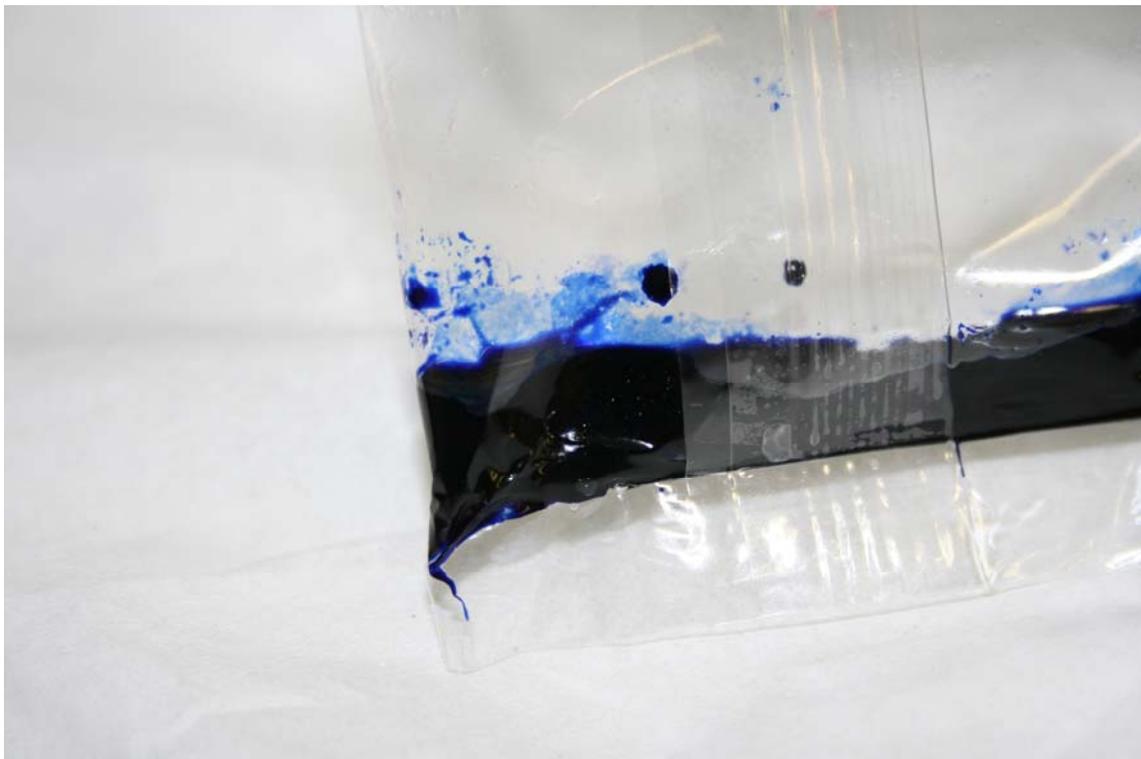


Seal integrity and the impact on food waste



An investigation into the contribution that inadequate heat sealing of food packaging might make to the generation of food waste, in the supply chain and the household.

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

Written by: Michael Dudbridge, Richard Turner



Front cover photography: Flow wrapped bag showing an edge leak and also a leak at the junction of the end seal with the back seal.

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Executive summary

A large proportion of food purchased for home consumption is sold packaged, originating from factory production lines consisting of various components including a weighing system, a manual or automated filling system, a method of modifying the atmosphere into which the food is packed and a method of sealing the pack.

The packaging performs a number of functions apart from merely containing the food. One important function is to provide a barrier from environmental contaminants which could cause the food to be unfit for consumption and lead to consumers throwing the food away or being exposed to food safety risks. This is a particular concern in food packs where a modified atmosphere surrounds the food to help preserve it.

The potential weakest link in the pack is the seal but there is little data available on the quantity of food waste which might be attributed to unsound food packaging seals.

In this project funded by WRAP (Waste & Resources Action Programme), a team from the University of Lincoln investigated the contribution that inadequate heat sealing of food packaging might make to the generation of food waste in the supply chain and the household. The objective of the work was to estimate the potential amount of food waste which is associated with inadequate heat seals created in the food packaging process. This was achieved through gathering data on the integrity of heat seals across a range of production sites, manufacturing different types of food products and using a variety of packaging machines and pack formats.

A further set of objectives relates to describing how seal integrity is monitored and to identify activities associated with best practice in the management of the food packaging process.

A combination of direct measurement and interview techniques were used to identify the proportion of unsound seals detected by current checking at factories and the potential level of insecure seals which could be produced under current factory working conditions. These proportions were applied to estimates of packaged food production to reach an estimated tonnage of potential food waste which could be generated in the food supply chain because of insecure seals in food packaging

Using two accepted testing methods (vacuum testing and dye testing) heat seal integrity was measured in 11 factories containing 105 heat sealing units, packing a variety of ambient, fresh, chilled and frozen foods. In addition, a questionnaire was developed and used as a basis for interviewing a number of factory managers.

Twenty-four per cent of heat seals were identified in the factory audits carried out in this study as being “at risk” of failure. It can be assumed that a proportion of these will be insecure in the food distribution system or in the home, yet only 1% of packs were identified by factory tests as being sufficiently damaged to be rejected by the factory quality testing systems. During the seal testing process, it was found that the most common quality check used in the factories was the ‘manual squeeze test’. It was also noted that almost all testing is carried out ‘off-line’.

Without further laboratory testing, to simulate the rigors of the supply chain or a survey of the food retailers, it is not possible to quantify how many of the 24% of packs exhibiting seal problems would leak in the supply chain, therefore, the expert group conservatively estimated that about 8% of packs leaving a factory might well fail to provide sufficient protection to the food through the supply chain and into the home, a far greater proportion than are currently being detected through quality control. This rate of seal failure is therefore estimated to equate to around 480,000 tonnes of potential food waste.

In addition to quantifying the potential level of food waste, the study identified a number of associated factors which require further investigation and quantification.

- It was found that the most common reason for seal failure was product contamination in the seal area and that sealing problems were more common where products had liquid and crumb components.
- Achieving adequate heat sealing was anticipated to be a greater problem in the future as new packaging materials, such as PLA (polylactic acid), are introduced more widely.

- The team identified some 'best management practice' procedures which could reduce waste generation but concluded that to achieve major improvements, technological changes were required.
- These technological improvements should include better filling and heat sealing methods to reduce product contamination of the seal area and the development of robust in-line seal monitoring systems and associated control systems.

The team concluded that:

- a potential 480,000 tonnes of food waste could be generated through unsound seals on food packaging;
- only 1% of packs were identified by factory tests as being sufficiently damaged to be rejected by the factory quality testing systems;
- undetected, potentially faulty seals could generate food and packaging waste at any point in the supply chain after they've left the processing factory;
- seal integrity is improved by certain best practices identified through this project, which could be disseminated within the industry;
- in some instances, technological changes are required including better monitoring, filling and sealing techniques that may reduce the incidence of inadequate seals; and
- further work would be required to quantify the actual waste in retail outlets and in the home as a result of seal failure.

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1.0 Background

Following a proposal to reduce food waste through improved methods of monitoring and managing seal integrity on food packaging, the University of Lincoln were asked to estimate the quantity of the food waste potentially being generated as a result of faulty food packaging seals.

The majority of food purchased for home consumption is sold packaged, originating from factory production lines consisting of various components including a weighing system, a manual or automated filling system, a method of modifying the atmosphere into which the food is packed and a method of sealing the pack.

There are a number of methods of non-manual pack sealing usually involving heat and pressure. Most methods employ some form of mechanical 'jaws' which cut and 'weld' a continuous sealing film onto a pre-formed plastic tray or tub. Another popular method of packing is to form a tube from a continuous roll of film which is filled and heat sealed above, below and behind as the product is deposited into the tube.

