

CHAPTER 1

Overview of sealing technologies, formats and systems

1.1 Introduction

This chapter provides a basic grounding in the principles of sealing a product inside a package. It includes the principles of making a seal using heat, ultrasonic energy and other sealing systems such as cold sealing using adhesives. This chapter also includes considerations of the chemistry of the materials being sealed together and how the sealing system must be designed and operated in a way that is compatible with the physical and chemical properties of the materials and also the product to be packaged.

This chapter also includes an overview of the various packaging system options available in the food industry such as bag making, pouch sealing, tray sealing, flow wrapping and form fill seal systems. These packaging options are included in much greater detail elsewhere in the book.

Finally, the chapter reviews the industry sectors that routinely use sealing technologies in their packaging processes – pharmaceuticals, food and other consumer products – and their need for pack security, shelf life extension and product protection from contamination and loss. Though the focus of the book is the food industry, the principles of sealing products into packages can be applied across many different industries.

1.2 The importance of packaging and seal integrity

Modern methods of retailing, especially food retailing, rely in the main on the shopper selecting pre-packaged products from the shelves of the retailer. It is vital that the food inside the package is protected from spoilage and leakage by the packaging that is surrounding it. Leaking packs on a supermarket shelf are an



Fig. 1.1 Modern methods of food retailing rely on pre-packaged goods being available for the shopper to select. The packaging and seal integrity are important factors in the selection process as are the distribution and safety of the foods in the shops. The extended shelf life that is offered by the packaging system is vital to the way that our food distribution systems work, making a wide variety of foods available to consumers.

indication of a lack of control in the production factory and this will cause shopper rejection of the pack and waste throughout the supply chain. If a leaking pack is inadvertently placed in the shopping basket then it may well generate a consumer complaint or in the worst case it may cause illness in the consumer.

Without robust packaging capable of withstanding the rigours of logistics and retail display the whole way that we shop for food and other consumer goods would not be possible. It is vital that factories supplying packaged goods understand the needs of the product and the needs of the consumer in terms of the package (Fig. 1.1).

There are many packaging materials, and systems and methods have been designed to use these materials to create packages to enclose, protect and retain the contents of the pack. Recent trends in packaging materials have moved away from rigid materials such as metal cans and glass jars towards semi-rigid and flexible materials such as thermoplastics. Sealing of rigid packaging is usually obtained using mechanical seals such as the double seam used in the canning industry or the screw cap in glass jars. The sealing of semi-flexible and flexible materials



Fig. 1.2 A double seam on a canned product where the mechanical strength of the material is used to hold the parts together. The small gaps are filled with a flexible mastic compound.

requires a bond between the layers to join them together. This bond is most commonly created by the controlled application of heat to the materials, but other options are available as will be explored later.

1.3 The sealing of rigid containers

Both metal cans and glass jars rely on two factors to create a strong seal. First, there is a need of a mechanical fix to join the can to the can end or the glass jar to its lid. This mechanical fix is created by bending and forming the rigid materials after filling to prevent the can end or jar lid from separating from the body of the package. This is not enough to create a seal though. The small gaps that appear in these mechanical fixes would allow the passage of oxygen and bacteria both into and out of the pack as well as possible leakage of product. The small gaps need to be filled to ensure that contamination or leaking cannot occur. This is achieved using flexible mastics, rubber-like materials that can move and distort their shape during the making of the mechanical fix so that the small gaps can be filled. This creates a hermetic seal – one where nothing can pass into or out of the pack (Fig.1.2 and Fig. 1.3).

1.4 Hermetic seals

Hermetic seals are required when packaging foods with a long shelf life. These foods are often termed ‘shelf stable’ and have their long shelf life even when stored in ambient, non-refrigerated, conditions. The food inside the hermetically

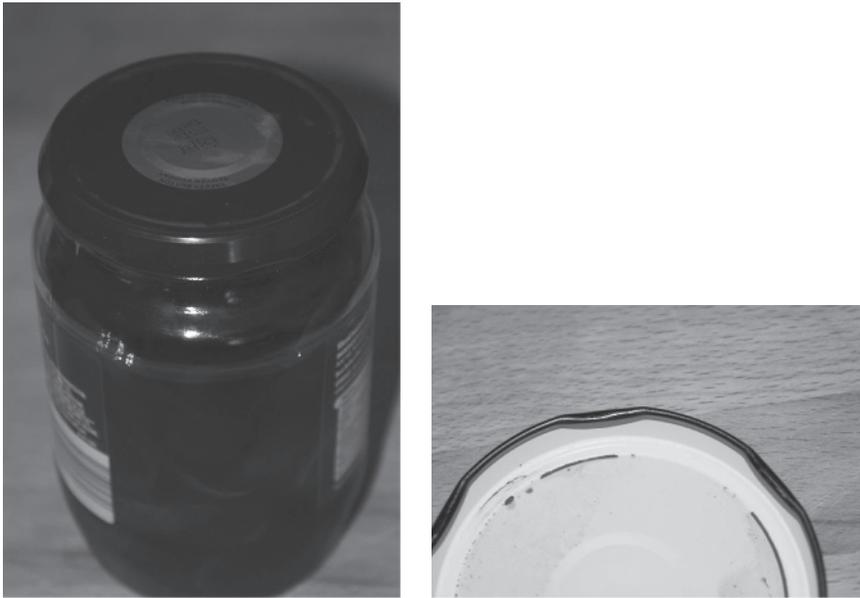


Fig. 1.3 A glass jar with a twist lid is a common package. Again, the strength is given by the materials, with the final seal being obtained using a flexible compound inside the lid.

sealed packs is often heat-processed after the packs are sealed to kill any bacteria inside the pack. This heat process is carried out in large pressure cookers, called retorts, where the packs are taken up to 120°C. This process is very demanding on the packaging. The combination of heat and pressure inside the retort means that the seals have to be very strong to withstand the process. The rigours of this process continue after the heating stage. During cooling any leak in the seal would see the can or jar suck the cooling water into the container, and with the cooling water could come bacteria and other contaminants. The development of this 'canning process' has been rigorous and the systems and package designs have been optimised to make the process as efficient as possible without risking the food safety of the products.

1.5 Developments in the canning process

In order to reduce the cost of the canning process there have been many changes. Each change is tested to ensure that the safety of the foods is not compromised as the efficiency of the process is improved. Many of the optimisation techniques used in rigid container packing systems have been repeated with semi-flexible



Fig. 1.4 Thinner materials used to reduce the cost of a package. In this can the wall thickness was reduced but the side wall strength was retained using the beaded shape, resulting in a lower cost can that performs well.

and flexible packaging system, so the themes will be seen again later in this book but applied to a different set of circumstances.

