtual water)	0.1	0.004	0.01	0.01
Agricultural land occupation (m^2.yr)	0.3	0.3	0.4	0.4
Pesticide hazard indicator E.I.Q., direct	0.001	0.002	0.01	0.01
abiotic depletion (kg antimony eq.)	0.004	0.003	0.003	0.003
photochemical oxidation -high NO_x (kg ethylene eq.)	0.0002	0.0003	0.0003	0.0003
acidification - (kg SO_2 eq.)	0.005	0.007	0.006	0.006
eutrophication (kg PO_4--- eq.)	0.0008	0.001	0.005	0.005

The impacts associated with Spanish melon consumed in July Scenario 1 and Costa Rican melon consumed in April Scenario 2 are similar. Given the assumptions needed to model these systems, the differences that can be seen in the Table above should not be regarded as significant. The carbon footprint of the Spanish melon scenario is greater than the Costa Rican scenario, partly due to the fact that Spanish electricity (used mainly in packhouse operations) is fossil-fuel derived to a much greater extent than Costa Rican, where 70% is generated from hydro electric schemes. The pineapple carbon footprint remains the same whatever time of year the pineapples are procured for sale in the UK. Within the pineapple scenario post-harvest activities are significant and 25% of the carbon footprint is from transport to the UK.

The water footprint of the Spanish melon scenario is almost half that of the Costa Rican scenario primarily due to the greater application of water through irrigation within the Costa Rican example examined. However when taking into account local water stress then the weighted water footprint is 35 times that of the Costa Rican scenario. In comparison, the pineapple scenario has a low impact in terms of weighted water footprint due to high water availability and rainfall in Southern Ghana where the pineapples are produced. Even though Ghanaian pineapples are not irrigated the volumetric water footprint for Ghanaian pineapples is high in comparison to the other scenarios due to the high levels of pollution resulting from fertiliser application which, in turn, contributes to the grey water component of the water footprint.

On the basis of the two melon scenarios then procuring melon from Spain or Costa Rica results in similar carbon footprints and the difference is not significant. The main difference is in the weighted water footprint; this is significantly higher for Spanish melon than for Costa Rican, reflecting differences in local water resource stress levels. Melon from both sources is “in season” according to the definition of ‘locally in season’ originally proposed by Defra; using this to direct food procurement would not lead to preferment of a less water-stressed source in this case.

The assessment of both the two melon and one pineapple scenario has shown that in these production scenarios the significance of agricultural processes is less than for the other four products assessed in this study. Post-harvest activities (product chilling, cold storage, packing and transportation) all contribute significantly to the LCA results. The range of performance post harvest is wide and its influence on the environment exacerbated by the different environmental significance of different technologies (particularly refrigerants). Within other studies there is evidence that significant improvements can be made in areas such as packing densities which can reduce environmental impact.

Discussion

‘Locally in season’ definition and the consumer perspective

The literature review highlighted that there is not one universally accepted definition of seasonality. The consumer research highlighted that consumers have only a vague definition of seasonal food. When pushed they predominantly defined seasonal foods as food which is grown, and possibly consumed, during a product’s natural growing season (without artificial heat and/or light). A large proportion of consumers associate seasonal foods with UK grown produce, although a significant proportion thought that it could be grown anywhere in the world. The Defra ‘locally in season’ definition takes a production perspective focusing upon how the food is produced, rather than where. This project also used a second definition which is based on the consumers’ perspective, by incorporating a local link between production and consumption.

The results of the consumer research indicate that a large number of factors influence consumers’ decision to eat seasonal foods. Reflecting findings from the focus groups, the principal reasons for consuming seasonal foods were taste and freshness. Environmental concerns were more peripheral, as were provenance and any price benefits. However, these are common to most types of food and more marginal concerns determine those who actually buy seasonal foods. Consumers are predominantly using seasonality as a quality criteria rather than pro-environmental purchasing criteria.

The research found that some shoppers saw seasonality as one of the characteristics of local food and a reason to shop locally. Consumers’ positive attitudes to seasonal foods were often intrinsically linked to the fact that they were perceived to be locally sourced.

The focus groups showed that consumers’ understanding of seasonality varied between different types of food. Broadly speaking fruit and vegetables were more likely to be identified as seasonal compared with meat and fish, reflecting the findings of prior research. On the whole consumers did not consider meat to be seasonal. However, certain products such as lamb and game were occasionally mentioned. An acquaintance with the seasonality of meat was much more common in rural areas. Knowledge about the seasonality of fish and seafood was even more specialised, confined to a few older respondents who fished themselves. The consumer survey supported this when asked if they had consciously eaten certain foods *because they were in season in the UK* during the past four weeks participants were more likely to correctly identify fruits that were in season in the UK (92.3%), followed by vegetables (58.5%), meat (44.2%) and fish (17.5%).

