There have been significant developments in packaging systems during the last ten years, prompted by a number of considerations, for example:

- marketing requirements for different, more attractive packs
- reductions in pack weight to reduce costs and meet environmental concerns over energy and material consumption (Chapter 24)
- new packaging requirements for minimally processed foods (Chapters 9, 18, 19) and modified atmosphere packaging (Chapter 20)
- the need for new types of tamper-resistant and tamper evident packs.

Packaging methods that have been developed to meet these requirements are described in subsequent sections.

Accurate filling of containers is important to ensure compliance with fill-weight legislation and to prevent ‘give-away’ by overfilling. The composition of some foods (for example meat products such as pies and canned mixed vegetables) is also subject to legislation in some countries, and accurate filling of multiple ingredients is therefore necessary.

The maintenance of food quality for the required shelf life depends largely on adequate sealing of containers. Seals are the weakest part of a container and also suffer more frequent faults during production, such as food trapped in a seal, incorrect sealing temperatures or can seamer settings. In this chapter the techniques used to fill and seal rigid and flexible containers are described. By themselves these operations have no effect on the quality or shelf life of foods, but incorrect filling or sealing has a substantial effect on foods during subsequent storage.

### 25.1 Rigid and semi-rigid containers

‘Commercially clean’ metal and glass containers are supplied as palletised batches, which are wrapped in shrink or stretch film (Section 25.1.3) to prevent contamination. They are depalletised and inverted over steam or water sprays to clean them and they
remain inverted until filling to prevent recontamination. Wide-mouthed plastic pots or
tubs are supplied in stacks, fitted one inside another, contained in fibreboard cases or
shrink film. They are cleaned by moist hot air unless they are to be filled with aseptically
sterilised food (Chapter 12), when they are sterilised with hydrogen peroxide. Laminated
paperboard cartons are supplied either as a continuous reel or as partly formed flat
containers. Both are sterilised with hydrogen peroxide when used to package UHT
products.

25.1.1 Filling
The selection of an appropriate filling machine depends on the nature of the product and
the production rate required. Gravity, pressure and vacuum fillers are each used for liquid
foods and are described in detail by Osborne (1980). In each case an airtight seal is made
between the container and the filling head, and liquid is filled until it reaches a vent tube,
which is set to give the correct fill-weight or volume.

Volumetric fillers (for example a piston filler (Fig. 25.1)) are commonly used for
liquids, pastes, powders and particulate foods. The filling heads are either in line or in a
'carousel' (or rotary) arrangement.

Large particulate materials (e.g. confectionery, tablets, etc.) can be filled into
containers, using a photo-electric device, similar to a sorter (Chapter 3) to count
individual pieces. Alternatively, a disc fitted with recesses to hold an individual item
rotates below a holding container and when each recess is filled the required number are
deposited in the pack. Smith (1999) describes developments in multi-head weighers that
are able to weigh different products simultaneously, prior to filling into the same
container. Examples include pre-packed mixed salads, mixed nuts and mixed selections
of confectionery.

Containers can also be filled by weight using either a net-weight or gross-weight
system. In the former, the weighed product is filled into a container and sealed, whereas
the latter system weighs the product plus package before sealing. Both systems use
microprocessors to control the rate of filling and final fill-weight (also Chapter 2). A bulk
feeder is used to quickly fill a pack to approximately 90% full, and it is then weighed.
The controller calculates the exact weight of material remaining to be filled and activates
a fine feed to top up the pack and re-weigh it. The microprocessor monitors the number of
packs and their weights, to produce a statistical record of fill weight variation.

All fillers should accurately fill the container (±1% of the filled volume) without
spillage and without contamination of the seal. They should also have a 'no container-no

Fig. 25.1  Piston filler.
fill’ device and be easily changed to accommodate different container sizes. Except for very low production rates or for difficult products (for example bean sprouts), fillers operate automatically to achieve the required filling speeds (for example up to 1000 cans per minute using rotary fillers).

Hermetically sealed containers are not filled completely. A headspace (or ‘vacuity’, ‘expansion space’ or ‘ullage’) is needed above the food to form a partial vacuum. This reduces pressure changes inside the container during processing and reduces oxidative deterioration of the product during storage (also Chapter 12). Glass containers and cans should have a head space of 6–10% of the container volume at normal sealing temperatures. Care is necessary when filling solid foods or pastes, to prevent air from becoming trapped in the product, which would reduce the head space vacuum. Viscous sauces or gravies are therefore added before solid pieces of food. This is less important with dilute brines or syrups, as air is able to escape before sealing. The functions of these added liquids are as follows:

- to improve the rate of heat transfer into solid pieces of food
- to displace air from the container
- to improve flavour and acceptability
- to act as a medium for adding colours or flavours.

