Retail Innovation Programme

Packaging technologies with potential to reduce the amount of food thrown away

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Executive Summary

An estimated 6.7 million tonnes of household food waste is produced each year in the UK, most of which could have been eaten. A large part of this is food that is merely perceived to have exceeded its useable life or is actually no longer fit for consumption.

WRAP has commissioned a number of research projects to gain a deeper understanding of food waste. This includes how food actually becomes waste, what food waste typically consists of, and an exploration as to how consumers could be equipped with tools and resources to plan their shopping and consumption.

This particular project focused on how packaging can help to reduce food waste through the following key areas:

- pack technologies that increase shelf life;
- technologies that bring the consumer’s attention to the life of a product and when a product is nearing the end of that life; and
- pack technologies that enable consumers to re-seal and re-use the product when not all of it is to be consumed at the same time.

Packaging should also aim to change consumers’ purchasing attitudes so that they consider the waste issue even before purchase.

To establish just how successful packaging could be in both helping to reduce food waste and in changing consumers’ attitudes, the following activities were carried out:
an investigation into food spoilAGE to identify the mechanisms of food degradation, causes, effects and potential solutions;
internet and database research to identify formats and technologies already in existence, along with the manufacturers of such packaging innovations;
site visits to a broad range of stores in the UK and France to identify what formats and technologies are currently being used - samples were purchased and photographed;
discussion of pack innovations with a number of industry experts, including manufacturers, food companies and retailers; and
discussion of gathered pack samples with consumers through informal qualitative research groups to obtain a clearer idea of consumers’ experiences, perceptions and expectations.

Desk and field research identified a number of packaging innovations and developments that seek to preserve the product inside - either before or after opening - or to help consumers manage their food better by making them more aware of the expiring life of the product.

The majority of these technologies are already being used by manufacturers and retailers to some degree. This suggests that they are already proving to be successful. However, in order to ascertain how successful these packs really are in helping consumers to reduce the amount of food they throw away it was essential to understand UK consumers’ perceptions of the pack formats and technologies currently available.
A number of informal qualitative focus groups revealed that some of these pack developments are more successful and appealing than others. More importantly, however, the research highlighted potential barriers to the success of these pack innovations, the main one of which is the real or perceived increase in packaging waste that will result. All consumers firmly believed that packaging waste is a far more significant problem than food waste - especially where plastics are concerned. Their perception is that food waste, being entirely organic matter, simply rots down into the ground where it does no environmental harm. Consumers do not understand the often complex relationships between waste and the generation of associated environmental impacts – e.g. the creation of methane, a potent greenhouse gas – from the landfilling of waste.

Furthermore, there is a strongly held belief that today’s hectic lifestyles make it almost impossible to plan meals effectively. Some of the more ethically minded consumers appear to succeed in this area, of which a proportion achieve a realistic reduction in food waste entering landfill, for example, home composting of fruit and vegetable waste.

Added to this, many consumers felt that their increased need for ‘on-demand’ shopping, which could play a significant role in helping to reduce food waste, is not supported by the retailers. Local supermarkets offer insufficient choice, inappropriate pack sizes and are generally poor value for money.

Any initiative to reduce household food waste, through packaging or any other means, needs to be supported by education to raise awareness of food waste and its implications as well as tackling the problem at its root.
1. Introduction

Design Bridge and PMT jointly undertook a research project on behalf of WRAP to establish how packaging can help reduce household food waste and to identify which packaging formats and technologies show the greatest potential. It must be noted that this research is limited to identifying potential rather than providing quantifiable evidence of waste reductions that can be made.

A market audit of packaging innovations was carried out, both directly through manufacturers and also by investigating what formats have already been adopted by retailers. These packs were put in the context of other factors, such as food degradation mechanisms, fridge temperatures and consumer behaviour. Samples of the identified packs were gathered and photographed.

Consumer behaviour was a crucial aspect to the research. A pack may demonstrate great functional potential but if there are any barriers to its purchase – perceived or otherwise – this potential may be lost. The most obvious example of this is the likely increase in packaging and packaging components in order to better preserve the food inside.

In order to gauge consumers’ responses to the gathered samples we conducted a number of informal qualitative research discussion groups. Consumers were presented with pack formats and asked a number of questions including how beneficial they perceived the packs to be and whether they would buy them. While the groups gave clear indications of the perceptions typical of many consumers, it must be noted that they may not be typical of all consumers. The limited resources dictated that the groups be held in-house at Design Bridge, which meant that the respondents only reflected the views of a London-based, fully employed, professional ABC1 sample. Additionally, available resources confined the responses to purely anecdotal evidence.
This report outlines the methodology employed to identify packs with potential and highlights some of the key barriers that may compromise this potential. This leads on to the identification of formats and technologies that demonstrate the greatest potential. Finally, recommendations are made on how the final pack formats can be tested with consumers in a broader, more reliable manner that should result in quantifiable potential.

Additionally, other study and research projects have been recommend that seek to identify alternative means of reducing food waste.

The WRAP Retail Innovation team works with retailers and their supply chains to reduce the amount of packaging and food that households throw away.
2. Relevant Experience

2.1 The role of Design Bridge

Design Bridge is an internationally renowned brand design consultancy with specialist skills in the disciplines of Brand Strategy, Graphic and 3-Dimensional Design.

With extensive experience in Fast Moving Consumer Goods (FMCG) packaging design for major international clients such as Unilever, Sara Lee, Reckitt Benckiser, ICI (Dulux), Nestlé, Diageo and Kraft, as well as numerous local and regional companies and their brands, Design Bridge understands the issues and concerns facing retailers, brand owners and consumers alike.

With over 13 years of structural packaging design experience in a diverse range of product categories we have amassed an encyclopaedic knowledge of the packaging industry and available technologies. The consideration of consumer perception and behaviour is central to our approach and guides our investigations into technologies and relevant packaging solutions.

In addition to our experience of the consumer brand world, Design Bridge has worked with WRAP on a number of projects to reduce household waste generated through the retail sector. These have included the creation of resealable packaging concepts and reduced ready meal packaging ideas. We have gained wider exposure to the waste minimisation agenda through our work in facilitating a number of workshops for WRAP and in the two dissemination events held so far for WRAP’s International Packaging Study (IPS\(^1\)).

\(^1\) A study undertaken by Pira International and WRAP during 2005 to identify and understand packaging innovations in a range of overseas retail markets and their application in the UK grocery retail market. An image bank drawn from this study can be found at: International Packaging Study database
2.2 The role of PMT

Dr Paul Butler has 20 years’ experience in the packaging industry. In this time he has led and managed many projects with full budgetary responsibility, including running a large R&D establishment of over 300 people.

In 2002 he formed Packaging Materials & Technologies Ltd, a consultancy service for the packaging industry specialising in packaging design, innovation, smart materials and smart packaging for organisations, including large companies such as DuPont, Rexam, Nestlé and Crown Technology.

Experiences central to this project brief are:

- packaging material expertise: polymers, metal, glass;
- knowledge of food shelf life degradation processes and their kinetics;
- international reputation as an expert in smart packaging for the past seven years, with particular expertise in the evaluation of time-temperature indicators (TTIs);
- up-to-date knowledge of new smart technologies for food waste reduction, eg ripeness sensors, breathable polymer films, anti-microbial coatings;
- up-to-date knowledge of smart materials and their potential in food packaging applications; and
- understanding of stand-up pouch development including novel opening/resealable mechanisms.
3. Food Spoilage

**Introduction**

The ‘Soggy Lettuce Report’ from the Prudential showed that the average person throws away £424 worth of food, based on interviews conducted with over 1,000 adults in 2004. A ‘shopping list of shame’ revealed that over half of people in the UK threw away lettuce, bags of salad, loaves of bread and fruit every week simply because they didn’t have a chance to eat them before they went off or exceeded the ‘use by’ date.

Frequently degradation is a complex event with a number of processes occurring simultaneously. In general, these types of perishable foods have a shelf life that is determined by the onset of biochemical processes (enzymatic/oxidation) or microbial decay.

In order to investigate fully how packaging can help reduce food waste, it was essential to have a clear understanding of the mechanisms of food spoilage. Frequently degradation is a complex event with a number of processes occurring simultaneously, as shown in the example for lettuce in the graphic below.
This knowledge of precisely how food ‘goes off’ enabled us to evaluate how effective existing pack innovations might be, as well as giving a more scientific context to the feedback gathered from the in-house consumer research groups.

The four main mechanisms involved in the deterioration of foods are:

1. Microbial spoilage sometimes accompanied by pathogen development;
2. Chemical and enzymatic activity, leading to colour changes (browning), flavour, vitamin loss and texture changes;
3. Oxidative deterioration/rancidity producing lipid breakdown in fats and changes in colour, flavour and texture; and
4. Moisture and/or other vapour migration giving rise to changes in texture, water activity and flavour.