1.5.1 Thinner materials

Glass and metal are expensive materials from which to construct a food container, and as a result of this cost packages have been redesigned with less material and thinner walls, but importantly the designs retain, or even improve, the pack strength. Clever design and careful analysis has removed excess material from where it is not needed and as a result the cost of the package has been reduced without any deterioration of the pack performance (Fig. 1.4).

1.5.2 New materials

Changes in sealing mastic materials have improved performance as has the lining material on the inside of metal rigid containers. Changes here have seen improved performance especially in resisting the effects of acid foods that can attack the materials during the shelf life of the product long after the food containers have left the factory.

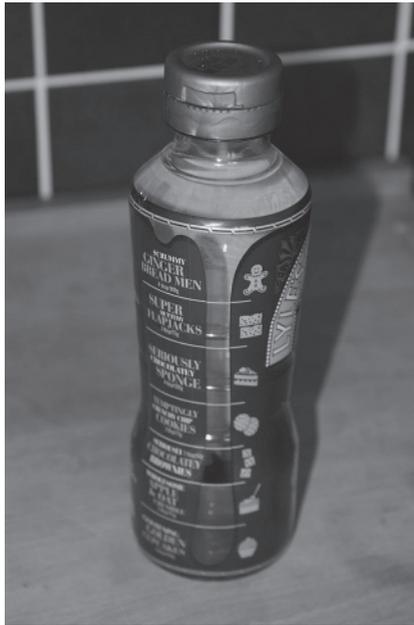


Fig. 1.5 The use of shrink labels adds a layer of protection to glass bottles with thinner walls.

1.5.3 Additional protection of the container from secondary packaging

Glass containers have become thinner as designers seek to reduce the package weight and this has, in some circumstances, caused an increase in damage to packages during logistics and retail display. Systems such as shrink sleeve labelling have allowed the new low-weight container to be retained because of the extra protection offered by the secondary package (Fig. 1.5).

1.6 Heat sealed packages

Semi-rigid and flexible packaging materials have the advantage over rigid packaging materials because of their low weight and low cost but they have a distinct disadvantage when it comes to sealing them to make a container. Because of their flexibility a mechanical fix for the package is not possible. To seal semi-rigid and flexible packages a different method of sealing must be adopted. The materials of the package must be bonded together to create a seal (Fig. 1.6).

Semi-rigid trays for ready meals and flexible bags for snack foods have to be sealed in order to retain the product and protect it from contamination or leakage.

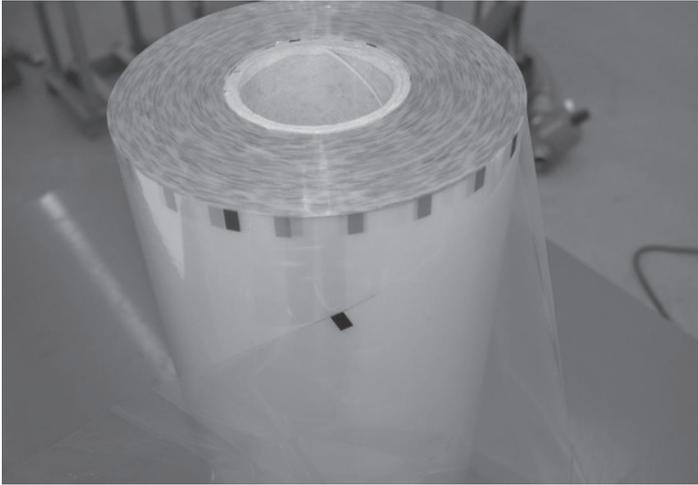


Fig. 1.6 Flexible materials have been made less expensive by a process of ‘down gauging’ or making thinner. If this process has not been done correctly then the performance of the pack can be affected in terms of seal integrity or strength. This thinner film has had eye marks added to allow the packing machine to compensate for the extra stretch that now occurs.

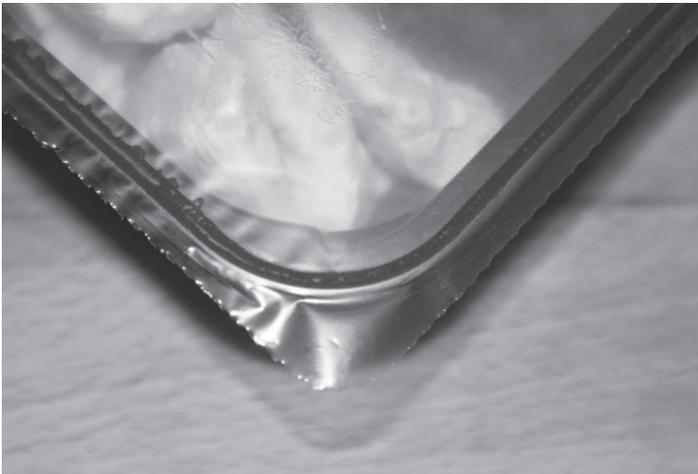


Fig. 1.7 The seals on this tray have to perform their function throughout the supply chain so the design and performance of the seals must be inspected and tested to ensure everything is as it should be.

The seal needs to be able to carry out its function during manufacture, logistics, and retail display and in the domestic situation (Fig. 1.7 and Fig. 1.8). If a seal fails at any time in the supply of the pack the product inside is open to contamination or leakage and could give rise to waste and possible consumer complaint.



Fig. 1.8 The seals on a snack food pack need to perform to the level designed to ensure that the product reaches the consumer at the expected quality. If the seals on this pack leak then off flavours will develop and the product will go soft before the ‘best before’ date on the pack.

1.7 What is a good seal?

People in the food supply chain often think about creating the perfect seal. The perfect seal is one that carries out its function for the life of the product and both retains and protects the product to the desired level. Different food products have different requirements of their packaging system and so seals that may be perfect for one group of foods may be inadequate for another.

Some examples would be as follows:

In long-life, low-acid ambient food products such as a can of soup the need of the seals on the can is that they are hermetic and do not allow the passage of air or bacteria into the product. If a can seam is examined under a microscope it may well be possible to find very, very small leaks of the order of 2 or 3 microns (millionths of a meter). The leaks are smaller than a bacterial cell so none could pass through and the rate of diffusion of air into the container would be so slow that it would be insignificant in terms of the shelf life of the product (Fig. 1.9). Indeed, the rate of oxygen migration into the pack may well be faster through the packing material itself. The so-called OTR (oxygen transmission rate) for packaging materials is a measure of their resistance to the flow of oxygen molecules through the packaging material itself.