The proportions of solid and liquid components in a container are also subject to legislation or trade standards in many countries.

25.1.2 Sealing

The requirements of closures for glass containers are described by Moody (1970) and Osborne (1980). Containers that are designed to enable consumers to use the contents a little at a time create a difficulty in ensuring that they are tamper-proof before opening and developments in tamper-evident closures are described in Section 25.3. Glass containers are sealed by one of the following types of seal (Fig 25.2).

- **Pressure seals** are used mostly for carbonated beverages. They include:
  - screw in (internal screw) screw out, or screw on screw off
  - crimp on lever off, crimp on screw off, or crimp on pull off
  - roll on (or spin on) screw off.

Examples include cork or injection-moulded polyethylene stoppers or screw caps, crown caps (pressed tinplate, lined with cork or polyvinyl chloride) or aluminium roll-on screw caps.

- **Normal seals** are used, for example, for pasteurised milk or wine bottles. There are many different types of seals including:
  - one or two-piece pre-threaded, screw on, screw off
  - lug type screw on, twist off
  - roll on (or spin on), screw off
  - press on, prise off
  - crimp on prise off, or crimp on screw off
  - push in pull out, or push on pull off.

Examples include cork or synthetic cork stoppers fitted with tinned lead, polythene or aluminium capsules, metal or plastic caps, and aluminium foil lids. Plug fittings
514 Food processing technology

Fig. 25.2 Lids for glass and plastic containers: (a) twist-off; (b) lug cap; (c) Omnia; (d) pry-off; (e) lever cap; (f) screw cap; (g) ROPP; (h) flanged cork; (i) hinge-open, snap shut, (j) sealing points on hinge-open, snap shut lids, (k) pre-threaded closure.
(After Hersom and Hulland (1980), Paine (1991) and Moody (1970).)
are made from injection moulded LDPE and have the required softness and flexibility to form a good seal.

- **Vacuum seals** include
  - screw on twist off
  - press on prise off, or press on twist off
  - two-piece screw on screw off, or roll on screw off
  - crimp on prise off.

They are used, for example, for hermetically sealed containers for preserves or paste jars.

Can lids are sealed by a double seam in a seaming machine (or ‘seamer’). The ‘first operation roller’ rolls the cover hook around the body hook (Fig. 25.3(a)) and the ‘second operation roller’ then tightens the two hooks to produce the double seam (Fig. 25.3(b)). A thermoplastic sealing compound melts during heat processing and fills the spaces in the
seam, to provide an additional barrier to contaminants. The can seam is the weakest point of the can and the seam dimensions are routinely examined by quality assurance staff to ensure that they comply with specifications (Table 25.1).

Free space is calculated using:

\[
\text{Free space} = \text{seam thickness} - \left[2t_b + 3t_e\right] \quad 25.1
\]

and

\[
\text{Percent Body Hook Butting} = \left[\frac{x - 1.1t_b}{L - 1.1(2t_e + t_h)}\right] \times 100 \quad 25.2
\]

Actual overlap = \(y + x + 1.1t_e - L\) \quad 25.3

where \(x\) (mm) = the body hook length, \(y\) (mm) = the cover hook length, \(t_e\) (mm) = the thickness of the can end, \(t_b\) (mm) = the thickness of the can body, \(L\) (mm) = the seam length and \(c\) (mm) = the internal seam length.

Different types of easy-open end are fitted to cans, depending on the product: ring pull closures are used for beverages, and different designs retain the ring pull within the can after opening to reduce litter problems. Full-aperture ring pull closures are used, for example, for meat products, snackfoods and nuts. Both types are produced by scoring the metal lid and coating it with an internal lacquer. A metallised peelable plastic strip is used to close cans of non-carbonated non-pasteurised beverages (Malin, 1980). In aerosol cans, a pre-sterilised top is seamed on, and a pre-sterilised valve is fitted. The can is then dosed with gas and pressure checked. A cap is fitted onto the valve and finally an overcap covers the valve assembly.