In order to influence behaviour related to food then unclear and complicated messages, or seeming to issue instructions about behaviour, are not helpful. Therefore communicating issues to consumers around the environmental impacts of seasonal food would require one simple definition and message for seasonal food.

Although environmental concerns were more peripheral than taste and freshness the research has revealed that consumers tended to focus on aspects of energy input during delivery, such as distance of transport etc. when discussing the benefits of seasonal food, rather than energy inputs during production. This view is contrary to the ‘real’ picture as energy and carbon is only one component of environmental sustainability and the main burden of environmental impact generally falls on production rather than transport. This reinforces the power of clear and simple messages – Distance of transport or ‘Food miles’ is a clear and simple message and the research reinforces how effectively this has been embedded into consumers’ perceptions.

A classification of seasonal food consumers was developed to facilitate understanding of the differences in buying and consuming behaviours of seasonal foods. Of the four customer segments identified, Growing Enthusiasts are distinctive as they are the only segment that generally intends to increase their consumption of seasonal foods in future. In addition, they are already more likely to consume seasonal foods. This group only accounts for 13.9% of consumers. In relation to the clarity of message the Growing Enthusiasts consider food grown in the region where they live to be seasonal and are less likely to consider food grown anywhere in the world to be seasonal. This group includes more women, more highly educated, more urban and more 25-34 and 55-64 year olds.

The Mixed Consumers segment are the largest group, accounting for nearly 40% of the population, and provide the greatest potential for increasing seasonal food consumption. This group includes more men and more people living in urban areas. This group tends to accompany a diet of year round staples with some seasonal produce and have a neutral attitude about changing their behaviour. Consumers in this segment tended to identify seasonal foods as UK grown, so again the content of seasonal foods messages would have to be carefully considered.

The other two segments would not offer good scope for increasing seasonal food consumption. The Satisfied Consumer group - which includes more women, rural and older consumers – already consumes large amounts of seasonal food and are uninterested in increasing this further. The Uninterested segment, on the other hand, have very low current levels of consumption, do not recognise any benefits to seasonal food and also highlight the barriers. This group includes more single people, men, those aged 18-44, living in urban areas.

Lifecycle Assessment: Environmental impact of consuming foods 'locally in season'

Based upon the single producer case studies, food from across the globe that is 'in season' produced during its natural growing period in some cases will have a reduced environmental impact compared to food 'out of season'. The same is true of food for the UK that has been produced in the UK 'in season': in some cases this will have a reduced environmental impact and in some cases it will have the opposite effect.

The consumer definition which incorporates a local link between production and consumption, e.g. produced and consumed in the same climatic zone without high energy use for growing or storage, was the most effective for identifying foods with lower environmental impacts for the case studies used.

There are practical problems in using Defra's original definition since out of season production is really limited to glasshouse production and the definition is unclear about storage. A weakness with all definitions is the impossibility of untangling local influences on impact from seasonal shifts in the place of production. So two products produced using identical systems will have different impacts depending upon the local environment in which they are produced – examples are impacts associated with water and energy use. Trade-offs between environmental impacts are also observed, for example between carbon and water, or between abiotic resources (fossil fuels) and land occupation (to capture solar energy).

Even if the environmental assessment is based solely on the carbon footprint then there is still not a seasonal food definition that will consistently result in reduced carbon emissions across different products. Applying yield sensitivity analysis to the illustrative case studies shows that the differences in the environmental impact between the case study scenarios could result from different production yields. This was also highlighted in the LCA literature review, which concluded that the strong influence of yield on calculated impacts casts doubt on the potential for a generalised resolution of the local vs. global debate to be easily reached.

Within the majority of the case studies the on-farm production stage of the product lifecycle dominates the environmental impact and the number of transport miles or whether the product is fresh or frozen is of lesser importance. This is consistent with most other LCAs of food products reviewed. However, the exotic fruit case study does show that post-harvest activities (product chilling, cold storage, packing and transportation) can contribute significantly to the LCA results in some instances. It is likely that this is related to water content of the produce, as foods that have high water content, such as melons and pineapples: (1) have high yields which leads to a relatively low carbon footprint per kg of product; (2) are bulky and heavy to transport, increasing the post-production carbon footprint; (3) tend to be more perishable than foods with low water content (e.g. cereal grains), so require refrigeration for storage, increasing the post-production carbon footprint; and (4) require careful storage to avoid damage, which limits the packing density, again increasing the post-production carbon footprint for storage and transport. The data provided about post-harvest activities support literature and anecdotal evidence of a wide range of performance and technologies in cold stores and packhouses; it is likely that in some instances post-harvest activities would show as more significant than they do here, particularly in carbon footprint studies of systems containing older cold-stores with low utilisation levels.