In a pack of biscuits the primary function of the packaging is to collate and retain the product and reduce the rate of moisture transmission into the pack from the environment. The shelf life of the product may be similar to that of a can of soup and this too will be stored and displayed at ambient temperatures. Biscuits are low in moisture and high in sugar and would therefore be classed

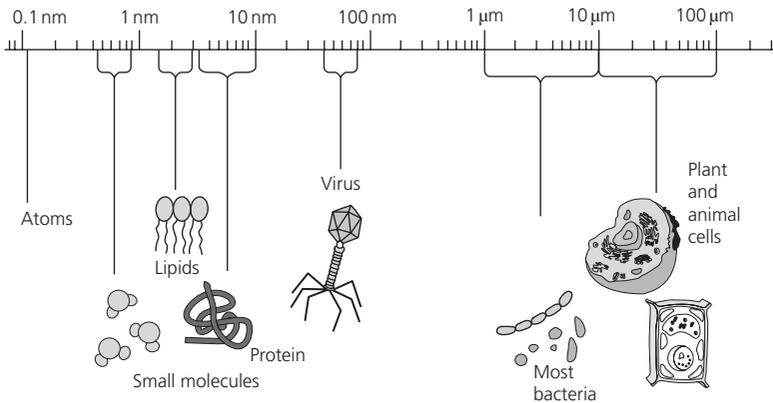


Fig. 1.9 Very small ‘micro’ leaks in the seal of a can or food package may be smaller than a bacterial cell and cause no risk to the product or its consumer from bacterial contamination, but as shown here, there are other considerations in the packaging of food products when you consider microscopic leaks.

as a low-risk food with respect to the potential for food poisoning. Because of the type of food and its requirements, it is clear that the package and its seals can be very different from those for a can of soup. Biscuits need protection from the ingress of moisture into the pack. On every pack of biscuits will be the storage instructions ‘store in a cool dry place’; this is to protect the product from the effects of moisture in the air. Leaking seals will not help the storage of dried products, but the packaging material itself will allow moisture through. The MVTR (moisture vapour transmission rate) for packaging materials is a measure of their resistance to the flow of moisture through the packaging material itself (Fig. 1.10).

In a pack of ready-to-eat cured meat the package may have been created with a modified and protective atmosphere inside to extend the shelf life of the product. Seals here not only have to retain the product and prevent bacterial contamination, they also have to retain the modified atmosphere inside the pack (Fig. 1.11). The important gasses in these systems are carbon dioxide and oxygen. The carbon dioxide needs to stay inside the pack to retain its protective effect and the oxygen needs to be kept out to prevent it facilitating chemical changes and encouraging the growth of bacteria already on the product when it was packed. It can be seen that the requirement for good seals in this scenario is paramount if the food is going to be preserved and be safe to eat. Preventing the migration of carbon dioxide out of the pack is very difficult because of the small molecule size, and preventing the migration of oxygen into the pack is even more demanding as the molecules are even smaller. The partial pressures of these gasses will encourage migration with even the smallest of faults in the seal. So in high-risk modified atmosphere packs the need for a very high level of seal integrity is vital.



Fig. 1.10 The moisture vapour transmission rate will have implications for the quality of dry foods. The packaging material as well as the seals will allow the passage of moisture.

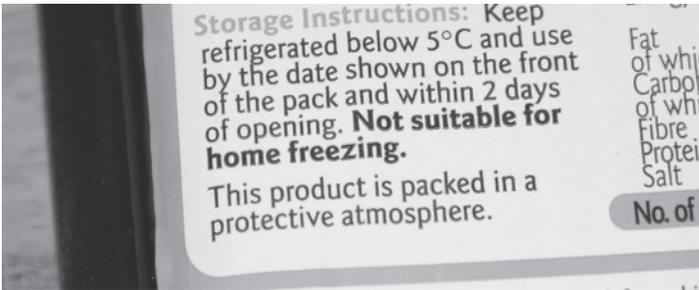


Fig. 1.11 The use of modified atmosphere packaging (MAP) and vacuum packaging puts very high demands on the integrity of the seals in the pack. Poor seal integrity would lead to gas exchange with the atmosphere outside of the pack and possible consequences for the shelf life and safety of the product.

1.8 So ... what is a good seal?

It can be seen from the examples above that a good seal is one that is adequate for the job it is required to do. For factories it therefore becomes important that decisions are made on the specification and performance of the seals it is making in its packages. A testing procedure for the seals should be set up to ensure that the factory is not producing seals that are inadequate in terms of their integrity or strength. Finally, the factory needs to set up management and control systems to ensure that if an inadequate seal is made it can be detected and that it is not allowed out into the supply chain (Fig. 1.12).

1.9 Seal management in a packing operation

In order for a factory to consistently produce seals that are adequate for the requirements of the product inside the pack, adequate for the logistics operation in the supply chain and adequate for the retail and domestic use and display of the product, a seal management system needs to be operated. A correctly designed seal management system will ensure that the packages produced meet the required standard in terms of seal strength and integrity and that the procedures in the factory are robust and able to detect a problem when it arises.

1.9.1 Setting the required standards

The first step in seal management is to ensure that clear standards are set for the performance and testing of the seals being produced. Typically, this means that performance standards are set within a defined and standardised test. International standards have been developed for the testing of heat seals and these are a good starting point, especially if the business has more than one factory, but working to standards set by ASTM International (formerly the American Society for Testing and Materials) can be good practice and ensure that your seals meet an internationally recognised standard.

1.9.2 Second step – set up a testing system for seals in your business

Calibration of testing equipment is always a good initial step in developing a testing procedure. We will see in Chapter 5 that this is not always carried out in a robust way. The use of the ‘manual squeeze test’ for checking packs is always an inadequate test. There needs to be some actual measurement here if good seal performance is to be obtained. Once a testing system has been developed, the standards of what is acceptable can be set. Typically a seal test would consist of a measure of the seal strength – maybe a peel test where the amount of force required to peel the seal apart is measured – and a test of the seal integrity – a leak test where perhaps the pack is placed in a vacuum tank and held under water (Fig. 1.13; the operator of the test is looking for bubbles from the pack), the pack is inflated and a pressure decay looked for or the pack is cut open and a dye is placed inside the pack (if the dye leaks out through the seals it indicates a problem). All of these tests are ‘off line’ and are maybe carried out every 15 or 20 minutes on single packs. The tests are also destructive in nature so not every pack can be tested. There is an increasing amount of attention being paid now to ‘on-line’ 100% inspection systems for the non-destructive testing of seals. The 100% testing systems fall into four groups.