Aluminium collapsible tubes are sealed by folding and crimping the open end of the tube after filling. Polyethylene or laminated plastic tubes are sealed using a heat sealer, which may also cut a hanging slot in the tube for retail display.

Wide-mouthed rigid and semi-rigid plastic pots and tubs are sealed by a range of different closures, including push-on, snap-on or clip-on lids, membranes made from aluminium foil laminates or thermoplastic films, and push-on or crimp-on metal or plastic caps (Fig. 25.4). Push-on, crimp-on and snap-on lids require a bead at the rim of the container. These closures are not tamper-evident and, although the seal is sufficient to retain liquids, they do not provide a sufficient moisture barrier to protect hygroscopic foods. Membranes are sealed to pots by a combination of pressure and high frequency activation or heating of a heat-seal coating. They are tamper-evident and, depending on the material selected, can be made to provide a barrier to moisture and gases. Where a product is to be used over a period of time, or where additional protection is required for the membrane, a clip-on lid may also be fitted to the pot.

Table 25.1 Seam specifications for selected cylindrical cans

<table>
<thead>
<tr>
<th>Type of can</th>
<th>Dimensions (mm)</th>
<th>Dimensions of seam (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diameter</td>
<td>Height</td>
</tr>
<tr>
<td>A1</td>
<td>65.3</td>
<td>101.6</td>
</tr>
<tr>
<td>A2</td>
<td>87.3</td>
<td>115.3</td>
</tr>
<tr>
<td>A21/2</td>
<td>103.2</td>
<td>115.3</td>
</tr>
<tr>
<td>A10</td>
<td>157.2</td>
<td>177.8</td>
</tr>
</tbody>
</table>

Actual overlap > 1.143 mm, % Body Hook Butting > 70%

* Range of lengths for cover and body hooks.
Adapted from Lock (1969).
Thermoformed pots or trays are filled and then lidded with a web of material that is heat sealed to the top flanges (Fig. 25.5). Small containers such as those used for individual portions for ultra high-temperature sterilised milk, honey or jam, are formed–filled–sealed in a single machine at up to 50 000 containers per hour (Guise, 1985). The equipment can also be easily adapted to produce multi-packs of four to six pots (e.g. yoghurt).

Plastic bottles are sealed using a variety of closures that can be tamper-evident, recloseable or able to form a pouring spout. An example (Fig. 25.6) is suitable for push-on or screw thread bottle necks, for squeezeable bottles that are used to pack creams, oils, sauces or syrups. The caps are made from injection moulded polypropylene, polyethylene or polystyrene (Chapter 24) and have a positive ‘snap-open, snap-shut’ action with a profiled pin to clean the aperture on reclosing. This gives a product seal and also ensures that the aperture is cleaned of product to prevent microbial growth and potential contamination of the product.

Fig. 25.4 Closures for sealing semi-rigid pots and tubs: (a) push-on; (b) snap-on; (c) crimp-on metal caps.
(Courtesy of UG Closures and Plastics.)
In each case the seal is formed by causing a resilient material to press against the rim of a container; the pressure must be evenly distributed and maintained to give a uniform seal around the whole of the cushioning material that is in contact with the rim. Typically, a resilient material is stamped out of composite cork or pulpboard sheet, and protected with a facing material (e.g. PVC, PE, EVA) to prevent any interaction with contents (together these are termed the ‘liner’).

The tightness with which the cap is fitted to a container is known as the \textit{tightening torque}, and with rolled-on, crimped-on and pressed-on caps, the effectiveness of the seal depends on pressure exerted on top of the cap during the sealing operation. To avoid the need for undue pressure, the width of the sealing edge is kept as narrow as possible. Glass bottles and jars have a narrow round sealing edge, whereas plastic bottles have flat sealing edges. Two other important considerations for caps are the \textit{thread engagement} (the number of turns of a cap from the first engagement between the cap and rim, and the point where the liner is engaged with the rim). This should be at least one full turn to allow uniform engagement of liner and rim. The greater the thread engagement, the more effective is the cap tightening torque in keeping it in place. The \textit{thread pitch} is the slope or steepness of the thread. The lower the number of turns, the steeper the slope of the thread and the more rapidly the cap will screw on or off (Paine, 1991).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig25.5}
\caption{Forming–filling–sealing of individual portion pots. (After Briston and Katan (1974).)}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig25.6}
\caption{Snap-on caps for squeezable plastic bottles. (Courtesy of Johnsen & Jorgensen (Plastics) Ltd.)}
\end{figure}
Push-on covers are used for injection moulded pots (for yoghurt, cream, etc.) and jars, often having a tamper-evident foil or diaphragm sealed to the top of the pot.