**Full details of the causes and effects of these types of deterioration can be found in Appendix 1.**

Table 1 shows matrix maps of food types against typical mechanisms of degradation and potential packaging solutions.

**Table 1**

<table>
<thead>
<tr>
<th>Food Group</th>
<th>Main Spoilage Category</th>
<th>Main Degradation Mechanism</th>
<th>Secondary Mechanism(s)</th>
<th>Critical Storage Parameters</th>
<th>Packaging Solutions - Shelf-Life Extension</th>
<th>Packaging Solutions - Consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread, cakes, biscuits, cereals, etc</td>
<td>Physical</td>
<td>Moisture migration</td>
<td>Microbiological</td>
<td>Humidity, oxygen, temperature</td>
<td>Reclosability (e.g. zippers), antimicrobials</td>
<td>-</td>
</tr>
<tr>
<td>Fruit</td>
<td>Chemical</td>
<td>Enzymatic browning</td>
<td>Moisture loss, microbial growth</td>
<td>Temperature, handling, ethylene, humidity</td>
<td>Protective packaging (e.g. clamshells)</td>
<td>Ripeness indicators</td>
</tr>
<tr>
<td>Vegetables, salads, etc</td>
<td>Chemical</td>
<td>Non-enzymatic browning</td>
<td>Moisture loss, microbial growth</td>
<td>Temperature, oxygen, carbon dioxide, humidity</td>
<td>Reclosability, breathable polymer films</td>
<td>Time-temperature indicators</td>
</tr>
<tr>
<td>Milk, dairy products, cheese, etc</td>
<td>Chemical</td>
<td>Oxidation</td>
<td>Rancidity, microbial growth</td>
<td>Temperature, oxygen, humidity</td>
<td>Reclosability</td>
<td>Time-temperature indicators</td>
</tr>
<tr>
<td>Meat (fresh &amp; cured), fish, seafood, etc</td>
<td>Microbiological</td>
<td>Microbial</td>
<td>Moisture loss, rancidity</td>
<td>Temperature, oxygen</td>
<td>Oxygen absorbers, antimicrobials, reclosability</td>
<td>Time-temperature indicators</td>
</tr>
</tbody>
</table>
The one common factor capable of slowing down nearly all of the various degradation mechanisms for all food types is storage temperature.

Recommendations in the United Kingdom (UK) concerning the microbial safety of foods advise that maximum temperatures in household refrigerators should not exceed 5°C. Surveys amalgamating results from many countries have shown that around 70% of the world’s refrigerators operate at average temperatures above 5°C. For example, the average air temperature in European fridges has been measured at 6.64°C, and according to a United States study nearly one-third of consumers have their refrigerators at too high a temperature.

All the food degradation mechanisms are temperature-dependent so that food stored in a refrigerator at 10°C, for example, might deteriorate at anything between 2 and 12 times faster than if stored at 0°C, depending on the mechanisms of deterioration.
4. Pack Formats and Technologies

4.1 Desk study and initial field research

Research was initially conducted via the internet and using existing Design Bridge and PMT databases to identify what technological innovations currently exist. The objectives of these technologies are as follows:

- pack technologies that increase shelf life;
- technologies that bring the consumer’s attention to the life of a product and when a product is nearing an end of that life; and
- pack technologies that enable consumers to reseal and re-use the product when not all of it is to be consumed at the same time.

The technologies identified were broken down into the following four categories:
- resealing/re-closing;
- portioning;
- materials and features; and
- communication.

A number of different manufacturers and systems were found, ranging from very simple applied elements such as adhesive strips to aid reclosing, to materials that can control moisture levels within the pack. All of these systems are production-ready; many have already been adopted by food manufacturers or retailers.

A full list of the identified manufacturers can be found in Appendix 2.
Following the desk research, store visits were conducted to establish what pack innovations have already found their way on to UK and Continental shelves.

In the UK, stores visited include the following:

- Sainsbury's
- Marks & Spencer
- Waitrose
- Tesco
- Aldi
- Lidl
- Netto

Aldi, Lidl and Netto were audited to cover the lower end of the retail market but also because of their Continental origins and product sources.

In France, Monoprix and Carrefour were visited.

### 4.2 Resealing/Reclosing

It is important to make the distinction between resealing and reclosing.

Reclosable packs give a much reduced barrier by replacing what is essentially a loose-fitting cover. Even these loose covers can offer protection, however, particularly by reducing moisture loss or damage by ‘freezer burn’.

Resealing creates a more complete barrier between the inside of the pack and the outside atmosphere (although in practice very few packs are completely resealable). However, there have been advances with resealability, particularly with flexibles, where technology has been borrowed from other sectors.
The benefit of flexibles is that the material costs stay comparatively low (and will reduce as volumes increase) and in many cases existing machinery can be adapted to apply resealing devices. Some examples are shown below.

Cathedral City cheddar cheese flow-wrap bag with integral seal.

Zipper used on dried fruits.
Grated mozzarella cheese in Amcor’s Flexcan self-standing pouch which features a low-tack adhesive strip under the overlap.

Alternative zipper with slider to close - more convenient but perhaps a little complicated for grapes.
More and more products such as pasta sauces and sharing foods (above and right) are produced by companies such as RPC Containers. They are reclosable and very presentable but result in greater packaging waste.

Wipak reclosable film top web lidding material provides a lightweight reclosable solution for Cathedral City’s sliced cheese packs.
Portioning is not an applied technology as such, but has more to do with the style or format of the pack.

The main benefit of portioning is that it allows consumers to open only as much as they want to use at that time, leaving the remainder of the product perfectly sealed.

Most products can be portioned and whilst packaging, when compared with a conventional pack, may be greater, there is a higher perceived pack value as the consumer can easily recognise the benefit.

Portioned packs take two basic forms: Form, fill, seal trays, such as the vacuum-formed Multivac-type packs, and individually wrapped (shrink, flow, etc) products.
More and more products, like this mini tub variant of Philadelphia cream cheese, are being offered in collated portions. The obvious benefit is that you only need open the amount you want to eat at that time – the remaining ‘pods’ are left undisturbed. This product is sold alongside conventional tubs.

Similarly, Waitrose is packing some of its thinly sliced ham in smaller multi-pack pods to enable consumers to open only what they need.
A number of retailers are offering meat portions that are individually wrapped for freezing, collated into a larger multipack. In both cases, zipper seals have been used to add further convenience.

Both M&S and Sainsbury’s offer individual portions of vegetables. The main focus of these products is one of convenience, but they also enjoy the product protection benefits of more typical portioned products.
4.4 Materials

Improvements are constantly being made in material technology, ranging from passive systems that create a barrier between the interior of the pack and the outside world to more active technologies that scavenge for oxygen or prevent the growth of bacteria.

Most packaged perishable food is already packed in a controlled or modified atmosphere and so the focus is on the packaging materials themselves to extend shelf life. This is particularly important, as once the pack is opened the controlled atmosphere inside is destroyed.

Materials can help even after the pack has been opened, but may work best in conjunction with other features.

These technologies are mostly used to ensure maximum shelf life for the retailer rather than the consumer.

A full report covering materials and active features can be found in Appendix 3.
Antimicrobial

Some packaging materials already include anti-bacterial agents. In many cases these are natural substances such as allyl isothiocyanate, which is found in mustards and horseradish.

In the UK we are already familiar with WasaOuro®, an antimicrobial material disguised as garnish often found in packed sushi.

Controlled permeability

In the USA, fresh produce is already packed in controlled permeability film, such as Intellipak from Landec Corp in California. These materials can change their gas permeability to cope with temperature fluctuations and thus better preserve the product within.
Carbon Dioxide generating or scavenging

High carbon dioxide (CO\(_2\)) levels (10–80%) are desirable for some foods such as meat and poultry because they inhibit surface microbial growth, thereby extending shelf life. This is the basis of high CO\(_2\)/low oxygen (O\(_2\)) modified atmosphere packaging. In other food systems, CO\(_2\) is formed due to deterioration and respiration reactions, and the gas produced has to be removed from the package to avoid further food deterioration and, in extreme cases, to prevent the package swelling or bursting.

This has led to the development of packaging that simultaneously releases CO\(_2\) and scavenges O\(_2\). Such systems are based on inserted sachets of either ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate. It is being used to package fresh ground coffee in flexible pouches, which more than triples shelf life.

Ethylene scavenging

Since senescent products such as bananas, tomatoes and oranges can be picked before maturity, they need to have their metabolism slowed down during storage if shelf life is to be extended.

Lowering oxygen does this in part, but these fruits and vegetables produce ethylene gas, which triggers ripening and if not removed causes the product to mature too quickly.

Several Japanese commercial applications use a silica gel which contains permanganate. The latter oxidises the ethylene and has been commercially successful for many fruit storage systems, especially kiwi fruits.
Desiccant/ moisture scavenging systems

Fresh, high moisture containing food has a high water activity and excess water can be produced during storage. This excess moisture can cause loss of texture and food spoilage due to the growth of micro-organisms. The water can be removed via the use of desiccating films or sachets, thereby extending shelf life. Desiccants work well for many products.