Fig. 1.13 Typical leak testing equipment to establish if the seals being made meet the required performance. There are many types of testing equipment available. Important is that the tests are carried out in a standard way, that the equipment is calibrated and that corrective action is taken if the results of the tests indicate that there may be a problem with the seal strength or integrity. (Pictures by kind permission of RDM Test Equipment Ltd.)

1.10 Testing systems

1.10.1 Mechanical squeeze test

This is where the pack is squeezed mechanically and a movement in the pack is detected by the testing machine. This can be done using a converging roller system above and below the pack or with a ram system where a flat plate is pushed into the pack and the resistance of the pack is measured. If the resistance of the pack to the push declines then it indicates a leaking pack.

1.10.2 Sniffer systems

These are where a tracer gas is placed inside the pack when the pack is sealed and then the presence of the gas outside the pack after sealing indicates a leaking pack. The trace gas is typically carbon dioxide, which is used in modified atmosphere packaging systems, but other gasses have also been introduced into packages with the sole purpose of using them to help detect leaks. This area will be explored further in the final chapter of this book, which looks at innovations and new developments.

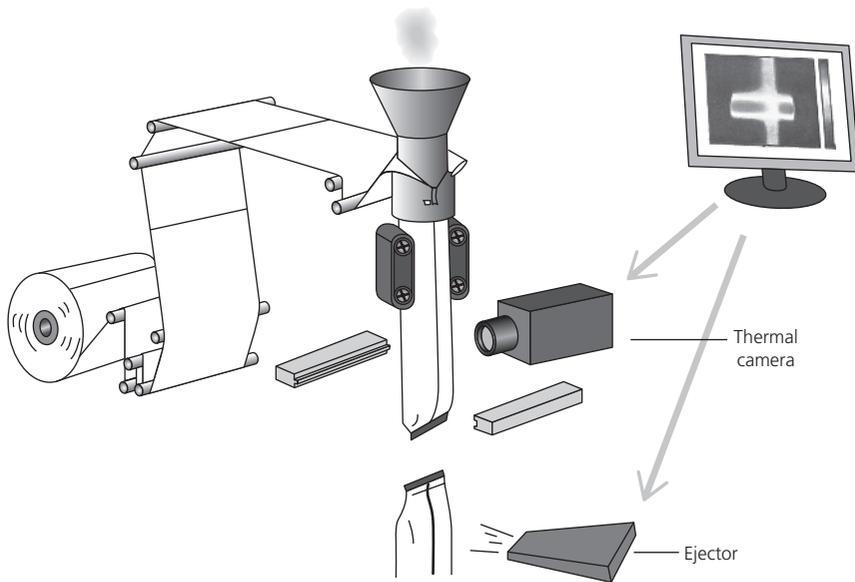


Fig. 1.14 A typical camera system automatically inspecting seals on the exit of a packaging machine. (Picture by kind permission of RDM Test Equipment Ltd.)

1.10.3 Vision systems

These are where cameras mounted above the out-feed conveyors of a sealing machine capture images of each pack and then a computer analyses each image looking for indications of anomalies in the seal area (Fig. 1.14). The vision system can use normal light to inspect the seals or it can use X-ray or the infrared spectrum to carry out the inspection.

1.10.4 Ultrasound systems

These are where the echo bouncing back from a pack is analysed allowing for seal integrity issues to be detected. The ultrasound creates an image of the seal and can therefore be used to detect anomalies in the seal area. Image capture time and image processing speed are improving, so while initially the system was used off line, it will soon be able to match packing speeds, allowing it to be applied in real time.

All of these on-line systems are subject to error and will generate false positives (saying there is a problem when the seals are fine) and false negatives (not detecting a seal fault when one is present), so the systems need to be calibrated and regularly checked to make sure they are working correctly. Where 100% inspection systems are used, the checking and calibration of them forms a very important part of the seal management in the factory.

1.11 How is a good seal made?

The sealing of flexible and semi-rigid packages can be carried out in a variety of ways. Here are the basic principles of some of the more common methods.



Fig. 1.15 Heated bar sealing. Perhaps the simplest form of generating a heat seal, a heated bar is pressed onto two layers of a thermoplastic and after a short dwell time of around half a second a seal is made. When the heated bar is removed there needs to be a short cooling time of around a quarter of a second to allow the thermoplastic materials to set in their new sealed configuration before any pressure or stress is put onto the seal. In this picture the heated part of the sealing system is covered with a layer of polytetrafluoroethylene (PTFE) tape to stop the thermoplastic from sticking to the heated surfaces of the sealing jaws.

1.12 Heat sealing

This is by far the most common method. Two surfaces of a thermoplastic material are brought together and heat is applied to the material. The thermoplastic material softens and the long chain molecules of the two surfaces join together. Depending on the type of thermoplastic, this joining can be either a chemical bond or a physical interweaving. Heat can be applied in many ways to the packaging materials.

1.12.1 Heated tooling

This is where a pre-heated bar or tool is pressed against the outside of the materials to be sealed (Fig. 1.15). Heat is transferred by conduction to the touching surfaces where the seal is made. This process is quite low cost and straightforward. It does, however, suffer from the slow transfer of heat through the materials, and this is especially important with thicker materials. The heated bar temperatures and the time that they are in contact with the outer surface of the materials can also lead to distortion of the package with some thermoplastics. The heat in the packaging materials also has to be dissipated after the seal is made to prevent the seal opening again because of the continued fluidity of the thermoplastic materials while they are still at elevated temperatures.