Cases and cartons
Plain or corrugated cases are first designed to give a flat ‘blank’, which is then cut, creased and folded to form the case or carton. It is important to fit as many blanks as possible to a sheet of paperboard to minimise wastage (Fig. 25.7(a)). Board is printed, cut out using a guillotine either on-site or by the case supplier, and then precisely creased and formed into a carton (Fig. 25.7(b)), which is then either glued or stapled. Different folding carton types are classified by the European Carton Makers Association using an ECMA Code, which also defines how the dimensions should be stated. Details are given by Ramsland (1989).

Multiple packs of cans or bottles are held together by paperboard, formed in a similar way to cartons. These have now been developed to have inter-locking lugs which dispense with the need for staples or glue (Fig. 25.7(c)).

Rigid laminated paperboard cartons have thermoplastic film on the inside. In one system a continuous roll of material is aseptically formed–filled–sealed (Section 25.1.2) whereas, in a second system, pre-formed cartons are erected, filled and sealed in an aseptic filler. In the second system the paperboard can be heavier than in form–fill–seal systems, because it does not require the flexibility needed for the forming machine. As a result the carton is more rigid and particulate foods may be filled without risk of contamination of the seam.

25.2 Flexible containers
Thermoplastic materials or coatings become fluid when heated and resolidify on cooling. A heat sealer heats the surfaces of two films (or ‘webs’) until the interface disappears and then applies pressure to fuse the films. The strength of the seal is determined by the temperature, pressure and time of sealing. The seal is weak until cool and should not therefore be stressed during cooling. Three common types of seal are as follows:

1. bead seals (Fig. 25.8(a))
2. lap seals (Fig. 25.8(b))
3. fin seals (Fig. 25.8(c)).

The bead seal is a narrow weld at the end of the pack. In a lap seal, opposite surfaces are sealed, and both should therefore be thermoplastic. In a fin seal, the same surface of a sheet is sealed and only one side of the film need be thermoplastic. Fin seals protrude from the pack and no pressure is exerted on the food during sealing. They are therefore suitable for fragile foods (for example biscuits and soft confectionery).

Other types of wrapper include aluminium foil for unusual shaped foods (e.g. chocolate Easter eggs) and twist wrapped cellulose film for confectionery.

25.3 Types of sealer
The hot-wire sealer is a metal wire, heated to red heat to form a bead seal and simultaneously to cut the film. A hot-bar sealer (or jaw sealer) holds the two webs in
place between heated jaws until the seal is formed. In the impulse sealer, films are clamped between two cold jaws, which each have a metal ribbon down the centre. The films are heated and fused, but the jaws remain in place until the seal cools and sets to

**Fig. 25.7**  (a) Positioning blanks on a sheet of paperboard to minimise wastage; (b) board is creased and formed into a carton (Fellows and Axtell (1993)); (c) inter-locking lugs which dispense with the need for staples or glue in bottle-carrier carton (Paine (1991)).
prevent shrinkage or wrinkling. These types of sealer conduct heat through the film and therefore risk causing heat damage to the film.

**Rotary (or band) sealers** are used for higher filling speeds. The centres of metal belts are heated by stationary shoes and the edges of the belts support the unsoftened film. The mouth of a package passes between the belts, and the two films are welded together. The seal then passes through cooling belts which clamp it until the seal sets. In the **high-frequency sealer**, an alternating electric field (1–50 MHz) induces molecular vibration in the film and thus heats and seals it. The film should have a high loss factor (Chapter 18) to ensure that the temperature is raised sufficiently by a relatively low voltage. The **ultrasonic sealer** produces high-frequency vibrations (20 kHz), which are transmitted through the film and dissipate as localised heat at the clamped surfaces. **Cold seals** (adhesive seals) are used to package heat sensitive products (for example chocolate, chocolate-coated biscuits or ice cream).

### 25.3.1 Form–fill–seal (FFS) equipment

FFS equipment has been one of the most significant growth areas in food packaging during the last 10–15 years. The advantages include reduced transport, handling and storage costs for materials compared to pre-formed containers, simpler and cheaper package production, lower labour costs and higher output (Robinson, 1992).