The weakest link in the pack is the seal and most food companies attempt to monitor the quality of the heat seal to ensure it can carry out its function.

There are many reasons that companies use heat seal packaging to package their products but the two which this project is most concerned about are:

- the ability of the seal to contain the product; and
- the ability of the seal to contain the atmosphere surrounding the product.

Some causes of heat seals failing to allow the packs to meet these needs adequately could be:

- mechanical problems related to heat, pressure and duration of both in the sealing operation;
- fouling of the seal area with product during the filling operation;
- interaction of the pack material and the film when being sealed; and
- interference by operators.

Food companies attempt to monitor and reject packs which are sealed inadequately. This is not a simple operation as there are few pieces of in-line equipment which can monitor each pack without slowing the rate of the packaging line. In addition, the complexity of measuring the quality of a heat seal is increased by:

- the lack of a common standard of seal integrity to which food companies operate; and
- the need to create a seal, which not only allows the pack to contain the product and the atmosphere at the point of despatch from the factory, but maintains that integrity throughout the distribution chain.

There is much anecdotal evidence of food and packaging waste caused by inadequate heat sealing of packs but very little published data. Preliminary investigation revealed that some companies kept records although these were often incomplete. The University of Lincoln was able to gain access to a number of food processing factories where interviews and measurement provided some insight into the issue. Access was granted on the strict understanding that the companies would remain anonymous.

This project set out to assess the quality of heat seals across a range of production sites manufacturing different types of food products using a variety of packaging machines and pack formats. This would enable the estimation of potential food waste which could be generated through inadequate heat sealing at food factories.

2.0 Objective

The objective of the work was to estimate the potential amount of food waste, which is associated with inadequate heat seals created in the food packaging process. This was to be achieved through gathering data on the integrity of heat seals across a range of production sites, manufacturing different types of food products and using a variety of packaging machines and pack formats.

A further set of objectives relates to describing how seal integrity is monitored and to identify activities associated with best practice in the management of the food packaging process.

3.0 Sample

The effectiveness of a company in achieving good sealing on its food packaging is extremely important. The number of potentially faulty packs which might be released into the food supply chain is highly sensitive and can affect the business relationships between suppliers and customers. For these reasons it is necessary to maintain the confidentiality of the participating companies and the data collected.

Initial discussions with the food industry identified five companies, representing a wide range of packaged food, willing to assist with the project by making data available and allowing access to factory procedures at ten sites. In reality we obtained the co-operation of six companies representing eleven factory sites. The factories examined in this study contained 105 heat sealing machines. The machine types covered all of the major heat sealed packaging formats – Vertical Form Fill Seal (VFFS), Horizontal Form Fill Seal (HFFS), Tray and Pot Sealing systems and Flow Wrapping systems were all included in the study.

It was important to ensure that the factories and companies in the sample represented a fair view of the food industry. Four factors were taken into account:

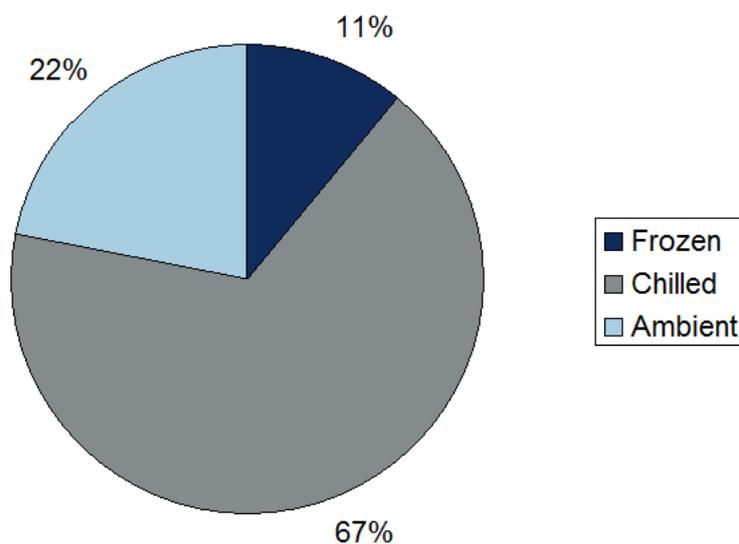
- Product category – ambient, fresh, chilled and frozen foods.
- Product constituent – meat, vegetable, both.
- Size of factory – measured by turnover.
- Intensity of production - measured by number of packs produced per day.

3.1 Category of food product

The categories were designated as ambient, fresh, chilled and frozen products. Figure 1 shows the proportion of each in the sample. Most of the packaging lines were packing chilled products which are the most vulnerable to leakages in terms of food safety and organoleptic properties. This is especially so when the food is packed in a modified atmosphere.

Fresh produce often requires packaging merely as a container for the product and to protect it from physical damage. Frozen foods share this as a major requirement.

Figure 1 Proportion of product type packing lines.



3.2 Product constituents

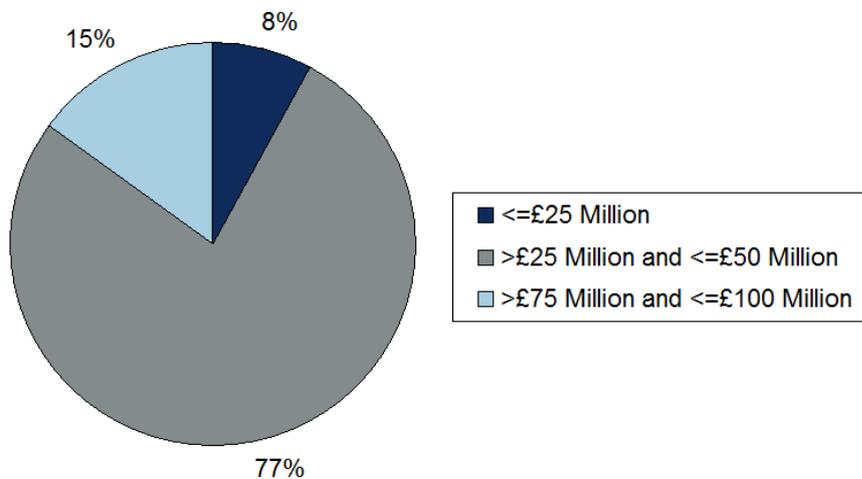
Subdivision of the above categories shows that the products at the factories investigated included meat products, vegetable based products and products containing both constituents. Factories were also selected to ensure that the test sites represented products containing liquids, sauces, particulates and powders.

Finally, factories were selected that represented all of the major types of heat sealed food packaging types. Vertical Form Fill Seal (bag makers), Tray and Pot Sealing systems, Horizontal Form Fill Seal (pack makers) and Flow Wrapping systems were all represented in the factories and were surveyed during this study.

3.3 Size of factory

We investigated six companies and 11 factory sites. There were a range of factory sizes to represent the various scales at which food production is carried out in UK, which is shown in Figure 2.

Figure 2 Factory size by turnover.



3.4 Intensity of production

This consists of the number of packs produced per week. This measure correlates strongly with turnover but not number of employees. It is a further indicator of the size of the factories. Many of the factories we surveyed were producing over half a million packs per week.

4.0 Methods

4.1 Overview

The study set out to produce quantitative data to meet the objective of measuring the extent of inadequate heat sealing and potential seal failure. We were given very good access to managers at various levels within the factories and as a result we were able to collect qualitative data including opinions, plans, relationships (e.g. between manufacturer and retailer) and environmental issues etc. There is clearly scope to develop this sample group as a focus group or concept testing group for further study.

The study consisted of two elements (1) an interview with senior managers at the factory site and (2) a visit to the factory shop floor to observe and measure aspects of seal integrity and waste generation caused by sealing faults.