Humidity control systems

For many other products what is needed is controlled humidity within a certain range to ensure product characteristics are retained and there are no deleterious property shifts due to the product getting either too dry or too wet. A type of pack has been created to allow water vapour to permeate freely in either direction through a patch of vapour transmissive material bonded to paper.

So far, this system has been used to control product integrity over a pre-determined shelf life for the storage of food, tobacco, musical accessories, digital film and medical devices.
Oxygen scavenging

Oxygen scavenging systems are predominantly applied elements such as Mitsubishi’s Ageless or Multisorb’s FreshMax patches. The Ageless system has already been adopted by Sainsbury’s for their packed premium sliced ham.

‘Ageless’ oxygen scavenging system applied to packaging for Sainsbury’s premium sliced ham.
4.4 Communication

Time is one of the least useful parameters on which to base our judgement of product quality unless products are stored at a constant temperature, which in practice they are not. To set the scene:

The UK Government’s Food Standards Agency surveyed 3,000 people in 2003 to discover how well ‘use by’ and ‘best before’ dates were understood. In each case they were asked ‘what if the use by/sell by date on a food product passed yesterday?’ and presented with options to indicate what they would do. The results showed there is still widespread confusion surrounding these dates. Only 41% demonstrated a correct understanding of ‘use by’ dates, leaving almost 60% of people who thought that food past its ‘use by’ date could be safely consumed. (Refer to Appendix 1).

Time-temperature indicators (TTIs) use chemical reactions to exhibit an irreversible change of colour in response to the combined effects of time and temperature, so offer the opportunity to measure cumulative abuse of products along the cold chain. Applied as labels, they provide manufacturers, retailers and consumers with a simple yet effective method of controlling the safety of perishable food product inventories.

Broadly TTIs fall into two types: those where the chemical ‘clock’ starts ticking the moment the active constituents are laid down during label production (supplier activated), and those where the consumer either pulls a tab or breaks a miniature vial to mix the chemicals and start the process (consumer activated). Supplier activated labels need to be shipped and stored at low temperatures to prevent activation prior to actual use.

Basic time indicators, such as Timestrip, are already available.
Possible confusion between TTI and ‘use by’ date

French Customer Surveys have shown that consumers perceive the TTI as complementary to the use by date, and a range of TTIs have been developed that change colour at a rate that closely matches the ‘use by’ date. Most people think that the TTI is a more reliable guide than the ‘use by’ date, and are prepared to pay a little more for the reassurance of freshness and quality.

Appendix 4 contains further details of the various TTI technologies.

The technology for TTIs has been around for some time, but only three types have made it to commercial reality for food products, manufactured by TEMPTIME, Vitsab Inc and Timestrip respectively. The first type is supplier activated; the other two are activated by the consumer. All three types have commercially applications, e.g. Monoprix, British Airways, Nestlé.

In Europe, the main user of TTI technology is the French supermarket chain Monoprix. They have applied Fresh-Check indicators to nearly 200 of their products over the last 15 years. One of the major factors in their application is to give Monoprix a competitive advantage, since they are only applied to Monoprix products that are sold alongside competitive brands and products.
A range of products from the French supermarket chain Monoprix that already feature Fresh-Check TTI’s.

In the UK, however, current interest in TTI’s is very small. The manufacturers, TEMPTIME, have confirmed that no discussions have taken place with UK retailers in recent years. This was also confirmed in conversations with a Packaging Technologist from one of the four main retail chains who felt that the benefit of TTIs was not clear. (See Appendix 5 on Fridge Temperature and 6 on French Supermarket Audit).

A leading UK dairy produce manufacturer contacted during this research has confirmed that TTIs are already in use in the distribution chain in order to confirm that a batch of any given product had not exceeded an established temperature limit. They expressed an interest in featuring them on consumer packs, but not at this stage due to the relatively high costs versus the individual product retail price.

Another type of indicator is the fruit ripeness indicator. This smart label that changes colour to indicate the ripeness of pears has been recently commercialised after five years’ development by two New Zealand scientists in partnership with the Jenkins Group, a label manufacturer.
The new sensor labels, inside plastic clamshell packages of green Anjou pears, react to the ethylene gas released by the ripening fruit, changing through a range of vibrant colours. Red means the pears aren’t fully ripe; as the pears ripen the label changes to orange. When the label turns yellow, it means the pears are soft, ripe and juicy, enabling shoppers to choose fruit that best appeals to their taste. The outer clamshell packaging prevents consumer damage to the fruit. Could further potential applications include other fruits such as avocados, pineapples, melons, etc?

Ripesense indicators are currently being employed in the USA on packs of pears, which are notoriously difficult to judge the ripeness of.
5. Consumer Research

5.1 Objectives and methodology

Having identified the various formats and technologies available, we then tested these with groups of consumers to discuss their experiences and gauge perceptions. The objective was to identify the most appealing packs and, therefore, the packs that offer greatest potential from a consumer and usage point of view.

Three 75-minute qualitative focus groups were conducted in-house, amongst the staff of Design Bridge. Respondents were chosen to reflect a range of consumer types, such as ecologically aware, those less aware of the food waste problem and recycling, mothers with established families, mothers with young families, single men and women and couples.

Whilst this sample gave a broad range of attitudes and behaviours, it did limit the responses to those typical of AB C1, fully employed, London-based consumers. It must also be noted that due to the informal nature of the groups, the information gathered, whilst informative and insightful, is strictly anecdotal. The groups were video-taped for internal reference purposes.
Each group consisted of 3 main discussions:

1. General Discussion - 20 minutes
   Attitudes to the problem of food waste, typical foodstuffs thrown away, attitudes to recycling, purchasing and eating behaviour. Additionally, issues such as ‘use by’ dates and attitudes to frozen foods were probed.

2. Current Technologies - 40 minutes
   An open forum to discuss the pack samples presented – resealing packs, portion packs, materials and communication devices.

3. The Future - 15 minutes
   How could the presented formats be improved, what else could they be used for, what else would be beneficial?

5.2 General discussion

During this first section individual round-the-table interviews were held to act as a warm-up exercise and to probe more fundamental issues and attitudes. The results of these discussions are outlined below:

**Actual food wastage**

- Typical food waste products include bagged pre-prepared salads, sliced meats (cooked and uncooked), meat in general, fresh fruit and vegetables and bread;
- Foods frozen by the consumers were also identified as a regular waste food; and
- Uneaten whole vegetables – such as lettuce or broccoli – were singled out as major offenders.
Consumer behaviour

- Many consumers still prefer to buy more than they need as this is better than not having enough – a general trend, it seems, for modern life;
- Value for money is still a key driver – why buy a portion pack of broccoli for 99p when you can buy a whole one for the same price?
- Most consumers admit that the root cause of food wastage is bad planning, or being unable to plan. Busy urban lives often mean that food purchased at the start of the week can often go unused as a result of plans changing unexpectedly (going out or working late, for example);
- Despite this, many still prefer to shop only once or twice a week as it represents far greater value for money;
- Ad hoc shopping is seen as costly and the choice available in local supermarkets is vastly inferior;
- Many local supermarkets concentrate on convenience and often sell inappropriate pack sizes for ‘on demand’ shopping. A premium is charged for the convenience of local shopping;
- Modern consumers are spoiled for choice and some are reluctant to eat the same things twice in a week; and
- Parents often find young children, particularly toddlers, can be wasteful as they sometimes refuse to eat the food that has been prepared for them.
Consumer perceptions

- By far the biggest issue is the fact that consumers believe food waste is a much less significant problem than packaging waste as it is organic and will decompose into the ground;
- Many respondents had concerns that packaging waste grew significantly in some examples shown; in many cases these were made of plastic and, therefore, a greater ecological problem;
- Many consumers could not distinguish landfill from composting - only those currently composting their vegetable food waste (in all cases, supported by their local authority) understood that landfill is not an effective or ‘green’ solution to food waste;
- The key driver for wanting to reduce food waste is financial – literally throwing money away – rather than concern for the environment;
- Many respondents also expressed guilt at throwing food away when so much of the world’s population suffers from hunger.
- However, thoughts frequently returned to increases in packaging waste; and
- Most respondents expressed an assumption that their fridge was set to the correct temperature, despite not paying much attention to any indicators that may have been incorporated by the manufacturer. They therefore assume that because their food is in the fridge it is properly stored, regardless of the actual fridge temperature.