1.12.2 Induction sealing

This is a system often used to seal caps onto plastic bottles. A magnetic coil is used to create a magnetic field that induces an electrical current in a foil layer of the cap. The induced electrical current produces resistive heating in the foil layer and

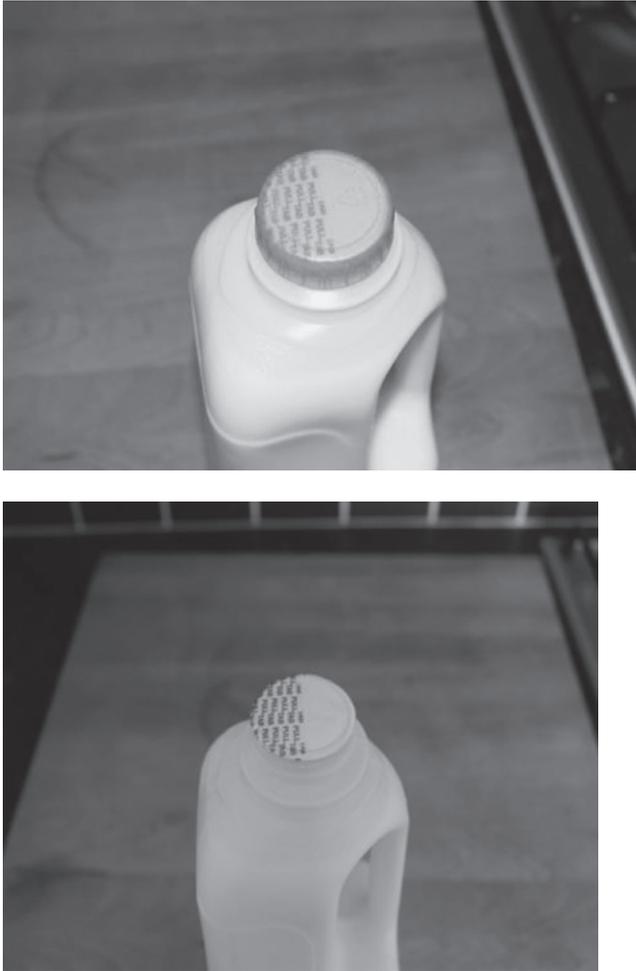


Fig. 1.16 An induction sealing system where a magnetic field induces an electrical current in a thin layer of foil. The subsequent heating is used to seal two thermoplastic layers together. This system is typically used in the sealing of plastic milk bottles.

this heat is then passed to a thermoplastic layer of the cap. The heat is then sufficient to soften the thermoplastic and cause a seal to be made (Fig. 1.16).

1.12.3 Ultrasonic sealing

Sound in the frequency between 20 and 40 kHz is used to create friction between two layers to be joined. The ultrasonic vibrations generate heat in the material surfaces so that a seal can be made. Energy is introduced into the seal area using an ultrasonic horn and anvil which causes local rises in temperature resulting in the seal. The vibrations have also been observed to move seal area contamination

out of the way, so this method is claimed to be better than conventional heat sealing at forming reliable seals in circumstances where a lot of seal area contamination occurs.

1.12.4 Spin welding

Here friction between two layers to be joined is used to generate heat and therefore a seal. The two parts to be sealed are pushed together and spun in opposite directions to generate the heat required. By definition, here the parts being joined have to be circular. This system is used, for example, to seal together the two halves of the widget that is used in the packaging of some canned beer.

1.12.5 Hot gas/radiant heat sealing

Here the surfaces to be sealed are heated by either hot air or radiant heat and then, when the thermoplastic has softened, the surfaces are pushed together. This system is often used with thicker packaging materials where waiting for the heat to conduct through the material is not an option. Packing that is made up of multilayer laminates that include cardboard are often sealed this way. If the heat was applied to the outside of the material then the outside would be damaged before the inside had reached a sealing temperature. Drinks cartons and sandwich packaging can be sealed in this way.

1.13 Non-heat sealing methods

Other non-heat methods of sealing are also employed and should be included here for the sake of completeness.

1.13.1 Cold sealing

This is a method of sealing a package that relies on the use of a latex cohesive layer applied to the packaging material. The surfaces are pressed together and the cohesive latex seals them. This is typically used with confectionery and ice cream products where the application of a heat sealing process may cause quality issues with the product (Fig. 1.17).

1.13.2 Adhesive sealing

In some applications an adhesive is used on one of the surfaces to make a closure. The adhesive is typically a hot melt and is used to seal cardboard cartons in the frozen and chilled food industry where perfect seal integrity is not required.

1.13.3 Solvent sealing systems

In these systems a solvent is used to break the intermolecular bonds in the surface of the plastic materials. Once the solvent is applied, the surfaces are pressed together and the molecules form new bonds with molecules from the other

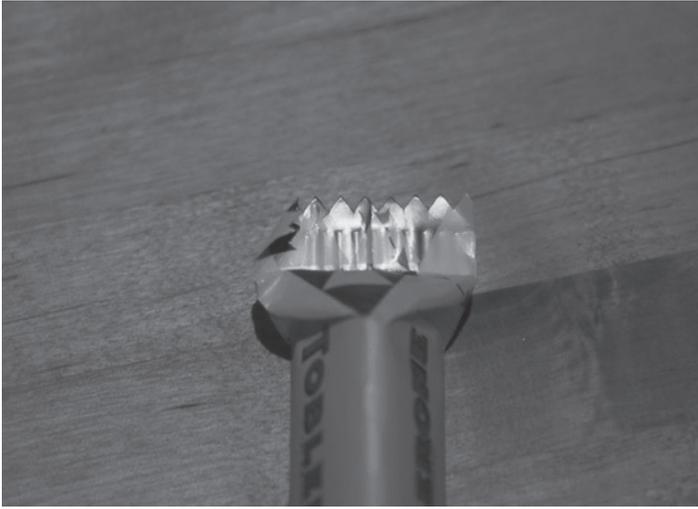


Fig. 1.17 The cold seal latex adhesive on the seal areas of a confectionery pack.

surface. This molecular bonding technique is very specialised but is used in some aspects of product packaging.

1.14 Packaging materials

So far we have briefly introduced sealing systems and some of the background of packaging. One important aspect of packaging systems is the packaging materials. There is a vast range of packaging material types, so first we will look at the important parameters when considering this aspect of sealing. We look in detail at materials later in the book, but here is an introduction to some of the factors that need to be considered.

1.15 Sealing parameters

There are several characteristics of packaging materials that need to be considered when selecting the best solution to match a need.

1.15.1 Sealing temperature

Thermoplastics of different chemical make-up and different structures have different melting points. The melting point of a thermoplastic is the point where the intermolecular bonds are reduced and the plastic takes on the behaviour of a liquid. In packaging we want the thermoplastic to start to loosen the intermolecular bonds to facilitate the sealing process but we do not want liquid behaviour.