A composite data collection document was developed in conjunction with WRAP and is given in Appendix 1. The data collection document was modified following an initial pilot study in one factory to improve its ease of use and the quantity of data collected. This was supported by test measurement documents to record vacuum testing and dye penetration testing of packs removed from the production line. Research by Camden and Chorleywood Food Research Association (CCFRA) – now Campden BRI – in a confidential research and development report (No 241)¹ concluded that it was important to apply the appropriate detection method to the pack type. There is further work required in the development of seal integrity inspection systems that are non-destructive to allow the possibility of 100% inspection of packs.

The key data items which were sought related to the companies and the individual packaging lines. The measurements were made on samples taken from each production line using a standard vacuum testing rig and a dye penetration analysis system.

The tests used during the audit were selected by the University to give an indication of seal strength and also to measure the proportion of packs with leaking seals or seals so weak that leaks could occur in the supply chain through normal handling procedures.

The Vacuum Chamber Test – Sealed packs were placed inside a Multivac Vacuum Chamber Machine and subjected to increasing levels of vacuum from 900mBar to 650mBar (Figures 3 and 4). The packs were exposed to the vacuum for a period of 15 seconds. The point at which a leak in the pack became apparent was recorded. Packs for this test were sampled from the production line **after** the point at which operatives had carried out their testing procedure – this was usually a manual squeeze test.

The Dye Penetration Test – Sealed packs were again sampled after the production operatives had carried out their checks. With this test the packs were carefully opened using scissors to avoid any damage to the seal areas. The content of the packs were then removed and the pack was rinsed if necessary. This gave us our test sample of an empty pack with all seals intact. Methylene Blue dye was then introduced into the packs and allowed to come into contact with the seal areas. After a period of two minutes the seal areas were observed for signs of the penetrative ink being drawn into seal faults by capillary action. Photographs were taken of all packs for later analysis.

¹ Available at http://www.campden.co.uk/publ/pubfiles/jls_4319.htm

Figure 3 The Multivac Vacuum Chamber Machine used to carry out the Seal tests during the audit.



Figure 4 A vacuum test in operation – here with the vacuum at a level of 874mBar. The pack needed to stay inflated for 15 seconds to pass the test. The pack would then be subjected to an increased vacuum to obtain a measure of seal strength.



4.2 The interview

A senior factory manager was interviewed and background data for the project was collected. This included factory turnover, number of employees and number of packs produced per day.

This interview obtained the company's commitment to the work and identified key factory personnel to assist with the shop floor study. General information about the company was also collected.

At this point there was a visit to the production and packaging facilities.

4.3 Shop floor study

Production lines were visited over a period of several hours for data collection to occur. The factories used in the study were, almost without exception, divided into High Risk and Low Risk areas. Data on packaging machines was collected during visits to the High Risk areas and seal integrity testing occurred in the Low Risk areas. Waste generation was monitored wherever it occurred in the packing process.

Vacuum Testing was carried out using a chamber machine. The packs were exposed to increasing levels of vacuum until it became apparent that a fault in the seal had occurred. This gave information regarding the initial seal integrity of the pack and also the seal strength and its ability to survive the rigors of the supply chain.

Dye penetration testing was undertaken using Methylene Blue Dye mixed with a small quantity of detergent to decrease the surface tension and increase the dye's ability to find small seal anomalies.

Further physical measurements were made of the quantity of waste food and the quantity of waste packaging disposed of.

The actual measurement was followed up by using the questionnaire to determine:

- waste handling methods;
- information on the physical aspects of the packing machine;
- the sealing parameters and adjustment procedures;
- any recorded information on packs rejected for inadequate sealing;
- packaging material consistency;
- type of maintenance used;
- packing machine performance;
- product type and constituent parts;
- seal monitoring methods; and
- methods of tackling heat sealing issues.

This approach provided measured seal quality data on a sample of recently heat sealed packs which could be compared with the company's information on the proportion of heat sealed packs which they deemed necessary to withdraw from issuing to customers.

The shop floor study was, inevitably, a snap shot of sealing performance but was supported by other data gained during the work.

5.0 Key results

The major objective of this work was to:

- estimate the proportion of packs which were outside a threshold thought to represent adequate heat sealing;
- identify the proportion of packs which were being detected during production as having seal integrity issues; and
- estimate the potential quantity of food which could be wasted because of seal failure.

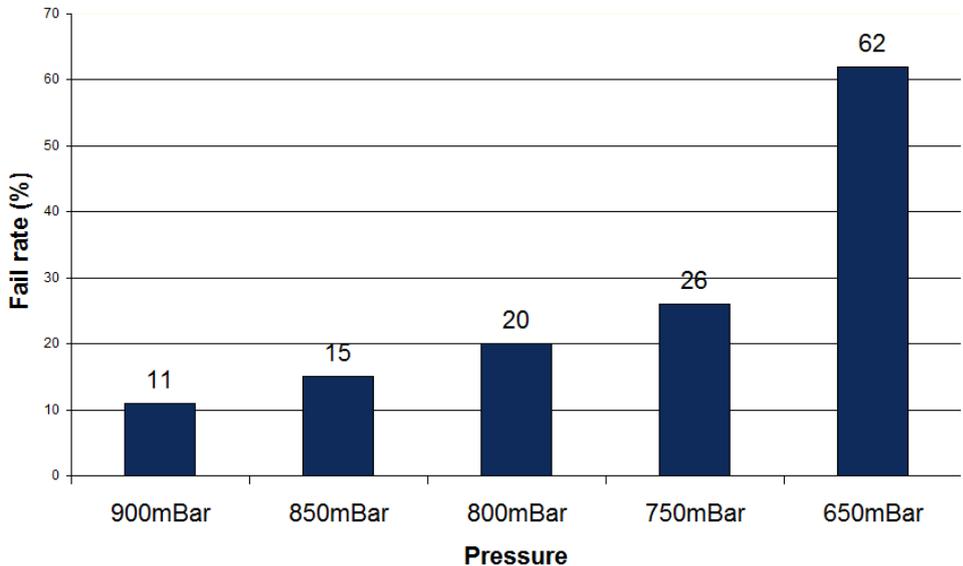
In addition to meeting these objectives, we were able to test a number of hypotheses as to why this was happening and to identify good practice in maintaining seal integrity.

We were also able to test a sample of packs using both vacuum and dye penetration methods to begin investigating the benefits of continuous versus sampling based seal integrity monitoring.

5.1 Rate of inadequate sealing

Vacuum testing and dye penetration testing were used on a sample of heat sealed packs straight from the packaging line. The results are shown in Figure 5.

Figure 5 Vacuum tests of food packs.



Even at a vacuum level of 900mBar there was a failure rate of 11% of the packs tested. The failure rate at higher vacuums predictably increased until over 60% failed at 650mBar. While there is no standard benchmark at which packs are judged inadequate, we conclude that **11% of packs are unlikely to fulfil the requirement of containing their product and atmosphere until purchased and used by the consumer.**

The dye penetration test is a more rigorous and exacting test consisting of the use of a penetrative dye brought against the inside of the seal area. Sealing faults are exposed by this method as the dye gets drawn into faults by capillary action. Very small faults can be seen in this way and this information can then be used to further investigate the cause of the fault. The results are shown in Figures 6-22.

Figure 6 VFFS bag showing a channel leak at the back seal and some evidence of the packaging material being overheated.



Figure 7 Flow wrapped bag showing an edge leak and also a leak at the junction of the end seal with the back seal.

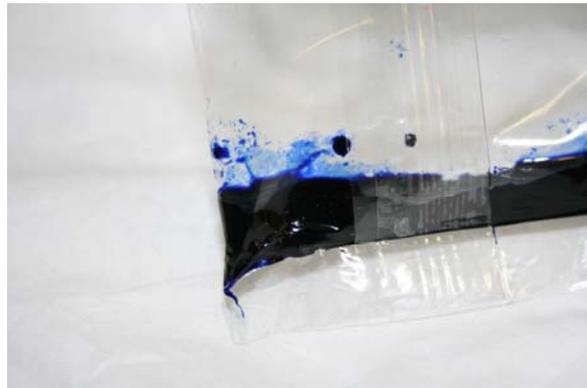


Figure 8 VFFS bag demonstrating that with adequate jaw pressure and correct settings even a major fold in the seal area will not necessarily leak.