Attitudes to frozen foods

- Many consumers understand that frozen foods are greatly improved over their perceptions of products from 10 or 20 years ago;
- It’s widely understood that fish or peas, for instance, are frozen the moment the are caught or picked which implies a greater quality than fresh produce which may be days old by the time it reaches the store;
Despite this, most (if not all) respondents argued that they would still prefer ‘fresh’ food over frozen;

Whilst freezers offer a certain kind of convenience in terms of greatly extending the life of a product, freezing food is seen as very inconvenient;

Most consumers forget what they have in their freezer (out of sight, out of mind) or forget how long the food has been in there;

As a result, some consumers believed that freezers increased food waste – by hiding and prolonging – rather than reducing it;

Another concern surrounding frozen foods is that of defrosting - it takes a long time and once defrosted there is a very small window of opportunity in which to cook the food; and

Defrosted food was identified as a significant contributor to food waste.
5.3 Current Technologies

A range of different packs representing the four main technology categories were presented to the consumers in focus groups and discussion was prompted by open questions, such as: ‘how effective are they?’, ‘what do you think of when you see/use the pack?’ and ‘how would this help you preserve or manage your food better?’

Below are the most consistent comments received for each pack type:

Reclosable packs

- Zipper seals are great – low cost and not that much more to throw away;
- These really work and mean I don’t need to use a separate bag or find an elastic band to keep it covered;
- Can be tricky to get into due to smaller aperture and sometimes difficult to re-close; and
- Easy concept to understand - most people are familiar with these devices.

Zipper Seals

- Over-packaged as the zip is so obvious; and
- Pointless on a product like this as the bag is full of holes to allow the grapes inside to breathe.
Important to ensure that they continue to stick with use.

Great for sharing but very expensive – I’d only buy these for a treat or a picnic;

Very, very wasteful – it would limit how many I would buy of these, even though the pots are re-useable; and

Re-closability is secondary – product presentation is the key reason for

Another lightweight pack, very interesting - not too much to throw away.
This is great - it solves my problem with ham and bacon packs not being re-closable;

- Very simple and it appears to actually work!
- Not too much packaging to throw away; and
- Easy to open as well as close.

Wipak reclosable film for Cathedral City sliced cheese packs

**Key Learning:**

Whilst many of these innovations were seen to offer genuine improvements over standard packs, not one of them was sufficient to coax consumers away from their existing brands. However, the respondents said they would accept a small price increase if they felt the product inside was being protected and they could witness the benefit the pack offered.
Portioned packs

- Great - I can never get through a whole tray of ham;
- Individual portions still look a bit large;
- Pack doesn’t say much about the quality of the product; and
- It’s a lot of packaging to throw away, especially given the size of each pod.

4x Ham Pack

- Really great for lunchboxes;
- Would definitely eat it all and not leave any;
- Much more packaging than tub; and
- I’d still buy a full tub as it’s much better value for money, even if I don’t eat it all – not great value for money.

Philadelphia Mini Tubs
Really good idea if you’re on your own;
Great way of getting variety without having to buy loads of vegetables; and
Very, very expensive – you can buy this for 99p or pay the same and buy a whole broccoli or bag of carrots.

Individual Veg Portions

Good that it’s ambient, but if I have to eat vegetables they might as well be fresh!
Pack doesn’t look appealing – not to English tastes;
Pack far too substantial – I’d feel guilty throwing all that plastic away; and
The shelf life’s too long – 1 year!

Carrefour 4x vegetable
This is a really neat idea - it challenges how we use herbs;
- Not as good as fresh and not as convenient as dried herbs;
- I’d forget I had it in the freezer!
- Would definitely try it, but it doesn’t look as good value for money as dried herbs.

A brilliant idea - why didn’t they think of it sooner?!
- This will definitely save me from opening the trays I normally buy and wrapping the portions myself;
- Zipper seals are perhaps a little step too far but it’s a nice touch – will prevent any portions from falling out; and
- Some concern over the quality of the meat – it’s not as well protected as the ones in the trays and you can’t fully see them in the bag.
Key Learning:

Portioning can work in some instances but generally there is a perception that it offers poor value for money, which is underlined by the prescriptive amount of product you get. The only real winner seems to be the individually wrapped meat portions – the benefit is obvious and the portioning is completely natural.

Materials

Naturally, materials and features are not technologies consumers are made aware of and so they have few comments about them. Generally, however, any aspects relating to materials that consumers are aware of reduce their trust in the retailer or manufacturer as they feel the food has been tampered with. Generally, respondents don’t want man to intervene, other than picking and packing. Anything that suggests further human intervention starts to ring alarm bells. This is even more unsurprising since consumers aren’t aware of the benefits of many of these technologies.

Some respondents were aware of modified atmosphere products (MAPs) and felt that this was science taking over – the misconception being that these gases weren’t natural and probably not healthy. At the very least it made the consumers feel that the food had been ‘tinkered’ with. Even O₂ scavengers made the respondents wary of what scientists had ‘done’ to the food inside.
Communication

Don’t see the point – the date’s all I need to know;
Don’t see how temperature affects it - I’d rather just know if my fridge was the correct temperature;
Might increase waste as it would highlight the fact that something’s expired whereas with the date I’ve usually got a day or so’s grace;
It’s a needless gadget that I’ve had to pay for; and
I don’t understand how it works so I don’t trust it.

A mock-up of the Fresh-Check Indicator

Don’t see the point – I know when my fruit’s ripe;
If you discard the pack, you’ve lost the ripeness indicator; and
I don’t understand how it works so I don’t trust it.

A mock-up of the Ripesense

Key Learning:
TTIs and similar technologies appear gimmicky to British consumers. They don’t understand how they work and how they can help, so therefore they don’t trust them, or feel they need them.
5.4 Research conclusions

At this early stage it is clear that certain pack formats can, in a small way, help consumers preserve their food better. However, the management of food is a greater problem than preservation.

Consumers often find that today’s hectic lifestyles often clash with any planning and management of the week’s food. Additionally, it appears that many traditional attitudes and values have been lost – we are now used to a huge variety of foods from around the world and are much less inclined to eat the same things throughout the week. Only a handful of respondents said they will prepare a dish that will be sufficient for a number of meals.

Additionally, attitudes to waste seem much more relaxed than in previous generations. Many of the respondents in their 20s and 30s admitted that they don’t prepare food like their parents or grandparents used to, and in view of this the concept of reducing food waste is lost on them.

It appears that education will be key in achieving a significant reduction in food waste entering the landfill system. This will need to act on many levels, from details such as using the correct fridge temperatures, to more far-reaching ones like influencing purchasing habits.

Of the formats tested with consumers, the following had genuine appeal, therefore, demonstrated the greatest potential:

- Zipper seal bags;
- Resealable cheese / meat trays;
- Individually wrapped meat portions; and
- Portioned meat trays
6. Conclusions

There are many developments in packaging that aim to extend the life of a food product either before it is opened or afterwards. As we have seen these generally fall into the four categories of reclosability, portioning, materials and added features, and finally communication.

A number of manufacturers and retailers are already employing these technologies, although for the most part adoption is relatively small-scale, in terms of the Stock Keeping Units (SKUs) that are packed in these more advanced and functional formats and technologies.

As we have shown in the anecdotal feedback from our in-house consumer research, there are a number of key barriers in consumers’ minds that prevent them from accepting these packaging developments. In principle, these are as follows:

- Firm belief that packaging waste is a far bigger and more worthy problem to tackle;
- Perception that food waste is not a significant environmental concern as it is generally organic material;
- Scepticism about the actual functionality and efficacy of many of the identified technologies;
- Resistance to change eating habits or compromise the quality and variety of food eaten;
- Reluctance to pay more for these added benefits and functions;
- Reluctance to switch brands if their own doesn’t feature these systems; and
- Resignation to food waste being inevitable as a result of today’s hectic lifestyles.
However, a number of pack formats have shown great potential, providing they are used for the right products and involve minimal or no on-cost. Our initial research indicates the following formats to be most appealing to consumers:

- Zipper seal Pouches
- Re-closable Trays
- Individually

There is, however, a greater need for education and communication. Fridge temperatures need to be correctly set to preserve food for longer. Consumers need help with management and planning, but it needs to be presented in the right way. This could, for example, involve recipe ideas on pack to help you be flexible with the ingredients you have. Furthermore, consumers need help with shopping. With a greater need for on-demand shopping – perhaps a reflection of how we used to shop as a nation before the larger supermarket chains became dominant – consumers need the variety and pack sizes that will enable them to get the best from their food purchases.

It must be borne in mind that findings from this research were based on focus groups with a limited number of consumers, and that consumer attitudes and behaviour will change over time. For example in France Monoprix have been using TTIs for more than 10 years, so that by now French consumers are comfortable and familiar with ‘La Puce Fraicheur’. In the early days leaflets and posters were used to raise awareness and educate consumers.
Surveys have shown that French consumers now perceive the TTI as complementary to the ‘use by’ date and that the TTI is a more reliable guide than the ‘use by’ date, and are prepared to pay for a little more for the reassurance of freshness and quality.
7. Recommendations

We recommend the following next steps to gain a deeper understanding of the role that packaging can and should play in the quest for reducing food waste and how to approach the more fundamental issues identified in this report.

**Consumer research**
We recommend a more robust method of gauging consumers’ attitudes to the identified pack technologies. This will include both qualitative and quantitative rounds to establish the formats that demonstrate the greatest potential and a means of objectively measuring that potential.