In **vertical form–fill–seal** (transwrap) equipment (Fig. 25.9), a web of film is pulled intermittently over a forming shoulder by the vertical movement of the sealing jaws. A fin seal is formed at the side. The bottom is sealed by jaw sealers and the product is filled. The second seal then closes the top of the package and also forms the next bottom seal. This type of equipment is suitable for powders and granular products, but liquids may contaminate the seal. Filling speeds are 30–90 min<sup>−1</sup>. Films should have good slip characteristics and resistance to creasing or cracking, in order to pass over the filling tube, and a high melt strength to support the product on the hot seal.

The vertical **flow pack** (flow wrap) equipment differs from the transwrap design in two ways: first a forming shoulder is not used and the film is therefore less stressed; secondly, the action is continuous and not intermittent. The side seam is formed by heaters and crimp rollers, which pull the tube tightly around the product, make a fin seal and lay it flat against the pack.

In the horizontal form–fill–seal (HFFS) system (**pillow pack** or **flowwrap**), products are pushed into the tube of film as it is being formed (Fig. 25.10). In both types, the transverse seals are made by rotary sealers, which also separate the packs. Filling speeds are over 600 min<sup>−1</sup> and films should therefore be thin and have a high melt strength, to produce a strong seal in the short heating time available (Briston and Katan, 1974).
HFFS equipment has gained in popularity due to its greater speed (up to 600 packs per minute) and flexibility: it can pack single pieces of food or multiple wrapped or unwrapped pieces; packs can accommodate irregular shaped foods that were previously difficult to pack using foil or glassine (Martin, 1991); it can be used for MAP products (Naylor, 1992) (Table 25.2), and the fin seals ensure a good gas and moisture barrier without risk of damage to the product from sealing head pressure (Fig. 25.8).

A modification of this equipment is used to fill laminated cartons aseptically. A web of material is sterilised in a bath of hydrogen peroxide and formed into a vertical tube. An internal heater vaporises any remaining hydrogen peroxide. The tube is then filled, sealed through the product, shaped into a carton and top sealed. The ‘ears’ on the base of the carton are folded flat and sealed into place.

In sachet pack machines, either horizontal or vertical packs are formed from single or double sheets of film. Horizontal single-web machines fold the film over a triangular shoulder and then form two side seams (Fig. 25.11). The sachets are then separated, opened by a jet of compressed air, filled and heat sealed across the top. The vertical single-web machine is similar to the transwrap machine. Horizontal machines have a smaller distance for the product to fall into the package and are therefore more suitable for sticky foods. Vertical machines have lower cost and take up less floor space.

On two-reel machines, one web forms the front and the second forms the back of the pack. Two blanks are cut from a roll of film, brought together and sealed on three sides. The package is filled and the final seal is made. Sachet machines are widely used for powders or granules (for example coffee, salt and sweeteners), liquids (for example cream) and sauces (for example ketchup and salad cream). Filling speeds are 70–1000
Table 25.2  Packaging systems for MAP products

<table>
<thead>
<tr>
<th>Type of system</th>
<th>Description</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoforming</td>
<td>Heat forming of semi-rigid and flexible containers, vacuum with gas flushing</td>
<td>Meat, poultry, fish, cooked meats, bakery products, cheese, nuts</td>
</tr>
<tr>
<td>Horizontal and vertical form-fill-seal, pillow</td>
<td>Single flexible web, gas flushing by lance or tube, venting to atmosphere</td>
<td>Bakery products, snackfoods, cheese, coffee, nuts, meat, fish, salads, fruit, vegetables</td>
</tr>
<tr>
<td>pack</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-formed tray or bag</td>
<td>Using HDPE, PET or HIPS trays or pre-formed plastic bags, vacuum with gas flushing</td>
<td>Meat, fish, nuts, prepared meals</td>
</tr>
<tr>
<td>Thermoforming, composite or pre-formed</td>
<td>Carton blank and plastic tray form composite tray structure with in-line lidding and vacuum with gas flushing</td>
<td>Meat, poultry, fish, cooked meats, bakery products, cheese, salads, vegetables, prepared meals</td>
</tr>
<tr>
<td>board/plastic tray</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bag-in-box</td>
<td>Barrier or non-barrier bag into corrugated or solid board case, vacuum with gas flushing</td>
<td>Bulk meat, poultry, fruit, cheese, nuts, dried powders</td>
</tr>
<tr>
<td>Vacuum skin packs</td>
<td>Multi-layer film top web shrunk over product contained in 'easy-peel' forming bottom web. Gas in headspace before lidding</td>
<td>Meat, fish</td>
</tr>
<tr>
<td>Shrink vacuum system</td>
<td>Two webs of film, upper heated and shrink over product on base web</td>
<td>Meat, fish</td>
</tr>
<tr>
<td>Vacuum skin system</td>
<td>Laminate top web shrunk over product on laminated board/film base</td>
<td>Meat, fish</td>
</tr>
<tr>
<td>Bag-in-carton</td>
<td>Lined carton, gas flushed</td>
<td>Powders, granular products</td>
</tr>
</tbody>
</table>