Figure 9 A foil tray exhibiting good seal integrity.



Figure 10 A foil tray showing the effect of damaged rubber in the sealing head.



Figure 11 HFFS pack showing good seal integrity with a knurled sealing pattern. Some evidence of sealing rubber breakdown is evident in the corner of the pack

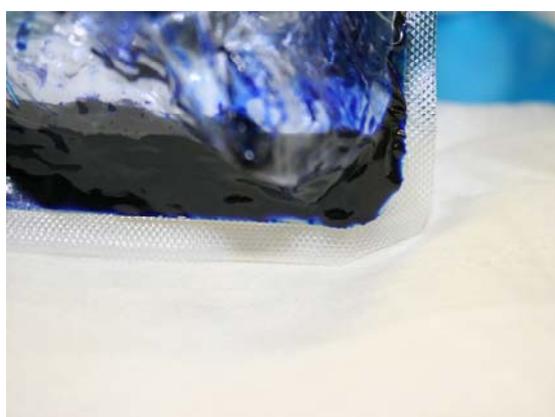


Figure 12 Very good seal integrity sealing a foil to a Polypropylene pot at high speed.

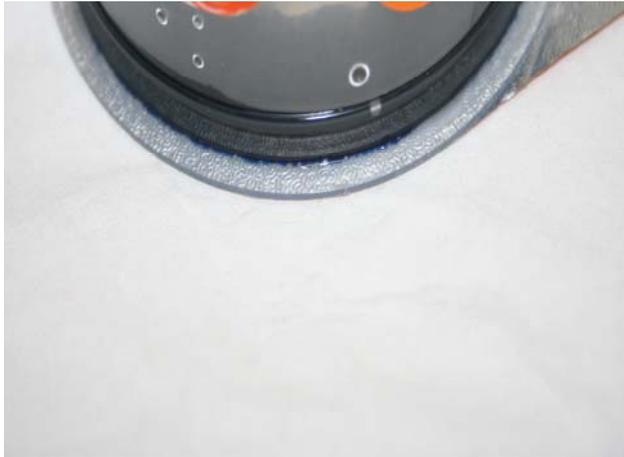


Figure 13 Very nearly a leaker – would it survive distribution?



Figure 14 The next pot from the same sealing head (as Figure 13) damage to the sealing rubber caused this fault.



Figure 15 Poor control over seal area contamination caused this fault – the seal area had sauce on it.



Figure 16 The two notches of blue ink matched exactly the damage seen on the sealing rubber.



Figure 17 The sealing rubber on this machine was cracked and producing a less than perfect seal.



Figure 18 A PLA tray being sealed at the wrong temperature giving a major seal failure.

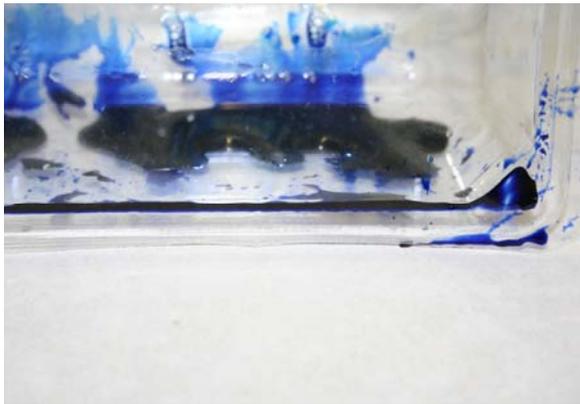


Figure 19 The product in this tray was deeper than the tray. The top film creased causing a leaker.

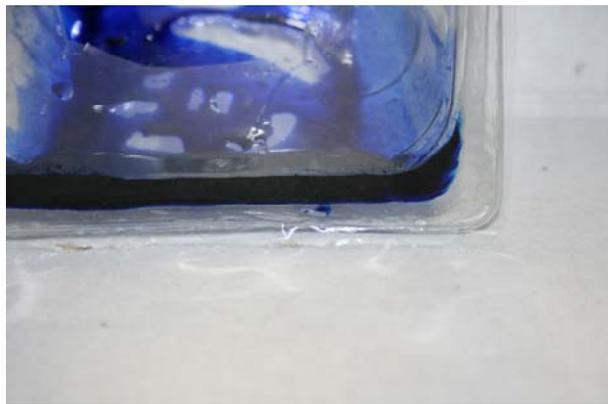


Figure 20 Product contamination in the seal area caused a major seal failure.

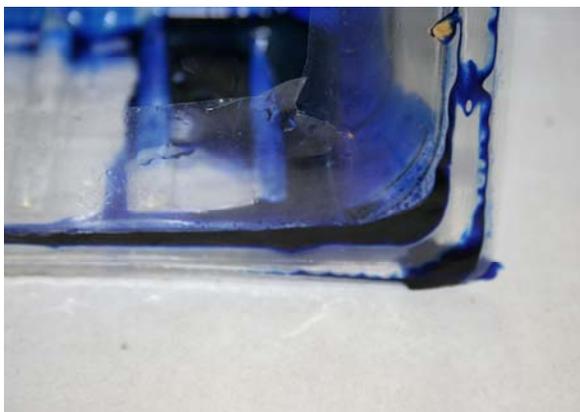


Figure 21 Perfect!



Figure 22 Some seal area contamination and cracked sealing rubber causing this faulty seal.

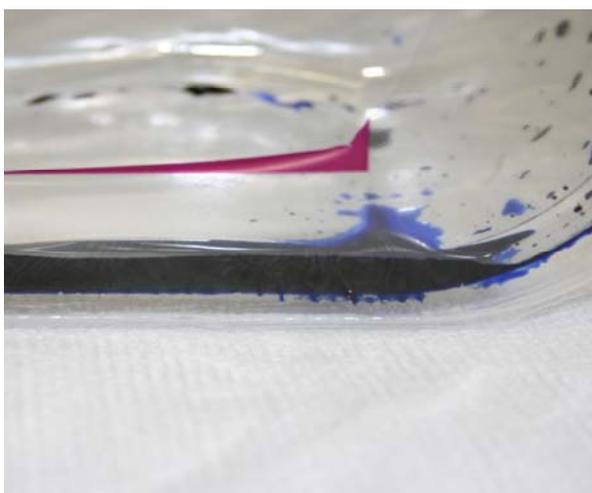
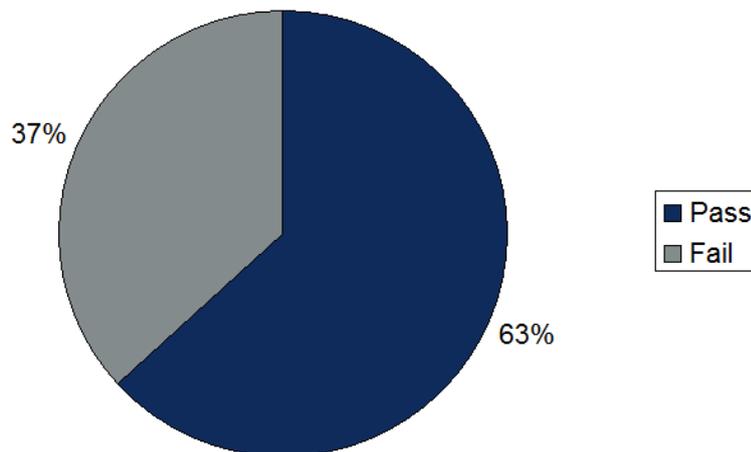


Figure 23 shows that 37% of the packs tested allowed ingress of dye during the tests. The problem of having no benchmark makes this statistic difficult to interpret. This exacting test may be allowing only 'gold plated' packaging to survive the methodology. It may be more suited to testing packs which require no air to reach the product e.g. those in modified atmospheres. Nevertheless, the measurements give a good estimate of the upper limit of inadequate heat sealing of food packs.