The sealing temperature is one where the intermolecular bonds in the thermoplastic loosen and molecules at the surface of the material are able to intermesh or chemically bond with molecules from the surface of the other piece of packaging material. Sealing temperature is really a small range of temperatures over which the desired seal can be made without the thermoplastic distorting or becoming so heated that the structure of the material is fundamentally changed. We will look again at the thermal properties of packaging materials later in the book as an understanding of packaging material behaviours is important.

1.15.2 Flow characteristics

When seals are made the softened surfaces of the thermoplastics are pushed together to give a good contact and the opportunity for the required intermolecular entanglement and chemical bonding to occur. If the seal area is contaminated then the two surfaces will not be able to join together. Some packaging materials have been designed with high-flow thermoplastics at the sealing surface. The plan with this type of design is that the thermoplastic material (in its semi-liquid state) will flow as the materials are forced together. The flow of the thermoplastic is designed to move seal area contamination away from the seal area and allow a good seal to be made. Packaging materials are designed to have certain sealing and flow characteristics by the manipulation of the chemistry and structure of the material. Often different types of thermoplastic materials are blended to give the required melting and flowing properties. These co-polymers mean that packaging materials can be designed to exactly meet the requirements of the business using them. Obviously, the more specialised the requirement the more expensive is the material but it is possible to fine tune the packaging materials to meet the needs of the business. Where more flow is required it is possible to increase the thickness for the material in a multilayer laminate to give more moving thermoplastic material and as a result sweep more contamination from the seal area. Where the flow of the thermoplastic is too great (maybe due to excessive dwell time) there is a quality fault called 'angel hair' where the thermoplastic exudes from the material and adheres to the sealing jaws. As the jaws pull away from the pack at the end of the dwell time the exuded thermoplastic is drawn out into very thin strands that look like hair. If there is an excessive or unusual quantity of angel hair on the jaws of your system it indicates excessive temperatures or dwell time.

1.15.3 Surface printing

Materials exhibit different qualities for printing on. Some materials accept inks very well and are able to hold a high-definition multicolour image. Other materials produce printing results that are not so good. Inks can migrate through packaging materials and this needs to be understood and defined when selecting packaging materials. The final part of printability of packaging is where the print occurs in the same area that a seal is going to be made. The impact of the ink on the sealing process needs to be understood as often when heated tools are used to form a seal on a printed surface the ink can transfer to the tool and build up over a period of

time. This can have the impact of reducing the heat transfer to the seal areas and ultimately can cause the seals to become weaker and fail.

1.15.4 Material strength

Different packaging materials have different strength characteristics and resistance to damage. Some thermoplastics are quite stretchy at room temperatures but become less so in a chilled or frozen environment. Some materials exhibit very good puncture resistance and others less so. There is a particular property of thermoplastics that needs to be considered: tear propagation. This concerns whether, when the sachet is opened by tearing across the top, the tear goes in a straight line or whether the propagation is random such that it could lead to the contents of the pack being wasted. This property can have big implications for the design of the packing system as well as for the accessibility of the pack to the consumer. The strength of a pack needs to be adequate to withstand the handling it will receive in distribution and retail display. Sometimes the pack material is strong enough before sealing but after the heating and cooling the material strength can change and as a result the material can become weaker and more liable to fracture.

1.15.5 Material structures

There are a large number of multilayer packaging materials. These are sometimes called laminates and they consist of different layers each of which brings its own characteristics to the packaging material. Some layers add strength and puncture resistance, other layers bring an oxygen barrier and, finally, some layers are put into the laminated material to impart sealing characteristics.

There has been a recent trend towards single-layer packing materials to improve recycling, and these materials have to carry out all of the required functions. These are often called mono-layer packaging materials.

With respect to sealing characteristics, there are some important parameters that need to be considered and the choice of materials used is based on the performance of different thermoplastics within these parameters (Fig. 1.18).

| Material | Clarity | MTR | OTR | Impact strength | Tg | Tm |
|----------|-----------|-----|------|-----------------|-----|-----------|
| PET | Excellent | 2 | 75 | Good | 80 | 250 |
| HDPE | Poor | 0.5 | 4000 | Good | -30 | 135 |
| PP | Poor | 0.5 | 4000 | Fair | -20 | 165 |
| PS | Excellent | 10 | 6000 | Poor | 100 | Amorphous |
| PLA | Very good | 22 | 42 | Good | 55 | 180 |

Fig. 1.18 Table of typical packaging thermoplastics with some indication of their performance in different parameters. The use of polymer mixtures can change these performance numbers radically so this table is intended as a guide only. More details of packaging materials are contained in Chapter 7. Tm is the melting temperature but the material does not have to be melted to create a seal. Tg is the so-called glass transition where the material starts to become more flexible as the intermolecular structures break and flex.

1.16 Packaging systems

Packages are made in many different ways and a wide variety of technology is used to improve packaging system performance. Some believe that high-speed packaging machines are the ultimate in interaction between a machine and a material, and many design solutions have been developed to produce the highest performing system.

1.16.1 Bag-making systems

Sometimes called vertical form fill seal (VFFS) systems, this is the single most popular way of pre-packaging products in the world. This is the type of system used for the packaging of snack foods, confectionery, frozen vegetables and breakfast cereals. A packaging material is delivered to the packing factory in the form of a reel of plastic film. The film is formed into a tube and the back seal of the bag is made. Next, product is delivered down the tube and sealing jaws close to seal the top of the bag. Simultaneously, the sealing jaws seal the bottom of the next bag and cut the film to release the filled bag. These machines can run very quickly at speeds close to 200 packs per minute on certain products, and so the time available to make a seal is very short (Fig. 1.19). As a result of the short time available it is important that the materials being sealed (the inside surfaces of the packaging film) have the correct characteristics to make a good pack with adequate seals. If the inner, sealing, surfaces are made of the wrong materials the packaging speed will be slowed down and reject packs will be made. One possible response in these circumstances is to increase the temperature of the sealing jaws to drive more heat into the sealing area. This may well result in seal area distortions and the pack looking scruffy and overheated.

1.16.2 Pouch sealing systems

This is a system often used in the creation of food pouches for pet foods or microwave rice packs. These products are both long life and displayed at ambient temperatures so seal integrity is very important to the quality and safety of the food. Often in these systems three sides of the pouch are made and sealed in a separate process (often in another factory or even in another country). The preformed pouch is fed into the filling machine, opened, filled and then the top seal is made. These products are then further processed using retorts to cook the contents of the pouch. Again there are many forms of machine to fill and seal pouches but they all have the same need to fill the pouch without contaminating the seal area. The pouches are usually made of quite thick materials (often multilayer laminates) and so the heating of the thermoplastic to make the seal can take some time. The seal also retains its heat after sealing so often there is a need to cool the seal area to return the thermoplastic layer to a more stable temperature before any pressure is put onto the seal.