The likely environmental costs and benefits of an increase in seasonal consumption would have to be assessed on a case-by-case basis and is dependent on many other variables including sources or companies as well as products. In simple terms the production of a product 'out of season' using state of the art facilities, management techniques and crop varieties could have a lower environmental impact than a product produced 'in season' with lower production standards. The potato case study also highlights the problem of making a black and white distinction between 'in season' and 'out of season' when the distinction depends on a variable attribute such as storage.

One could take the attributes of the original Defra 'locally in season' definition and extend to fresh produce (fruit and vegetables) for a number of 'rules of thumb' for identifying food with a lower carbon footprint. *Crops outdoor grown or produced during the natural growing/production period for the country or region where it is produced. Crop protection methods that do not use heat generated from fossil fuel. Minimise transport and do not use air freight. Minimal use of chilled or frozen storage.* However, these rules do not address other environmental impacts.

The research did reveal that consumers are more attuned to aspects of energy/carbon input during delivery, such as distance of transport, when discussing the benefits of seasonal food, rather than energy or other inputs during production. The lamb case study has shown that meat is more complex than fruit and vegetables and such rules of thumb cannot (yet) be established. Those aspects of practice, place and time that actually drive the differences between the carbon footprints of meats produced in different ways and in different places have yet to become clear from the available information in the range of published studies.

Conclusions

The term 'locally in season' emerged from the Defra report 'A Framework for pro-Environmental Behaviours, January 2008'. The report highlighted a pro-environmental behaviour of eating more food that is 'locally in season', measuring the benefit in savings of CO_2 per household based upon the reduction in air freight. The report suggested that the consumption of locally in season food had a modest environmental impact and was tentative about whether this behaviour should remain as a high-level goal.

The Defra starting point as a definition of 'locally in season' was - *Food that is outdoor grown or produced during the natural growing/production period for the country or region where it is produced. It need not necessarily be consumed locally to where it is grown. (*This applies to seasonal foods produced both in the UK and overseas).

The definition of environmentally sustainable food is multidimensional, complicated by local resource availability at point of production. There is not one consistent definition that results in a reduced environmental impact across different products as there are trade-offs between environmental impacts. Used in isolation defining food as 'in season' is not a good blanket criterion for environmental sustainability.

Based upon the case studies the consumer definition which incorporates a local link between production and consumption, e.g. produced and consumed in the same climatic zone without high energy use for growing or storage would – for the case studies used - deliver greater benefit. If the definition is applied to food sourcing then it would significantly constrict consumer choice.

Throughout all the case studies, the variability between the environmental impacts of the different supply scenarios was most commonly of a low to medium magnitude; any benefits derived from a shift in procurement would be of a similar nature. However, the trade data shows that the majority of the food production scenarios assessed are complimentary supply scenarios and have evolved to fill gaps in availability rather than compete at the same time of year. A focus on procuring locally in season food might reduce the availability of some foods, and the nature and scale of the wider environmental effects of that focus would, of course, depend on what (if anything) consumers bought instead of foods no longer available. Improving production efficiency (for example increasing yields) and improving (or upgrading) post-harvest technology seem likely to provide a surer route to reducing the environmental impacts of food than shifting to 'in season' consumption.

Within the case studies the researchers have also considered UK production and import data. The practicalities of shifting to a diet based upon a definition which incorporates a local link between production and consumption would mean that consumers who chose to adopt these principles would forego products throughout large parts of the year. This is more feasible with items such as seasonal soft fruit but much more difficult with staple food products such as potatoes that supply a large proportion of energy and nutrient needs.

In attempt to support a seasonal food definition when claiming environmental benefits of seasonal food, additional procurement criteria should be applied which takes into account a range of performance indicators such as resource efficiency and good agricultural practices; importantly resource availability at point of production should also be considered.

If seasonality is used to convey positive environmental attributes of a food product, supported by an assessment of environmental impacts, then these messages should be targeted at consumers who are attentive to these messages. The consumer research found that messaging to promote seasonal should be focused on two key segments – Growing Enthusiasts and Mixed Consumers.

There is a conflict between the need to provide the consumer with a clear and simple message and the need to conduct a complex environmental risk assessment. It is not practical to expect a consumer to conduct such an assessment themselves.

The Growing Enthusiasts segment is the only segment that already intends to increase their consumption of seasonal food. They perceive themselves to have reasonable knowledge of seasonality and have an affinity with food that is produced locally. In this case, a definition that incorporates a local link between production and consumption would have a greater impact.

Mixed Consumers, other hand, have a neutral attitude to altering their consumption of seasonal food. They currently consume a diet of year round items, supplemented with some seasonal food. Consideration of the definition is also important for this group as they consider seasonal food to be UK-grown. Although Mixed Consumers recognise the benefits of seasonal food, they are also far more influenced by the barriers than the Growing Enthusiasts segment, so strategies targeting this group should also include efforts to overcome barriers, such as increasing availability. Given the relatively low levels of knowledge regarding natural growing seasons, education to increase awareness should also be considered. As this large group represents a wide variety of consumers, a range of strategies would be required.

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References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.