This research would cast a larger net for recruitment, test a wider, more typical sample in terms of socio-economic groups, life-stages and locations.

**Identification of barriers**
Following the more in-depth consumer research, key barriers and issues should be investigated. These barriers include the fact that consumers don’t understand the significance of the food waste problem, or the perceived and actual increase in packaging waste.

Further investigation into how these barriers can be removed or worked around should be carried out.

**Consumer behaviour**
This will involve an exploration that will follow on from this project and the other food waste research projects to determine how consumers’ behaviour and attitudes can actually be modified. Through education, consumers will gain a deeper understanding of the food waste issue generally and the implications of throwing food away.
A number of programmes will help this, including home composting, which has already been introduced across a large number of local authorities. Furthermore, work should be carried out with the retailers to understand how consumers’ needs can be met more effectively, both from a purchasing and usage point of view. This will help to tackle food waste at the root cause.

**Retailer perspective**

An investigation into shopping trends – such as local supermarket, shopping on demand – to gain an understanding as to how consumers’ food purchasing and preparing needs can be more effectively met by the retailers.

Research should be carried out to identify how consumers feel about purchasing patterns (eg weekly or on-demand shopping), the role of different food shops (out of town vs. local urban stores) and how retailers could proactively change the way we shop and use our food, for the better of all.

**On-pack labelling initiative**

During the French supermarket audit (Appendix 6) there was a noticeable difference in labelling with regard to temperatures for safe storage of food. This was usually expressed as ‘store between 0 & 4ºC’ in stark contrast to the UK practice of stating ‘keep refrigerated’. More specific storage temperature guidance on-pack could bring about a reduction in household food waste.

**Fridge temperature initiative**

Exploration should be carried out as to how household fridge temperatures can be more effectively managed and maintained.

This exploration should draw upon the learning gained from previous consumer research about perceptions of fridge temperature, as well as how the importance can best be communicated. This study will include on-pack communication (such as storage advice already found on French packs) and in-fridge indicators.
Retailers could, perhaps, conduct an initiative to help consumers set their fridges to the correct temperatures using, for example, temperature indicators given away in-store. The benefits of retailers looking after consumers’ interests could herald a major customer loyalty advantage for those taking up such a scheme.

**One simple initiative to help reduce food waste**

Only a few refrigerators come equipped with a thermometer. To help reduce food waste, and contribute to a reduction in food poisoning and other illnesses related to the unsafe storage of food, retailers could give away inexpensive plastic fridge thermometers. These would also offer an opportunity to brand a store, and remind consumers of this brand and its commitment each time the fridge door was opened. To control the scheme, the giving away of free fridge thermometers could be integral with the various loyalty card give-aways.
Appendix 1

Report of food spoilage types

Food Degradation Mechanisms

The four main mechanisms involved in the deterioration of foods are:
1. Microbial spoilage, sometimes accompanied by pathogen development.
2. Chemical and enzymatic activity, leading to colour changes (browning), flavour, vitamin loss and texture changes.
3. Oxidative deterioration/rancidity producing lipid breakdown in fats and changes in colour, flavour and texture.
4. Moisture and/or other vapour migration giving rise to changes in texture, water activity and flavour.

Microbial spoilage

Microbial growth follows an initial lag phase and then enters a rapid exponential growth phase before levelling off. At some point, the bacterial count on the surface of the food becomes high enough for mould growth and the production of slime, discoloration and off-odours. These are obvious signals for consumers to throw food away.

Spoilage micro-organisms need oxygen, humidity and a food source for growth. They are generally harmless when consumed. Mould on cheese and jams, for example, can easily be removed leaving a perfectly safe product. Pathogenic (illness-causing) microbial activity can be deadly and does not always give the consumer warning signs in the same way as spoilage bacteria.
Probably the single most important factor in preventing microbial food spoilage is temperature. Micro-organisms multiply rapidly with an increase in temperature, with a 2 to 12 times increase in growth rate for a 10°C increase in temperature.

**Chemical and enzymatic activity**

Complex chemical and enzyme reactions take place as food, particularly fresh food, deteriorates. A common process is enzymatic browning – a chemical process resulting in food going brown. Browning is a visible signal to consumers to throw food away, even if it is still nutritionally sound. It is commonly observed on the cut surfaces of apples, potatoes, bananas and many other fruit and vegetables, and can be very rapid. The elimination of oxygen from the cut surface of fruits or vegetables greatly retards the browning reaction. Seafood such as shrimp is also affected by this process.

Enzymatic browning is one of the most devastating reactions for many exotic fruits and vegetables, in particular tropical and subtropical varieties. It is estimated that over 50 percent of losses in fruit occur as a result of enzymatic browning.

A less common deterioration process is non-enzymatic browning – a chemical process that produces a brown colour in foods without the activity of enzymes. This mechanism creates colour, texture and odour changes to food which may be desirable, eg the browning of meat, the colour formation in beer, or undesirable, eg sugar caramelisation, the browning of dried apples and apricots.
Oxidative deterioration/ rancidity

These are the most important mechanisms of deterioration in foods containing unsaturated fats and oils – vegetable and animal fats and oils, vitamins, dairy products, flavour oils and cereal grains – covering a wide array of processed and natural products. Unsaturated fats and oils react with oxygen to produce peroxides, with resultant reaction products including aldehydes, ketones, alcohols and acids that affect the food. Rancid flavours and aromas result.

Moisture/ vapour migration

Water activity is the measure of how tightly bound water is within food products and is a critical parameter in determining bacterial growth. The basis of dried foods is preservation through control of a very low water activity. Crispness and crunchiness, for example in biscuits and breakfast cereals, disappear if the water activity is too high, and if a dried or low water-activity food becomes damp, this can eventually initiate microbial spoilage. Similarly a food having a high water activity, such as bread, raw meat, or cooked pasta, may start out as moist, chewy and tender, but become hard, tough and stale as the water activity drops.

What determines shelf life?

In general, most perishable foods that are properly stored have less than 14 days of shelf life. With minimal processing technologies such as aseptic technology combined with controlled atmosphere or modified atmosphere packaging, such foods may last up to 90 days. Properly stored semi-perishable foods, such as some cheeses and frozen desserts, have a shelf life of up to 6 months, while shelf-stable foods, such as most canned goods, last more than six months and as long as three years under proper storage conditions.
Product shelf life is the time period for the food to become unacceptable from sensory, nutritional, or safety perspectives. For consumers, the decision to discard a food is not straightforward. If a food shows distressing signs of changes in appearance, odour or taste, common sense would dictate rejection. But what if the food is a few days past its ‘use by’ date, and shows none of these signs?

‘Use by’, ‘sell-by’ & ‘best before’ date stamping

Consumers are confused by all these date codes, only some of which are a legal requirement. There is a clear legal distinction between ‘display until/sell by’ dates which are not compulsory and ‘best before/use by’ dates, which are compulsory for most pre-packaged foods (under the EU Food Labelling Directive 2000/13/EC). ‘Display until/sell by’ dates help retailers in stock management and it is not illegal to sell goods once these dates are passed. ‘Use by’ dates are compulsory and are generally used on highly perishable pre-packaged food. It is illegal for shops to sell food after its use by date.

The UK Government’s Food Standards Agency surveyed 3,000 people in 2003 to discover how well ‘use by’ and ‘best before’ dates were understood. In each case they were asked ‘what if the use by/sell by date on a food product passed yesterday?’ and presented with options to indicate what they would do. The results showed there is still widespread confusion surrounding these dates. Only 41% demonstrated a correct understanding of ‘use by’ dates, leaving almost 60% of people who thought that food past its ‘use by’ date could be safely consumed.
The formal definitions are:

‘sell by’ date (not a legal requirement): a calendar date on the packaging of a food product that indicates the last day the product can be sold. It tells the retailer how long to display a product and guides stock rotation. This date is for the convenience of the retailer, and does nothing to tell the consumer how long the product will last.

‘use by’ date (a legal requirement on perishable products): this is the last date a consumer is recommended to use a product while it is at peak quality. This date is recommended for best flavour or quality. However, the FSA's formal advice is more prescriptive: ‘Don't use any food or drink after the end of the use by date on the label, even if it looks and smells fine. This is because using it after this date could put your health at risk and cause food poisoning.’

‘best before’ date (a legal requirement if not using a ‘use by’ date) a calendar date on the packaging of a food product which represents the recommended time limit within which a food should be used for best flavour or quality. It is not a purchase or safety date. It is not illegal to sell or offer to sell food except eggs past its ‘best before’ date providing that it is still in good condition. According to the FSA ‘This is because eggs can contain salmonella bacteria, which could start to multiply after this date.’