The dye penetration test is a useful tool in preventative maintenance of sealing machinery. It reveals, as can be seen above, faults in the sealing system that would otherwise go unnoticed and this could lead to better machinery care and earlier detection of leakage.

Figure 23 Dye penetration test



Taken together these tests indicate that between 11% and 37% of pack seals could be judged inadequate depending on the level of sealing required for the product and the atmosphere it is packed in. Further research, outside the scope of this project, is required to determine a benchmark test for the adequacy of heat sealing for different products. The mean of these figures is 24% and we intend to use this estimate as the proportion of inadequately heat sealed packs which leave the packing line and potentially create food and packaging waste.

Food companies have a range of methods for identifying inadequate seals; 'leakers' or 'seal failures' as they are known. So, having measured the potential level of inadequate heat seals we questioned food company personnel on their view of the proportion of inadequate seals which were being produced.

When confronted with the question of the rate of seal failure most companies were able and willing to give an answer. It often took some time to identify the rate of seal failure as several data sources had to be accessed. While the average number of seal integrity problems over a year is usually small (about 1% of production in the sample group), this represents the percentage of packs which the current methods of checking manage to detect.

When we asked factory managers about customer complaints relating to seal failure, numbers of around 1.5 to 2 per 100,000 packs were revealed. This indicates that even with considerable effort going into checking for 'leakers' at the factory, some make it into the supply chain. Anecdotal evidence and observations in food retailers suggests that the problem is much higher than two packs per 100,000 suggested by customer complaints data.

This further supports the belief that potentially leaking packs are being released into the supply chain. The actual quantity of food and packaging wasted between factory and final consumer will be dependent on the rigors of the distribution channels.

Minimising the problems of seal integrity is of great importance to food companies for a number of reasons:

- the problem is often severe for a short period rather than running at a constant low level. This causes disruption to the whole food production process;
- it can often cause a shutdown of the production line;
- penalties for letting 'leaking packs' reach the retail customer are often severe;
- the cost of monitoring at the factory can be high;

- using manual methods of monitoring often gives inconsistent results;
- products which are packed in modified atmospheres rapidly lose shelf life when exposed to even small quantities of air; and
- packed food represents the stage of production where considerable value has been added to the raw material and therefore is a greater cost to the business than food products rejected earlier in the processing chain.

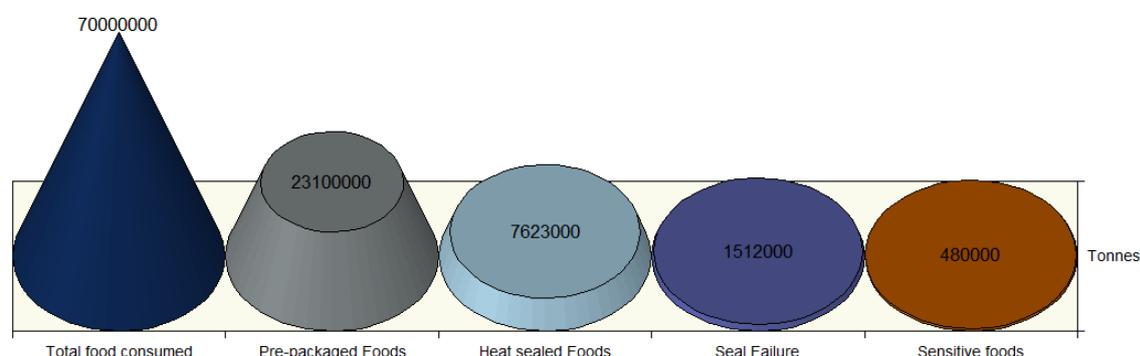
The importance of reducing this apparently small average number (24%) of poor seals becomes clear when related to the vast volume of packaged food produced each year. Food consumption in the UK is around 70 million tonnes per year; of that food, conservative estimates say that one third is pre-packaged in some way and of the pre-packaged food around a third is sealed using heat sealing systems.

The importance of the problem of insecure heat seals depends on the type of food packed e.g. food sealed in modified atmosphere packs (MAP) is much more vulnerable to wastage from ingress of air than food packed in a normal atmosphere. So, of the 24% of packs at risk of failure there is only a proportion of products that would be impacted by the failure in sufficient a way as to become waste as opposed to being consumed. For example, a small seal failure on a bag of frozen peas or a packet of tea would only have a small impact on product quality and is unlikely to cause food waste. The same size of failure on a pack of bacon or a pot of yoghurt would almost certainly cause product damage to the extent that it could not be eaten.

In the absence of further laboratory testing to simulate the rigors of the supply chain or a survey of the food retailers we have used industry experts to estimate the quantity of food at moderate to high risk of losing its hygienic and / or cosmetic integrity because of leaking seals, and conservatively estimate that about 8% of packs leaving a factory might well fail to provide sufficient protection to the food through the supply chain and into the home, a far greater proportion than are currently being detected through quality control (~1%). This rate of seal failure is estimated to equate to around 480,000 tonnes of potential food waste. Further work would be required to quantify the actual waste in retail outlets and in the home as a result of seal failure.

Figure 24 illustrates this conclusion, taking 70 million tonnes of food consumed in UK as the baseline.

Figure 24 Potential food Waste because of Seal Integrity Issues.



5.2 Further analysis of inadequate seals

Data collected included identifying:

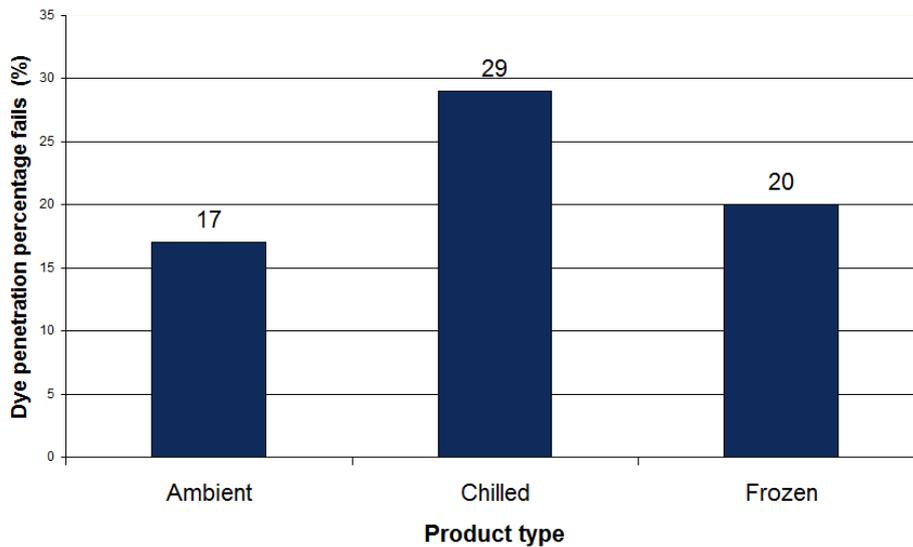
- factory turnover in £ millions;
- product type;
- product constituents; and
- age of sealing machines.

The relationship between these parameters and the extent of ingress of dye during the dye test was examined.

It was considered that company size when measured by turnover might affect the proportion of unsound seals when measured using the dye test. The data did not support this theory.

It was also conjectured that more weakened seals would be associated with chilled products rather than frozen or ambient products. Chilled products did exhibit the highest level of seals which failed the dye test as shown below.