Fig. 1.19 A typical VFFS bag-making machine. This one is a large-scale machine capable of packing 5 kg of potatoes at around 40 bags per minute. Other machines are used for high-speed packing of snack foods with speeds approaching 200 bags per minute.

1.16.3 Tray sealers

This is a system where a preformed tray is sealed with a thin film lid (Fig. 1.20). It is a very popular packaging format in the ready meals industry. There is a difference between this system and the previous one. In this system we have two materials of different thickness being joined together and this presents some issues when it comes to heating the seal area. In this system the seal area tends to be heated from only one side and this has an impact on the temperatures reached and the speed of operation. A cycle time on a machine to seal trays would be typically 4 seconds with a seal time of around 1 second. To increase the output of the machine to higher numbers of trays per minute, machines have increased in size and are sealing multiple trays at the same time. The bag maker and the pouch sealer typically seal just one package at a time.

1.16.4 Horizontal form fill seal (HFFS) systems

This is a system where the tray is thermoformed on the machine rather than the tray being preformed in a supplying factory (Fig. 1.21). These systems are widely used for the packaging of sliced meat and cheese products. The same



Fig. 1.20 A typical tray sealing system used widely for ready meal packing as well as fresh poultry portions. (Picture by kind permission of Proseal Ltd.)



Fig. 1.21 A typical HFFS used widely for the packaging of sliced products including ham, bacon and sliced cheese products. (Picture by kind permission of Multivac UK Ltd.)

considerations apply here in terms of sealing the packs as apply to preformed trays. The heat is typically applied from one side only so time is needed for a good seal to be made. The rate-limiting step on a thermoforming machine is typically the forming of the trays.

1.16.5 Flow wrapping system

This is a high-speed system used in many parts of the food industry to contain and protect products. The system is most popular with solid single items like confectionary bars, meat pies and even pizzas but has also been developed using trays

and backing boards to be able to wrap multiple items such as crumpets, biscuits and sausages. The latest innovation in this system of packaging has been to use it to wrap minced beef in a modified atmosphere to help reduce the packaging weight of the traditional packing method of a sealed tray.

There are other packaging formats that will be covered later in the book, especially those that are common in the dairy and beverage industries.

All packaging formats and systems that rely on the effect of heat on a thermoplastic to generate a seal (no matter how that heat is applied or generated) suffer a similar set of issues during the formation of the pack that can compromise the integrity or strength of the seal. We will look in detail later at the major causes of seal integrity issues but suffice it for now to point out that on high-speed packing machines, using defined thermoplastics and with defined machine settings and tolerances, it does not take much to disturb the interaction between machine and packaging material and as a result a faulty pack can be made.

1.17 The requirements of industry for seal integrity in its packaging systems – an overview

1.17.1 Safety

The integrity of a pack is paramount to considerations of food safety. The risk of product contamination with bacteria or other substances is a huge consideration in many markets but especially for food and beverages. Poor seal integrity can result in consumer complaint or illness with a consequent negative impact on brand image. Loss of business and bad publicity are strong possibilities if seal integrity is not managed correctly within a food manufacturing business.

1.17.2 Containment

The prevention of leaks from packages is an obvious and visible requirement in distribution chains. If product is able to escape from a package then the package becomes unsellable and there is also the knock-on effect on neighbouring packages causing them to become unsellable too (Fig. 1.22).

1.17.3 Shelf-life extension

Some products can retain their quality and safety for longer if the package is fully sealed and seal integrity is good. Snack foods are often packaged in a low-oxygen atmosphere to reduce rancidity and flavour changes in the product over time. If the package is not fully sealed then the protective atmosphere inside the package may leak out leaving the way clear for the ingress of oxygen and moisture. As a result, the snack food may become stale more rapidly than expected and become unsellable.

Without the modified atmosphere being correctly sealed into the pack its protective effect is quickly lost, so the product is likely to be of lower quality or even dangerous at the end of the shelf life.

Shelf-life extension is also a feature of non-MAP (modified atmosphere packaging) systems. The correct protection in an adequately sealed package can extend



Fig. 1.22 A leaking yoghurt container will spoil the rest of the pots in the case, so one leaking container can cause more waste than just that one container. Sometimes whole pallets of product are wasted because of spillage from one container. This is especially the case with something like vegetable oil or beetroot, for example.

the life of everything from a cucumber, by reducing moisture loss and slowing respiration, to biscuits, by reducing moisture pick-up.

1.17.4 Seal strength

A seal needs to have sufficient strength to withstand the rigours of logistics and retail display. A weak seal leaving your factory could fail and as a result cause an issue in the supply chain even though the pack was sealed when it was made. There is a compromise between seal strength and the openability of a package and this is why seal strength measurements should be undertaken as well as seal integrity measurements (Fig. 1.23).

1.17.5 Accessibility

One of the major sources of consumer complaint to retailers is customers who are unable to gain access to the contents of a package without having to attack the pack with sharp implements (Fig. 1.24). Injuries caused by inaccessible packaging are a major concern, especially as the population in the developing world gets older and dexterity becomes a bigger problem. Packages are being designed with easy-open features to try to help with the balance that is required between seal strength and accessibility. Accessibility is especially an issue with meals that are reheated in the home inside the packaging. Peeling the lid from a tray of curry as it is taken from the microwave oven can be difficult enough, but a real safety issue can occur if the lid of the tray is firmly attached to the tray. The potential for burns and scalds is a risk that should be taken into account in packaging design and in the operation of the sealing systems. It is important to make sure the pack performs as required when it is in the hands of the consumer.



Fig. 1.23 A typical method of measuring seal strength using a peel test. The force required to peel the seal apart is measured to check it meets the requirements of being strong enough to pass through logistics and retail sale while at the same time allowing the consumer to open the pack. (Picture by kind permission of RDM Test Equipment Ltd.)



Fig. 1.24 Frustrated consumers complain in large numbers if the packaging is not correct on the products they buy. Too weak and leaks occur on the way home from the shop. Too strong and injuries can be caused trying to get into the pack.