Adapted from Hastings (1998).
min\(^{-1}\), depending on the size of the sachet and the type of product. Sachets are automatically cartoned, and the cartoning machine is therefore an integral part of sachet production (Guise, 1987a, and 1987b).

Various devices are used to assist in opening of flexible packs, particularly where a strong film is used. These include tear-tape applied longitudinally or transversely to the pack, slits or perforations that are either produced mechanically by the wrapping machine or cut by laser after wrapping.

Bag-in-box packaging is filled through the tap hole at up to 600 bags h\(^{-1}\), after first removing air. The tap is then sterilised and refitted and the bag is placed into the outer carton.

### 25.4 Shrink-wrapping and stretch-wrapping

Low-density polyethylene is biaxially oriented to produce a range of films that shrink in two directions (Chapter 24). The shrink ratios are measured in both the machine direction (MD) and the transverse direction (TD). Films are preferentially balanced (shrink ratios are MD = 50%, TD = 20%), fully balanced (MD = 50%, TD = 50%) or low balanced (MD = 10%, TD = 10%). A small amount of shrinkage is usually required to tighten a loosely wrapped package, but contoured packages require a higher shrink ratio. The size of film required to shrink-wrap a sleeve-wrapped package is calculated using

\[
\text{width} = A + \frac{3}{4} C \\
\text{length} = 2(\text{length of package}) + 10\% \text{ shrink allowance}
\]

where \(A\) (m) = width of the package, \(B\) (m) = length of the package and \(C\) (m) = height of the package.

The total mass of film used equals the width multiplied by the length, divided by the yield (a measure of film density) (m\(^2\) kg\(^{-1}\)). The size of the film required to shrink-wrap an overwrap using centre-fold film is found using:

\[
\text{width} = (B + C) + 10\% \text{ shrink allowance} \\
\text{length} = (A + C) + 10\% \text{ shrink allowance}
\]

The total mass of film used equals twice the width (m) multiplied by the length (m) divided by the yield (m\(^2\) kg\(^{-1}\)).
The film is shrunk by passing through a hot-air tunnel or beneath radiant heaters. Alternatively a heat storage gun fires an intermittent pulse of hot air to shrink the film when a package passes beneath. This reduces energy consumption by 70%. Shrink-wrapped trays have now largely replaced fibreboard shipping cases for many products.

In stretch-wrapping, low-density polyethylene, polyvinyl chloride or linear low-density polyethylene (Chapter 24) is wrapped under tension around collated packages. The main advantages over shrink-wrapping include lower energy use than in shrink tunnels (1.5–6 kW compared with 20–30 kW), and lower film use. In shrink-wrapping, 5–10% extra film is used to allow for shrinkage, whereas stretch film is elongated by 2–5%. Together this gives a 10–15% saving in film.

25.5 Tamper-evident packaging

The habit of some consumers of grazing (opening packs, tasting the food, and returning it to the shelves) and a number of cases of deliberate poisoning of packaged foods in attempts to blackmail companies, have caused food manufacturers to modify package designs. Although total protection is not possible, tamper-resistant packaging delays entry into the package and tamper-evident packs indicate whether tampering has occurred (Box, 1986). The main problems occur with bottles and jars because they need to be re-closable. There are a number of options to make packs tamper evident (Table 25.3 and Fig. 25.2) including:

- heat-shrinkable polyvinyl chloride sleeves for bottle necks
- foil or membrane seals for wide-mouthed containers, cartons and plastic bottles
- rings or bridges to join a hinged cap to a lower section on bottles (the container cannot be opened without breaking the bridge or removing the ring)