Storage temperature effects: the one common factor capable of slowing down nearly all of the various food degradation mechanisms for all food types is storage temperature.
Recommendations in the UK concerning the microbial safety of foods advise that maximum temperatures in household refrigerators should not exceed 5°C. Surveys amalgamating results from many countries in the world have shown that around 70% of the world’s refrigerators operate at average temperatures above 5°C. For example, the average air temperature in European fridges has been measured at 6.64°C, and according to a study from the United States, nearly one-third of consumers have their refrigerators at too high a temperature.

All the food degradation mechanisms are temperature-dependent so that food stored in a refrigerator at 10°C, for example, might deteriorate anything from 2-12 times faster than if stored at 0°C, depending on the mechanisms of deterioration.

**Food Types**

**Fruit**
Fruit ripening is triggered by a burst of ethylene - a simple hydrocarbon gas (H₂C=CH₂). Sometimes a wound will cause rapid ethylene production, so that picking a fruit will sometimes signal it to ripen, as will an infection of bacteria or fungi on the fruit or any form of fruit damage, such as from consumer handling. This ethylene signal causes enzymatic changes that result in ripening and eventually enzymatic browning, a major cause of fruit waste. Much of this is internal damage which the consumer only discovers just before the fruit is to be consumed.

**Lettuce/ salad greens/ vegetables**
Lettuce and salad greens spoil and turn an unappetising brown colour due to enzymatic browning accelerated by exposure to oxygen. Salads in sealed plastic bags turn brown more slowly but in this environment they can become a breeding ground for microorganisms that affect texture and colour, and eventually lead to sliminess.
Milk
The determinants of shelf life of fresh dairy products are usually the spoilage bacteria that have the ability to grow, albeit slowly, even at refrigerated temperatures. This microbial growth induces changes in the taste and odour of milk leading to souring and rancidity. Milk is one of the most temperature-sensitive food products with each 10ºC in storage temperature producing a fivefold increase in deterioration.

Bread
Bread initially stales due to changes in water activity, then airborne and parasitic bacteria colonise surfaces producing moulds and yeasts. Bleaching gives white flour a far longer shelf life than wholewheat flour.

Cereals, biscuits, etc.
Cereals and biscuits first exhibit a fall in crunchiness, becoming soft and unpalatable, followed by taste and odour changes resulting from rancidity and oxidation of fats.

Cooked/processed meats
Some of the major producers of premium meat products have identified oxidative degradation as a primary factor affecting meat colour, flavour and product shelf life. Oxygen produces an immediate colour change in meats, primarily a loss of redness in products such as ham or turkey, signifying the age or possible mishandling of the product. This initial colour change gives the meat an aged and undesirable appearance to consumers.
**Fish**
Bacteria are usually found on all agricultural and fishery products, but in limited numbers not enough to cause illness. Bacteria are the major cause of seafood spoilage. Microbial and enzymatic activity quickly degrade fresh fish but these processes lead to the formation of strong-smelling compounds such as ammonia, hydrogen sulphide and mercaptans. Therefore, sensory analysis is the main method of evaluating fish freshness with smell being the most important indicator.

**Coffee**
The shelf life of roasted ground coffee is almost entirely determined by oxygen exposure, and keeping oxygen away from the product can increase shelf life by up to 20 times.
Appendix 2

Pack Manufacturer Contact Details


10. Mitsubishi – Kagaku Foods Corporation - www.m-kagapu.co.jp - Manufacturers of anti-microbial materials such as WasaOuro.


18. Jenkins Group Ltd - www.ripesense.com - Manufacturers of Ripesense active ripeness indicators currently in use in the US.

Appendix 3

Pack Technologies

Packaging technology solutions - technologies that actively extend shelf life

Antimicrobial systems
Antimicrobial additives are materials that are incorporated into a packaging material to reduce or eliminate microbial spoilage and inhibit the growth of yeasts and moulds. Potassium sorbate, for example, is commonly used in polyethylene packaging materials for cheese.

Current research is focused on developing natural preserving systems rather than those based on artificial additives and chemical preservatives, so that the longer shelf life requirements of industry and retailers and the consumers' desire to eat healthily can both be met. As an example, rye bread containing no preservatives and packed in modified atmosphere polyethylene bags, has a shelf life of up to 8 days before various fungal spores start to appear on the bread surfaces. Inhibition of all forms of fungi is possible using tiny quantities of allyl isothiocyanate, found in mustards and horseradish. Allyl isothiocyanate is the active ingredient of WasaOuro®, antimicrobial sheets used in box lunches and take-out food in Japan in the form of green plastic pieces cut into leaf shapes and disguised to look like salad garnish.
Oxygen scavenging systems
The key advantage of oxygen scavenging packaging systems is that they are capable of keeping external oxygen away from the product as well as removing residual oxygen packaged with the product at filling time. Since oxygen is the nemesis of high-quality fresh food and beverage products, it is not surprising that the potential markets for oxygen scavenging packaging systems are huge. Substantial markets are crowns for beer in glass bottles, fruit juices, sport drinks, case-ready meats, and trays and lidding stock for fresh pasta and home replacement meals. Oxygen scavengers are also important in the trend towards single-serve packages because smaller packages have an increased surface volume and exposure to oxygen.

One of the pioneering products of this type developed by the Mitsubishi Gas Chemical Company is Ageless®, based on the oxidation of activated iron powder to ferric compounds (i.e. the process of rusting). This technology is used commercially in the UK to extend the shelf life of premium sliced ham, supplied by Sainsbury’s and other stores. The active patch is firmly attached behind the label and between it and the top polymer film so there is no danger of it being eaten.

Manufacturer details:
Mitsubishi Gas Chemical Company, Inc.
Mitsubishi Building 5-2,Marunouchi 2-Chome, Chiyoda-ku Tokyo 100-8324, Japan
Website: http://www.mgc-a.com/ageless/index-GI.html
Carbon Dioxide (CO₂) generating or scavenging systems
High CO₂ (10-80%) levels are desirable for some foods such as meat and poultry, because they inhibit surface microbial growth and thereby extend shelf life. This is the basis of high CO₂/low oxygen (O₂) modified atmosphere packaging. In other food systems, CO₂ is formed due to deterioration and respiration reactions, and the gas produced has to be removed from the package to avoid further food deterioration and, in extreme cases, to prevent the package swelling or bursting. This has led to the development of packaging that simultaneously releases CO₂ and scavenges. Such systems are based on inserted sachets of either ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate. It is being used to package fresh ground coffee in flexible pouches, which more than triples shelf life.

Manufacturer details:
EMCO Packaging Systems The Coach House Felder Court, Worth Deal, Kent UK. CT14 0BD
Telephone: 01304 620400
Website: http://www.emcouk.com/EMCO_FreshTech.shtml

Ethylene scavenging systems
Since senescent produce such as bananas, tomatoes and oranges can be picked before maturity, they need to have their metabolism slowed down during storage if shelf life is to be extended. Lowering oxygen does this in part, but these fruits and vegetables produce ethylene gas, which triggers ripening and if not removed causes the product to mature too quickly. Several Japanese commercial applications use a silica gel which contains permanganate. The latter oxidizes the ethylene and has been commercially successful for many fruit storage systems, especially those for kiwifruit.
Manufacturer details:
Multiflex Packaging Pty Ltd
103 Bernard Street,
Cheltenham,
Victoria 3192 Australia
Tel: 03 9555 4944
Website: http://www.peakfresh.com/index1.htm

Desiccant/moisture scavenging systems
Fresh, high moisture containing food has a high water activity and excess water can be produced during storage. This excess moisture can cause loss of texture and food spoilage due to the growth of micro-organisms. The water can be removed via the use of desiccating films or sachets, thereby extending shelf life. Desiccants work well for many products.

Humidity control systems
For many other products what is needed is controlled humidity within a certain range, to ensure product characteristics are retained and there are no deleterious property shifts due to the product getting either too dry or too wet.

The technology consists typically of a small pouch insert, roughly 6 cm by 8 cm, made out of a high water vapour transmissive material bonded to paper, and containing a saturated salt solution thickened with an odourless, tasteless food-grade gum. Inside is two-way pure water vapour transmission, either emitted from the pouch or absorbed by it, to maintain a given humidity level to within ± 1%. The package is designed to allow water vapour to permeate freely in either direction, so environment with higher humidity than desired, it must have room for the water-vapour to enter the pouch from its exterior and be condensed into water. Conversely, it must have water vapour available in the headspace to permeate the package walls and increase the relative humidity if it is lower than the desired level. Salt formulations are available for all humidity increments from 13% Relative Humidity (RH) to 95% RH, with packages designed to control product integrity over
a pre-determined shelf life for the storage of food, tobacco, musical accessories, digital film and medical devices.

Manufacturer details:
Humidipak, Inc. 17613 Minnetonka Boulevard. Wayzata, MN 55391-3316 USA
Website: http://www.humidipak.com/

**Controlled permeability films**
Fresh fruit and vegetables following harvesting and packing respire by giving off CO₂ and consuming O₂. Each fresh fruit or vegetable has a specific gas composition microclimate for maximum shelf life. As the storage temperature rises and falls, the production and demand rates of the two gases change rapidly and conventional packaging films cannot adjust or keep up with these new permeation requirements.