1.17.6 Display attractiveness

With modern retail methods and the competition for shelf space the attractiveness of a package on the shelf can be the difference between making a sale or not for your product. A well-designed pack can be rendered unsellable by a poorly formed seal. The seal could be perfectly sound in terms of its strength and integrity but if it

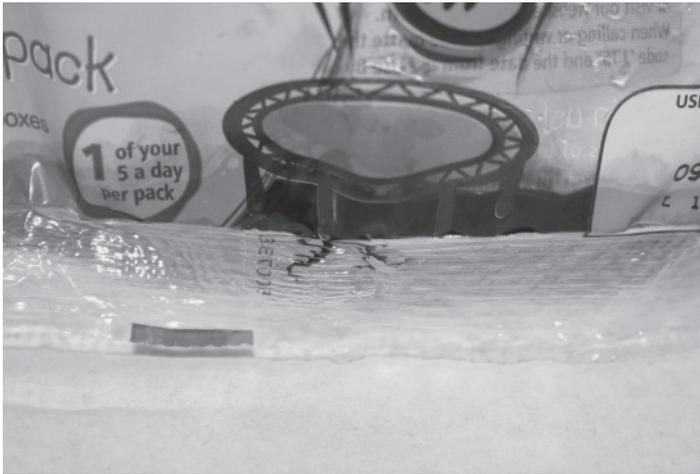


Fig. 1.25 Here is an overheated seal on a product. It looks scruffy as the thermoplastic materials have been made too hot. As a result, as the thermoplastic cooled it formed crystals in its structure making the material hard and brittle. This is a common problem in some industries where poorly trained packing machine operators feel that the correct response to poor seals is to turn up the temperature of the heat sealing system – it's their 'go to' response to weak seals. The true cause of the sealing problem is never investigated and as a consequence the root problem is never eliminated. This picture also shows that a dye that has been placed inside the pack is starting to leak out in the centre of the pack. So the high temperature has not solved the leaking pack issue.

looks like there has been a problem with the package there is a chance that the pack will not be selected by the shopper (Fig. 1.25).

1.17.7 Portion control and multi-compartment trays

Some pack designs require good seals in order to control portions and doses. Multi-chamber packaging with individual portions is a growing trend to try to assist the consumer in the use of the product. The seals made on a pack are not always just around the perimeter. They are sometimes required to keep the components of a product separated until the point of opening and use. For example, yoghurt may need to be kept separated from crunchy pieces until the consumer is ready to eat the product; a sauce may need to be kept separated from rice or pasta in a ready meal. Checking the seal integrity of the internal seal will be impossible without destructive testing, so techniques need to be developed to allow routine checks to occur and to ensure that all is as it should be.

1.17.8 Consumer confidence

Pre-packaged products are purchased by consumers partly because they have confidence in what is inside the package. They know that their product has not been tampered with and it has been sealed to give them that confidence. If a package is

discovered to be not sealed correctly then all confidence in the contents of the package can be lost. If pack seals are not adequate the product is left liable to damage and deterioration, and the consumer is aware of this. Sealed packages are a major feature of modern retail systems for a wide variety of products from food to DIY and from pharmaceuticals to consumer electronics. The seal is a major part of what is being purchased in the eyes of the consumer. Without the seal being in place the consumer will treat the product inside the package with some level of suspicion. A consumer is buying more than just the contents of a package; they are buying confidence in the contents, and good seals are an important aspect of that customer assurance.

1.18 Industry sectors – some recent increases in seal performance requirements

Pharmaceuticals and foods are the major consumer goods sectors where seals are important to the physical, chemical and biological safety and the quality of the product in the pack, but packaging seals are also important in the very function of some products. Innovation in the coffee market has brought forward a group of products that could be described as coffee pods. Without seals of exacting specifications the pods would not function correctly and the product would not be possible at all. The creation of multi-chamber washing detergent pods has a similar requirement. The phased release of the washing chemicals during the wash cycle could not work without correct sealing both internally and externally. The creation of new packaging formats and new packaging materials often hinges on the basic requirement of creating a reliable and predictable seal. There have been recent examples where new packaging materials were developed which were fully compostable so that they would break down in landfill or anaerobic digestion systems and would be more environmentally friendly as a result. The new materials proved difficult to use because the packing material was not as tolerant of temperature variations on the sealing machines. Slightly too cold and a seal was not made. Slightly too hot and the same thing happened. To use this type of material new control systems had to be developed for the sealing machines to keep the sealing temperatures in a much tighter tolerance than had previously been required with conventional thermoplastics. Some products rely on good seal integrity for their very existence. Without good reliable seals there are a number of product groups that could not exist. Equally, there are product groups for which seal integrity is so vital to the shelf life of the product that the economic viability of that whole category would not work. Waste would greatly increase and on-shelf availability would decrease; consumers would be unwilling to pay the higher prices that would result. An example here is the supply of sliced cured ready-to-eat meat products. Without good seal performance the shelf life of the product is considerably reduced to the point of being unviable.

1.19 Making changes to packaging materials or systems

It is vital that if any changes are planned with either a packaging material or a packing machine that the implications of the change are fully explored. It is possible that even a minor change could have unpredicted consequences and as a result put consumers and company reputations at risk.

For example, a simple move to make some packaging thinner to reduce the waste implications when the product is used – called ‘light-weighting’ – can have implications for the packaging system where its performance could change because of the thinner gauge materials being used. It could also have implications for the shelf life of the product, with increased oxygen and moisture transmission rates. As a result of the unpredicted changes, the costs of the increasing waste from the packing operation, the supply chain and the consumer could exceed the saving made in packaging weight. So any change in packaging should be fully assessed with a complete analysis of all the possible implications before the change is confirmed. Making changes to packaging systems has to be carefully considered to ensure that the seals, a vital component of the package, are not impacted by any changes. This lesson was learned during changes for the fresh produce industry. Many companies discovered difficulties in sealing PLA (polylactic acid) packaging materials when changes were made. The reason for the change was that PLA was seen as being compostable material and beneficial to the environment, but the change caused an initial large increase in sealing problems and consequent increase in waste.

Even a change of supplier has to be carefully tested to ensure a predictable performance is achieved. Thermoplastic materials from different suppliers will have different packaging performance even for materials that are called the same thing. There are wide variations in material performance and temperature/time requirements for something that is notionally the same material. This is caused by slight differences in processing and storage conditions at different suppliers. So while the chemistry says it's the same material, its ability to produce the same seal characteristics is not the same. This is especially the case where recycled materials are used in a package. As the proportion of recycled materials is increasing there is a tendency for the variability of sealing performance to increase also.