Figure 25 Dye test failure by product type



Chilled products, including salads and indeed wet leaves, were associated with the highest proportion of dye penetration failures when constituents of the products were analysed. Loose particles and breadcrumbs were also associated with seal failure.

The age of the sealing machine was found to have no relationship with the rate of seal failure. Much more important was the machinery care systems and attitudes that were evident in the factories. Some of the factories we visited obviously gave achieving the desired seal integrity a high priority, and this was exhibited on the shop floor with very good management and control of the issue.

5.3 Disposal and repacking of food

The survey found that, on average, 60% of the food from damaged packs was disposed of and 40% was repacked. The split depended very much on the industry sector, with some sectors repacking no food and others able to repack a fairly large proportion. This is a consequence of strict adherence to High Risk and Low Risk areas within food factories.

Final packaging usually occurs in a high risk environment where the food will not be subject to further processing to reduce health risks. In addition, it is usually in the form that the customer expects to receive it and any further processing will reduce quality, or at least the perception of quality. Once sealed into the retail pack, the food generally moves out of the High Risk area to a Low Risk area where it is packed into crates or outer cases. The move from High Risk to Low Risk is usually rapid and automatic. It is usually in a Low Risk area where a seal integrity issue is first detected. Such activity also has an impact on manufacturing costs and is, by no means, possible or practicable in all cases.

For these reasons it is usually difficult to repack food at this point in the chain and it must be disposed of safely. This usually means to landfill.

5.4 Disposal of packaging

This project did not set out to measure the quantity of waste packaging produced but in our sample, no packaging material could be recovered after the food was incorporated, to prevent contamination of the recycling stream, and it was therefore disposed of as waste. In all the factories, measures were being undertaken to separate recyclable items from those which were not but in the majority of cases, separating food stuff from packaging in the final product is not possible.

6.0 Managing the sealing activity

Managing packaging and sealing is one of the most important activities in food manufacturing.

As part of this study we questioned food company managers about how they managed the procedure.

The three major ways in which the process is managed are:

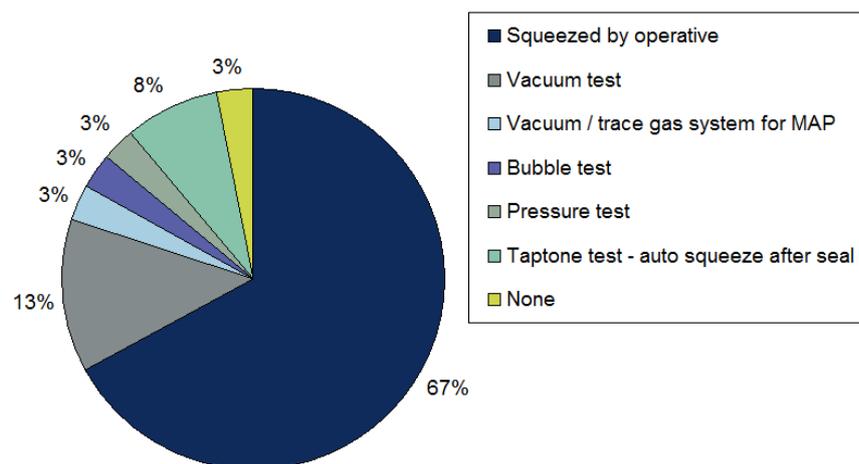
- methods for monitoring the integrity of seals;
- management of the Standard Operating Procedures (SOPs); and
- maintenance procedures.

6.1 Methods for monitoring the integrity of seals

Observation of the packaging lines and discussion with team leaders established how the companies monitored and maintained the quality of the food packages.

The most common method of monitoring the integrity of the seals is by manually squeezing the packs, shown in Figure 26. If the pack appears to leak it is rejected. Previous investigations available to us indicate that the precision of this method could be questioned while controlled experiments have shown that low level leaks are difficult to identify.

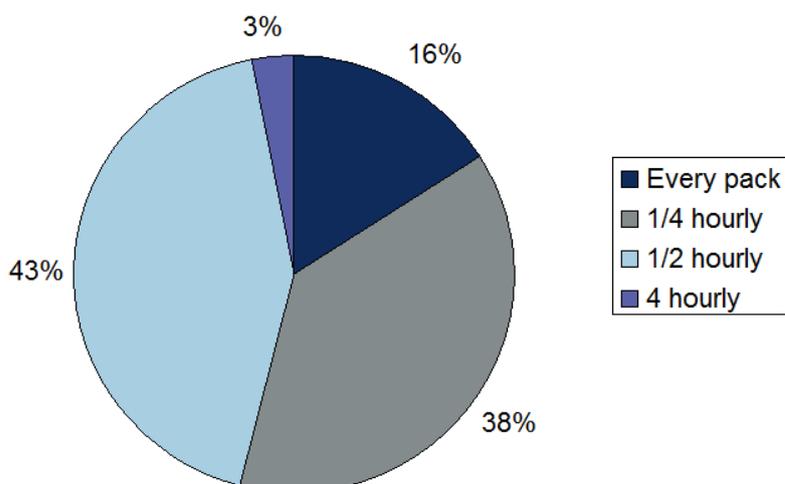
Figure 26 Seal integrity monitoring methods.



This system relies on all production workers being vigilant and an informal method of deciding on when corrective action is needed and what that should be. When a more formal method of monitoring is in place, the most common sampling interval was half hourly (shown in Figure 27) but checking every 15 minutes was done in 38% of the sample and 16% claimed to monitor every pack.

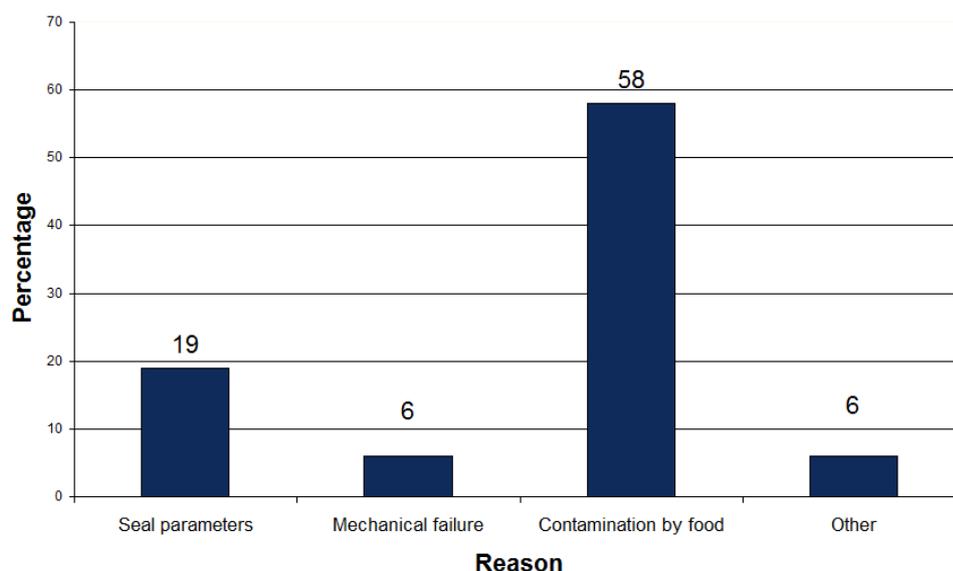
The intensity of sampling was related to the importance of maintaining product in its packaging e.g. products in modified atmospheric packaging (MAP). Factories with good seal integrity monitoring did so because their product was reliant on good seals for food safety or quality concerns.

Figure 27 Frequency of seal integrity testing.



The reason for seal failure was in most cases 'contamination by food' (Figure 28). Problems with setting the parameters of the sealing units also figured, but such problems usually lead to systemic failure which may be more easily identified (a continuous series of failed seals) than the more random nature of food contamination.