Controlled gas permeation Intellipac™ polymeric package materials, manufactured by Landec Corp., Menlo Park, California, are side-chain-crystallisable (SCC) polymers with the ability to change their gas permeation dramatically over small temperature ranges. The permeation of CO₂ and O₂ can be independently varied, and these materials are finding increasing usage in packaging to extend the freshness of packaged prepared fruit and vegetables by providing the perfect microclimate for each type of product and ensuring this remains constant with changes in storage temperature.

This packaging system is commercial in many US supermarkets for ready-prepared cut vegetables, under the ‘Eat Smart’ label, which typically have double the shelf life of similar products in regular packaging.

Manufacturers Details:
Landec Corporation 3603 Haven Avenue Menlo Park, CA 94025
Website: http://www.landec.com/
Packaging Technology Solutions – Technologies that Communicate Food Condition

**Time-temperature indicators**
Since most products deteriorate by diffusion controlled processes that are hugely sensitive to temperature but relatively insensitive to time, it follows that time is one of the least useful parameters on which to base our judgement of product quality unless products are stored at a constant temperature, which in practice they are not.

Time-temperature indicators (TTIs) use chemical reactions to exhibit an irreversible change of colour in response to the combined effects of time and temperature, so offer the opportunity to measure cumulative abuse of products along the cold chain. Applied as labels, they provide manufacturers, retailers and consumers with a simple yet effective method of controlling the safety of perishable food product inventories.

Broadly TTIs fall into two types, those where the chemical ‘clock’ starts ticking the moment the active constituents are laid down during label production (supplier activated), and those where the consumer either pulls a tab or breaks a miniature vial to mix the chemicals and start the process (consumer activated). Supplier-activated labels need to be shipped and stored at low temperatures to prevent activation prior to actual use.

The technology for TTIs has been available for some time, but only three types have made it to commercial reality for food products, manufactured by LifeLines Technologies (now TEMPTIME Corporation), Vitsab Inc and Timestrip, respectively. The first type is supplier activated; the other two are activated by the consumer. All three types have commercial applications, eg Monoprix, British Airways, Nestlé.

Manufacturer details:
TEMPTIME Corporation
116 American Road, Morris Plains, NJ 07950, USA
Website: http://www.lifelinestechology.com/

Vitsab, Inc.
Belmont, North Carolina USA & Malmö, Sweden
Europe/Africa/Middle East Sales and General Information Contact:
Christer Ahlberg | + 46 40 21 50 20 | info@vitsab.se
Website: http://www.vitsab.com/
http://www.timestrip.com/
See Appendix 4 and 6 for more details on TTI's

Fruit ripeness indicators
A smart label that changes colour to indicate the ripeness of pears has been recently commercialised after five years’ development by two New Zealand scientists in partnership with the Jenkins Group, a label manufacturer. The new sensor labels, inside plastic clamshell packages of green Anjou pears, react to the ethylene gas released by the ripening fruit, changing through a range of vibrant colours. Red means the pears aren’t fully ripe; as the pears ripen the label changes to orange. When the label turns yellow, it means the pears are soft, ripe and juicy, enabling shoppers to choose fruit that best appeals to their taste. The outer clamshell packaging prevents consumer damage to the fruit.

Manufacturer details:
Jenkins Group Ltd Email: sales@jenkinsgroup.co.nz
Physical Address: 5 Tiri Place Mount Wellington Auckland, New Zealand
Website: http://www.ripesense.com/
Appendix 4

Time-Temperature Indicators (TTIs)

Summary

Broadly TTIs fall into two types: those where the chemical ‘clock’ starts ticking the moment the active constituents are laid down during label production (supplier activated), and those where the consumer either pulls a tab or breaks a miniature vial to mix the chemicals and start the process (consumer activated). The technology for TTIs has been available for some time, but only three types have made it to commercial reality for food products, manufactured by LifeLines Technologies (now TEMPTIME Corporation), Vitsab Inc and Timestrip respectively. The first type is supplier activated; the other two are activated by the consumer.

TEMPTIME (www.lifelinestechology.com)

This TTI is available as an inexpensive label with a bull’s-eye design with a central circle consisting of two overprinted layers surrounded by a pre-printed reference colour circle. A solid-state polymerization reaction takes place through the two layers turning the top layer black as the reaction proceeds. The temperature/time sensitivity can be very finely tuned to match food degradation kinetics. To summarise:

- Colour change label kinetics can be matched exactly to kinetics of food degradation, over a very wide range of products
- Produces a distinct colour change which is easy to read – product past sell-by date when centre colour is darker than reference
- Can be applied with conventional labelling machines
Active from point of production, so needs to be stored in deep freeze to prevent premature activation.

**Vitsab (www.vitsab.com)**

This TTI uses a highly sensitive enzymatic indicator system that operates best with food products that last for a few weeks under refrigerated conditions. The TTI is activated by breaking two small pouches, freeing the solutions to mix. The reaction ends by the dye changing colour from green to yellow – this colour change happens very rapidly, so that there is a definite end point. Vitsab can tune this device by varying the type of substrate and the amount of enzyme. To summarise:

- Colour change kinetics can be matched to kinetics of food degradation
- Best for food degradation processes that occur in hours to days
- Bright and distinct colour change which is easy to read
- Requires activation at point of use
- Unactivated labels can be stored at room temperature with long shelf life.
**Timestrip (www.timestrip.com)**

This TTI depends on capillary action of a red-dyed liquid migrating along a micro-porous wick material at a constant rate. The distance the liquid migrates relates to time elapsed at that temperature. An easy-to-read signal is produced. To summarise:

- Colour change progresses along a linear path with good end-point visualisation;
- Device is somewhat sensitive to temperature but normally separate systems are necessary for refrigerator and freezer environments;
- Requires activation at point of use;
- Labels are inexpensive; and
- Unactivated labels can be stored at room temperature with long shelf life.

**Follow up Conversations with TEMPTIME regarding Monoprix TTI Experiences**

A call was made on 21/3/06 to Etienne Le Labouier, Sales Director Europe for TEMPTIME to find out more about Monoprix's use of TTIs.

**Communication to consumers**

Monoprix have been using TTIs for more than 10 years, so that by now French consumers are comfortable and familiar with ‘La Puce Fraicheur’. In the early days leaflets and posters were used to raise awareness and educate consumers.

Possible confusion between TTI & ‘use by’ date

Surveys have shown that consumers perceive the TTI as complementary to the ‘use by’ date, and a range of TTIs have been developed that change colour at a rate that closely matches
the ‘use by’ date. Most people think that the TTI is a more reliable
guide than the ‘use by’ date, and are prepared to pay a little more
for the reassurance of freshness and quality.

TTI range & application

Labels are applied by the food packer, either by hand for small
volumes or by machine for larger volumes.

<table>
<thead>
<tr>
<th>Type</th>
<th>4.5°C</th>
<th>7.7°C</th>
<th>22°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>8 days</td>
<td>5 days</td>
<td>18 hours</td>
</tr>
<tr>
<td>P</td>
<td>14 days</td>
<td>9 days</td>
<td>30 hours</td>
</tr>
<tr>
<td>D</td>
<td>23 days</td>
<td>14 days</td>
<td>2 hours</td>
</tr>
</tbody>
</table>

The codes M, P and D in the left-hand column represent the characteristics of that label, i.e. the
kinetics of the label and the length of measurement / monitoring for which that label has been
designed.

TTI Prices

Available in 1,500, 3,000 and 9,000-label reels. Prices are very
volume-dependant and were quoted as:

<table>
<thead>
<tr>
<th>Volume/year</th>
<th>Price/label (Euro cents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2M</td>
<td>~5</td>
</tr>
<tr>
<td>10-20M</td>
<td>~2.5</td>
</tr>
<tr>
<td>&gt;60M</td>
<td>~2</td>
</tr>
<tr>
<td>200-300M</td>
<td>~1.5 – 1.6</td>
</tr>
</tbody>
</table>

~ = approximately
Monoprix strategy using TTIs

This was confirmed as a means of uniquely identifying Monoprix’s own label products against brand leaders. Where no equivalent brand leader was on-shelf, TTIs were not employed.

Cheese, milk and yogurt products were not targeted currently. There was a technical problem with the use of TTIs on yogurts since these normally undergo an incubation period after packaging.

Future Trends

Temptime have several new initiatives planned for 2006:

- Fresh mushrooms with a Spanish packer
- Milk with a Middle East retailer
- Cheese products with a French repacker.
Appendix 5

Fridge Temperatures

Why reducing average consumer refrigerator temperatures by a few degrees will do much to reduce food waste

Virtually all food degradation mechanisms are exponentially sensitive to temperature and only linearly dependent on time, so small increases in temperature have a big effect on growth rate. Most micro-organisms grow only slowly at 4ºC but reach a maximum or optimal growth rate at around the body temperature of 37ºC. By 45ºC most micro-organisms have stopped growing – holding at and above the maximum temperature results in their destruction.

A good example of this is heat treatment of milk. Treatment of milk at 72ºC for 15 seconds (or 66ºC for 30 minutes), termed pasteurization, will kill common micro-organisms including tuberculosis bacilli, *E. coli* and *Salmonella enterica* strains.

The relationship between shelf life food deterioration and temperature is generally expressed by the factor $Q_{10}$, defined as the difference in shelf life quality loss for each 10ºC increase in temperature. So a very temperature-sensitive food would have a high $Q_{10}$; and a very temperature-insensitive one a low $Q_{10}$. If a food product has a $Q_{10} = 2$ (a common value), this means that the shelf life is halved for each increase in10ºC of storage temperature.

The microbiological spoilage of milk is particularly sensitive to temperature with a $Q_{10}$ of 5. So a typical shelf life of 10 days at 4ºC reduces to around 2 days at 14ºC.
The importance of correct storage temperatures

In line with many other countries, the UK Food Standards Association recommends that maximum temperatures in household refrigerators should not exceed 5°C, and the coldest part of the fridge should be between 0°C and 5°C.

Surveys amalgamating results from many countries in the world have shown that around 70% of the world’s refrigerators operate at average temperatures above 5°C. For example, the average air temperature in European fridges has been measured at 6.64°C, and according to a study from the United States, nearly one-third of consumers have their refrigerators at too high a temperature. However many of these surveys are more than 10 years old and there appears to be no more recent data available.

According to the ‘Soggy Lettuce Report’ from the Prudential, milk is one of the most common foods to be wasted. It is possible that much of this waste results from consumers storing milk in fridges with higher than recommended temperatures. Microbial growth induces changes in the taste and odour of milk lead to souring and rancidity. This could happen before the ‘use by’ date printed on the packaging.
Average refrigerator temperatures in the UK (left-hand scale) plotted together with the predicted shelf life of a milk-based product (right-hand scale). A shelf life of 10 days is sharply reduced in warmer-than-recommended refrigerators.

Refrigerator temperatures of 4°C prevent the growth of many bacteria, extending the shelf life of many products. However, there are a large number of micro-organisms still capable of slow growth at 4°C and these will eventually spoil foods. Refrigeration merely slows down the process of spoilage.

Refrigerator storage temperatures are thus also critical in preventing the growth of pathogens (illness-causing bacteria) in high-risk foods. These are perishable foods capable of supporting pathogen growth that are intended to be eaten without further treatment such as cooking, which would destroy such organisms. They include

- All cooked meat and poultry;
- Cooked meat products including gravy, stock, and roll/sandwich fillings;
- Milk, cream, artificial cream, custards and dairy products;
- Cooked eggs and products made with eggs, eg mayonnaise;
- Shellfish and other seafood; and
- Cooked rice.
For retailers - one simple initiative to help reduce food waste

Only a few refrigerators come equipped with a thermometer. To help reduce food waste, and contribute to a reduction in food poisoning and other illnesses related to the unsafe storage of food, retailers could give away inexpensive plastic fridge thermometers. These would also offer an opportunity to brand a store, and remind consumers of this brand and its commitment each time the fridge door was opened. To control the scheme, the giving away of free fridge thermometers could be integral with the various loyalty card giveaways.
Appendix 6

French Supermarket Audit

French Supermarket Visits - Calais, 13 March 2006

Monoprix

Monoprix stores are typically located in urban areas and feature moderately priced clothing, furniture and cosmetics, in addition to groceries. This one was located near the centre of Calais in a busy shopping area close to a main intersection. With sales of more than US $4 billion, the company is seen as an innovator among retailers in France and maintains a unique position in the French market with a strong emphasis on premium quality and superior service.

Freshness pact

Near the chill cabinet foods, clearly displayed on the wall was a ‘freshness pact’ notice informing shoppers that if they discovered a product past its expiry date the store would reimburse them to the tune of 3 euros.
Time-temperature indicator labelling

Time-temperature indicators (TTIs) were visible in many of the products in the chill section of the store. These were the expected Fresh-Check® labels – la PUCE FRAICHEUR – manufactured by TEMPTIME.

According to TEMPTIME, the Fresh-Check programme now covers some 400 store brand SKUs in dairy, meat, poultry, fresh-cut salads, delicatessen and ready-to-eat meals. In this small store around 40-50 items were labelled, and a selection appears below.
The TTIs were used only on Monoprix branded products, so that differentiation was achieved from other brands by use of the label.
It became clear that the TTIs were a strong marketing tool – if the Monoprix product had no other brand competition on the shelf a TTI was not used. Also labels were used on a range of products with very different shelf lives – hence the use of a code on the label which presumably signifies the speed at which the chemical ‘clock’ at the centre of the TTI operates. The following products were purchased for further study and the relevant codes identified.

<table>
<thead>
<tr>
<th>Product</th>
<th>‘Use by’ Date</th>
<th>Days remaining from 13/03/06</th>
<th>Code symbol on TTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lardons</td>
<td>12/04/06</td>
<td>30</td>
<td>F</td>
</tr>
<tr>
<td>Crab sticks</td>
<td>04/04/06</td>
<td>22</td>
<td>+ M7</td>
</tr>
<tr>
<td>Rillettes</td>
<td>30/03/06</td>
<td>17</td>
<td>H</td>
</tr>
<tr>
<td>Macaroni with ham</td>
<td>26/03/06</td>
<td>13</td>
<td>H</td>
</tr>
<tr>
<td>Sliced ham</td>
<td>23/03/06</td>
<td>10</td>
<td>+ M8</td>
</tr>
<tr>
<td>Couscous salad</td>
<td>17/03/06</td>
<td>4</td>
<td>P</td>
</tr>
<tr>
<td>Grated carrot salad</td>
<td>17/03/06</td>
<td>4</td>
<td>P</td>
</tr>
<tr>
<td>Steak hamburger</td>
<td>17/03/06</td>
<td>4</td>
<td>B</td>
</tr>
<tr>
<td>Ready to eat lettuce salad</td>
<td>16/03/06</td>
<td>3</td>
<td>M</td>
</tr>
</tbody>
</table>
Historical experiences

Monoprix has more than 10 years’ experience in the commercialisation of TTIs – the Fresh-Check programme began in 1990 and expanded by region and product category from 1991 to 1993. According to TEMPTIME, the creation of a clear freshness image using on-product indicators is a tactic that drives growth at Monoprix. In France, the store is regarded as ‘best in class’ in terms of freshness image, and its share in fresh foods is significantly higher than its overall market share. Monoprix’s own brand short shelf life products continue to grow at a faster rate than comparable items at other supermarkets.

Jacques Michault, Commercial & Purchasing Director – Monoprix, states that ‘It’s a huge step forward for customers to tell whether or not a product can be eaten safely.’

Carrefour

A visit was made to the Carrefour hypermarket at Cité Europe, representing the largest supermarket group in Europe.

Yogurts

Freshness was again a selling point, with signage indicating that yogurts were guaranteed to have at least 7 days shelf life remaining.
Shelf-stable vegetables

A new development in packaging innovation was seen in the processed vegetable section – ‘Les Conserves Pratiques’. Competing with tins and glass jars of vegetables were shelf-stable, portionable, microwaveable vegetables, available in either 2-portion or 4-portion trays.

Pricing of these items was around 10-15% higher than the equivalent glass jar or tinned version, and the 4-portion size premium was around another 10% over the 2-portion size.

The products have a one-year ambient shelf life, so high barrier plastics are used in their construction. The lower tray appears to be nylon with a thick multilayer plastic peelable lid. No manufacturers’ marks are evident on the packaging.
**Overall impressions**

Examples of packaging easy openability/reclosability were as difficult to find in Carrefour and Monoprix as in UK supermarkets. Where they existed, the packaging clearly displayed this feature using words like ‘new’ or ‘exclusive’.

As expected in France the amount of packaging used in dairy products like cheese and yogurt was much greater than in the UK. Most cheese types came in a range of pack sizes, including many in individually wrapped portions.

A noticeable difference in labelling was the use of recommended temperatures for safe storage of food. This was usually expressed as ‘À conserver entre 0ºC et +4ºC’ – store between 0 & 4ºC. This is in stark contrast to the UK practice of stating ‘Keep refrigerated’.

A comparison of typical French and British storage advice on-pack
A second key difference was the absence in either French supermarket of 'sin-bins' for short-dated or close to 'use by' date products. Clearly there is a policy of removing stock well before its 'use by' date. In Carrefour’s case this extends to a promise to remove all yogurts from sale if they have less than 7 days left before their ‘use by’ dates. In Monoprix’s case this was backed up with hard cash of 3 euros if an item was found or even returned that had passed its expiry date.

Both supermarkets communicated their commitment to freshness via some form of written ‘freshness pledge’ clearly visible in store.

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