Figure 28 Reasons for seal failure.



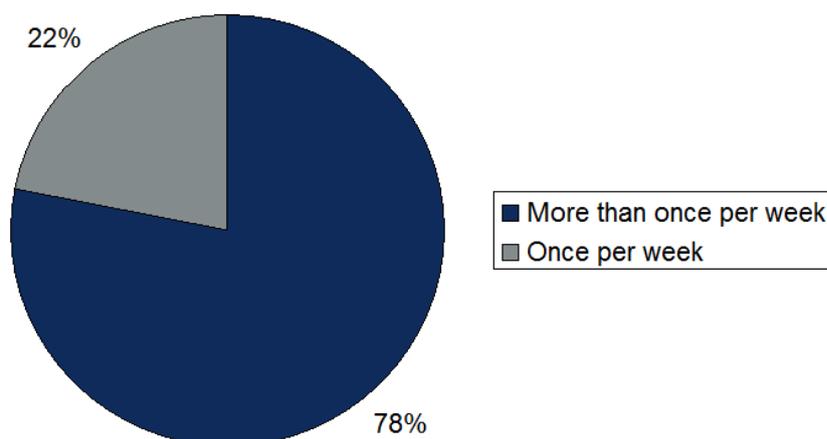
It is clearly important to monitor the integrity of seals. While this study cannot establish clear statistical correlations between monitoring methods and reduction in package seal problems, observation and discussion with the managers identify a clearly defined monitoring system as a key element in good practice for food packaging.

An interesting observation during the testing was around the issues of seal peelability. Consumers like the convenience of easy to open packs with peelable seals – the definition of peelable is a matter of opinion and difficult to quantify. No evidence was seen in any of the factories of a "peelability" test. Seal strength and peelability are closely related and this is a possible area for future work.

6.2 Management of the Standard Operating Procedures

Lean manufacturing theory would suggest that Standard Operating Procedures (SOPs) should lead to more consistent and more effective sealing of food packs. We gathered some data on how often the operating procedures were changed (Figure 29).

Figure 29 Frequency of changing operating procedures.



Eighty per cent of the packaging lines were adjusted more than once per week. The remaining 20% were adjusted at least once per month. This level of micro management is related to team leaders making instant decisions often without much data to support those decisions. We feel that if there were a better link between the monitoring function and the adjustment, i.e. a better feedback loop system, better seal integrity (and other aspects of packaging management) could be achieved.

The factories with more robust SOPs for their packing systems appear to have fewer seal integrity issues with their packs. A disciplined approach to the operation of sealing machines is a key component of better seal integrity performance.

6.3 Maintenance procedures

Maintenance procedures are thought to be crucial in achieving efficient and effective sealing of food packs.

To investigate whether good packaging could be at risk from inadequate maintenance procedures, we asked about systems employed. About 50% of the packaging lines used 'Planned Preventative Maintenance' (PPM). This is judged to be a low proportion of packaging lines using the system. While there is insufficient data to establish clear, statistical evidence of poor sealing and lack of PPM, the better performing packing lines seem to use planned maintenance systems.

7.0 Good practice

The Good Practice that has emerged from the study is:

1. Robust methods of filling packs without the possibility of seal area contamination is essential if the largest cause of failure is to be minimised. This is achieved in several ways by different machine manufacturers. Masking systems for tray sealers and Horizontal Form Fill Seal systems and pinch bars for Vertical Form Fill Seal machines were observed working well during the study. A “dipping” filler tube for food from an automatic weigher and a dipping nozzle with clean cut off for sauces were seen as best practice in the manufacture of ready meals. Examples were seen of packs being wiped clean prior to sealing; however, this, on the whole, was not very successful and still resulted in a large number of rejects and waste.
2. The use and adherence to Standard Operating Procedures (SOPs) is key in the operation of sealing machines. Sealing temperatures are critical to the strength of a seal along with the dwell time used. If these parameters are incorrectly adjusted the opportunity for seal failure or integrity issues is greatly increased. Machines were observed running “hot and fast” during the study to increase output. The result was seals that had become overheated and damage to the film being sealed. The use of new PLA packaging was observed in several factories. It was apparent that the PLA materials needed much tighter temperature control with even small temperature fluctuations causing packs to fail.
3. Planned Preventative Maintenance (PPM) is essential to the performance of sealing machines. Machinery care by the operator was seen as being the most robust form of PPM. At one factory an individual had been selected and trained in the maintenance of all sealing heads for the tray sealers used. The heads were maintained to a very high standard and as a result the sealing performance was among the best observed. Several factories visited had no system for the routine inspection of sealing rubbers on their machines. As a result, the rubbers were only being replaced when they started to make leaking packs. In the better performing factories sealing rubbers were replaced on a regular basis by a trained person to ensure they were correctly fitted and in good condition. Several sealing systems were observed that displayed issues of head or jaw alignment. As the parts of the machine came together to make the seal the pressures were not even, as a result, uneven seal widths were observed on dye penetration tests and these machines produced a high number of faulty seals. A final area of concern observed during the study was the control of sealing temperature – temperature sensors were not working correctly on several machines and, as a result, faulty packs were being manufactured.
4. Seal testing was mostly carried out using a manual squeeze test. The best practice observed was in a factory using Modified Atmosphere Packing on its products; each line was equipped with a vacuum chamber machine with a built in CO₂ sensor. Any leak could be detected using this system. The issue was that the system was off line and sample packs were tested every 15 minutes. The best on-line system seen used an ultrasound sensor to check that a small vacuum was present inside the pack. This system checked all packs but was difficult to set up and rejected some good packs. It also relied on a hot fill system to generate the vacuum so would not be appropriate for all sectors.
5. Rework of packs with seal faults can only be achieved if the fault is detected in the High Risk area and the pack rejected before it passes to the Low Risk area. Where this can be done the waste going to landfill can be reduced substantially. Some of the factories employed a person to check packs, albeit only with a manual squeeze test, immediately after leaving the sealing machine and prior to them passing to Low Risk. There are two issues with this: firstly, the cost of the checker is high and the motivation difficult to maintain, indeed with some lines running at speeds of over 200 packs per minute one person could not check all packs anyway. The majority of seal faults are caused by food entrapment in the seal and are fairly random in nature, the chance of any system relying on sampling, detecting a random event reliably, are very low. The second issue is one of time; most heat seals require a cooling period of several seconds for the packaging materials to bond, testing by squeeze test too soon after sealing could actually make the issue worse.
6. While there were some reports during the study of packaging faults being a cause of seal problems this was not observed during the tests. Packaging material variation will be observed more easily in the factories if SOPs and PPM are to a high standard. In the absence of robust management of seal integrity packaging materials outside of specification are unlikely to be the cause of most of the waste generated in sealing operation.

8.0 Conclusions

This study, though limited in size, is the first attempt to measure the issue of seal integrity with regard to its impact on waste in the food industry.

The following conclusions were reached:

- 11% of the heat sealed packs tested allowed gas ingress when exposed to low levels of vacuum testing (900mB).

This is a mild test of the robustness of the package seal. Research by Camden and Chorleywood Food Research Association (CCFRA) – now Campden BRI – in a confidential research and development report (No 241)² concluded that it was important to apply the appropriate detection method to the pack type. On the basis of this research, the Lincoln team regard 11% as the base number of packs that are vulnerable to the rigours of the distribution chain.

- 37% of the heat sealed packs tested allowed dye ingress when the more stringent 'dye penetration' test was applied.

The dye test is a more robust test and while taking account of the CCFRA caveat, the Lincoln team concludes that this could be taken as a good estimate of the upper figure for the proportion of packs that are vulnerable to the rigours of the distribution chain.

- About 1% of the heat sealed packs were judged by standard food company methods of seal assessment to be inadequate for dispatch to customers.

While the level of detection varied by factory, 1% is judged to be a fair average value to assign to the number of packs trapped by current methods of detection at the processing units.

- The most common method of testing for heat seal integrity was the 'manual squeeze test'.

This is the simplest of tests. It was outside the scope of this project to comment on the efficacy of the test. However, although the test is quick and cheap, it is apparent that it is difficult to achieve consistency from a test relying on purely human intervention and could lead to over or under rejection of packs. The economics of this test and indeed the trade-off between waste production and economic efficiency have not been examined in this study.

- No companies in the survey use the 'dye penetration' test.

While a number of companies have introduced off-line seal testing methods, none use the dye test. The reason for this has not been investigated but initial thoughts are that the test may be too robust, it may be complex to administer or it could be time consuming.

- There is no commonly accepted benchmark test for the adequacy of heat sealing.

This is a weakness in the philosophy of testing and sealing. If a benchmark test, acceptable by processors and their customers (taking account of economic, environmental and social objectives) could be devised, it might be possible to reduce waste throughout the food supply chain.

- Current testing methods rely on manual intervention and off-line testing.

An in-line testing method (applying an accepted benchmark test) should allow faster intervention on the packing equipment and a reduction in waste.

² Available at http://www.campden.co.uk/publ/pubfiles/jls_4319.htm

- 480,000 tonnes of heat sealed packaged food could potentially become waste through unsound seals after leaving the factory.

This figure could be reduced by better seal monitoring, particularly in-line testing where fast intervention would be facilitated.

- Current practice must be improved by developing better monitoring and sealing technology.

This technology could replace the manual squeeze test, which is the most common checking method and generally occurs at some distance from the sealing operation. The feed-back loop is therefore long and unresponsive.

- The most common reason for seal failure was product contamination in the seal.

Further design improvement in packaging equipment could reduce this problem. This emphasises how important it is to tackle the problem of seal integrity by identifying all the components in the system (appropriate benchmark test, sealing parameters, seal contour, packaging material, filling methods, operator training etc.) and optimising all of them.

- Ingress through packaging seals was more common where liquid and crumb components were being packed.

Greater care is needed in managing products which include components with a high risk of causing seal integrity problems.

- Differentiation of wastes into packaging and food after packaging to facilitate disposal was not normal practice in the sample.

Better and earlier detection of seal integrity problems should reduce the number of such packs. This reduction in volume might allow time to separate the components. The decision currently appears to be an economic one.

- Achieving adequate heat sealing was anticipated to become a greater problem as new packaging materials are introduced.

The study did not identify a greater rate of seal integrity failure where new packaging materials were being used but did highlight their requirement for tighter control of operating conditions. This may be because the number of packaging lines in the sample using these materials was small. More research is needed to ascertain the extent of any problems.

- Introducing current best practice could reduce the problem significantly but a technological step change in monitoring and heat sealing technology is required to tackle the problem.

A systems approach to achieving lower food and packaging waste should include the good practice elements identified above. It is felt that major improvements would require technological changes in the methods of filling, sealing and monitoring seals.

9.0 Moving forward

The study has pointed the way towards some changes that could be implemented to reduce the waste caused, throughout the supply chain, by faulty heat seals. These are:

1. The development of systems to ensure that the seal area is free from contamination prior to sealing;
2. The implementation of PPM systems to ensure that the machines are in good condition, in particular the sealing rubbers on tray sealers, the head / jaw alignment and the control of temperatures;
3. The introduction of SOPs with the discipline to operate to the standard for the machine and product;
4. The implementation of seal testing systems to replace the over reliance on manual squeeze testing. The testing should be 100% of all output to ensure that all packs are tested, which would ensure random failures are detected as well as machine or system failures;
5. Re-work should be maximised by testing for seal integrity as early as possible after sealing and while the product remains in the High Risk area of the factory;
6. The development of new sealing technologies that are less prone to the issues of seal area contamination;
7. The development of standards for the peelability of sealed packs; and
8. Further work in the food supply chain to establish the impact of seal integrity on wastage in store and in the homes of consumers.

Since the completion of the factory audits within this project the work has continued and the learning has been applied in several applications.

The University of Lincoln has been called into several food businesses to investigate, identify and help rectify instances where seal integrity has become an issue.

In addition, food retailers appear to have recognised that their wastage in store is partly due to sealing issues. The faulty seals are causing product escape from the packs or are leading to quality faults that render the products unmarketable or generate consumer complaints. The University of Lincoln is aware of cases where seal integrity issues have provoked an EPW (Emergency Product Withdrawal) at great cost to the retailer and the supplying company.

Seal integrity is soon to be the topic of a series of seminars organised by the University of Lincoln to bring the issue to more food processors and to start work on systems to reduce or eliminate the problem from the factories.

Appendix 1 Composite data collection document

Online test results

Date

Machine Code

Vacuum Test Results

	Pass		Fail
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Packs exposed to stated pressure for 15 seconds. Observed for seal failure.

Absolute Pressure mBar	Pack Number				
	1	2	3	4	5
900					
850					
800					
750					
650					

Dye Penetration Test

Seals exposed to dye for 30 seconds and catagorised for dye penetration. 0 to 4

	Pack Number				
	1	2	3	4	5
Dye test					

Comments

Any observations by the tester that may be relevant to seal integrity.

WRAP PROJECT - Seal Integrity				
Company Information				
Unique Number:				
Company Name:				
Factory Name:				
Contact Name(s):				
Address:				
Post Code:				
Telephone No:			Email:	
Turnover by factory (£million per year):			Number of employees at the factory:	
Number of packs produced per year:				
Machine Data				
Machine unique letter:				
Packing Machine Make:			Model:	
Type of Container: eg tray			Packaging material:	
Type of film:			Age of machine:	
Number of Tooling Changes per day:				
Sealing Parameters				
Dwell time:			Temperature:	
Pressure:				
How often is the machine adjusted from the standard ops procedure	Frequently	Once per week	Once per month	Rarely
Seal failure				
Number per day:			Reason:	
Proportion of total packs per day:				
Packaging material consistency				
Type of packaging:			Consistency of quality: Very moderately inconsistent	
Type of film:			Consistency of quality: Very moderately inconsistent	

Maintenance system used			
PPM:		Exceptional:	
Machine Performance			
Target Speed (packs per minute):		Actual Speed (packs per minute):	
Limiting factor e.g. printer speed, human element, sealing unit, etc			
Product			
Product description:			
Product type:	Fresh	Frozen	Chilled
Product constituents	Fine particles	breadcrumbs	Wet leaves
	Liquid sauces	Loose particles	Other (describe):
Waste Handling			
Quantity of Waste reworked per hour:		Quantity of Waste dumped per hour:	
Main reason for rework:		Main reason for dumping:	
Quantity of Packaging reworked per hour:		Quantity of packaging dumped per hour:	
Main reason for rework:		Main reason for dumping:	
Pack monitoring High care			
Monitoring Method:		Monitoring Frequency:	
Reason for Pack failure – <ul style="list-style-type: none"> • seal parameters • contamination by food • mechanical failure • other (describe) 		Number per hour	
Pack failure – cause e.g. change in food texture, raw material:		Pack failure – action taken:	

Pack monitoring Low care	
Monitoring Method:	Monitoring Frequency:
Reason for Pack failure – <ul style="list-style-type: none"> • seal parameters • contamination by food • mechanical failure • other (describe) 	Number per hour
Pack failure – cause e.g. change in food texture, raw material:	Pack failure – action taken:
Customer complaints	
Most common complaint:	Seal failure: (complaints per 100,00 packs):
Current methods of tackling seal integrity problems	
With packaging supplier:	With equipment supplier
With both	Within the company only
Other (specify):	
Possible records	
Maintenance:	Quality:
Production:	Customer comments:
Customer complaints:	Integrated data systems e.g.SAP:

**Waste & Resources
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