<table>
<thead>
<tr>
<th>Table 25.3 Tamper-evident packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current tamper-evident packages</strong></td>
</tr>
<tr>
<td>Film wrappers that must be cut or torn to gain access</td>
</tr>
<tr>
<td>Blister or bubble strip packs (visible evidence of backing material separated from blister, each compartment must be broken, cut or torn to gain access)</td>
</tr>
<tr>
<td>Heat-sealed bands or wrappers placed over a cap or lid and shrunk by heat. A perforated strip enhances tamper evidence (must be cut or torn to gain access)</td>
</tr>
<tr>
<td>Pouches (must be cut or torn to gain access)</td>
</tr>
<tr>
<td>Inner seals – induction seals are better than adhesive seals (must be cut or torn to gain access)</td>
</tr>
<tr>
<td>Breakable caps – the cap or part of it is broken to gain access to the container and cannot be replaced</td>
</tr>
<tr>
<td>Sealed metal or plastic tubes with both ends sealed. (The mouth has to be punctured to gain access and crimped ends cannot be unfolded without leaving evidence)</td>
</tr>
<tr>
<td>Aerosols are inherently tamper resistant</td>
</tr>
<tr>
<td>Cans and composite containers in which the top and bottom are joined to the walls so that they cannot be pulled apart</td>
</tr>
<tr>
<td>Child resistant closures (clic-lok, squeeze-lok, ringuard, pop-lok, etc.). However, these are not normally used for foods</td>
</tr>
</tbody>
</table>

526 Food processing technology

- roll-on pilfer-proof (ROPP) caps for bottles or jars (during rolling, a tamper-evident ring in the cap locks onto a special bead in the neck to produce a seal which breaks on opening and drops slightly)
- a safety button in press-on twist off closures for heat sterilised jars (a concave section, formed in the lid by the head space vacuum, becomes convex when opened). This may also be combined with a breakable plastic strip that together give both a visual and audible signal that a jar has not been previously opened.

25.6 Labelling

The label is the primary point of contact between a processor and a customer and is therefore an integral part of the marketing strategy for a product. The label is the main method of persuading a purchaser to buy a product without having sampled it, rather than a competing brand on a retail shelf. Details of the factors to be taken into account in the design of labels, legislative requirements and the information required on a label are beyond the scope of this book, and details are given by Blanchfield (2000).

Labels are made from paper, plastic film, foil or laminated materials, pre-printed by either lithographic or rotogravure techniques (Chapter 24). Cans and glass bottles are usually labelled using a hot-melt adhesive at 500 or more containers per minute. A wide variety of label combinations are possible to produce a distinctive brand image for the product. The main types of label are as follows:

- **Glued on labels** – the adhesive is applied at the time of labelling or the label is pre-glued and wetted for application.
- **Thermosensitive labels** – heat is applied at time of application (e.g. biscuit and bread wrappers). These are more expensive but they can also be used as a closure.
- **Pressure sensitive labels** – these self-adhesive labels are pre-coated with adhesive, mounted on a roll of release paper and removed before application.
- **Insert labels** – are inserted into transparent packs.
- **Heat transfer labels** – the design is printed onto paper or polyester substrate and transferred to the package by application of heat.
- **In-mould labels** – this involves thermoforming the container and labelling at the same time. A printed paper label that has a heat-activated coating on the reverse side is placed into the thermoforming mould before the parison is inserted (Chapter 24, Section 24.2.5). When air is injected to blow the package shape, the heat activates the coating. A combination of heat, air pressure and the cold surface of the mould secures the label to the pack and sets the adhesive. The label also contributes to the strength of the pack and reduces polymer use by 10–15%.
- **Shrink sleeve decoration** – used for glass and plastic containers. An axially oriented PVC or PP sleeve is made larger than the container and heat-shrunk to fit it. Alternatively, an LDPE sleeve is made smaller than the container and stretched to fit it. In both methods, the sleeve is held in place by the elasticity of the film, and no heat or adhesives are used. When shrunk over the necks of containers sleeves also provide a tamper-evident closure.
- **Stretchable inks** – that are applied before or during bottle manufacture for labelling plastic bottles.
25.7 Checkweighing

Checkweighers are incorporated in all production lines to ensure compliance with fill-weight legislation (average weight or minimum weight legislation) and to minimise product give-away. They are pre-set to the required weight for individual packs and any that are below this weight are automatically removed from the production line. They are microprocessor controlled and are able to weigh up to 450 packs min\(^{-1}\) and automatically calculate the standard deviation of pack weights and the total amount of product that is given away. This data is collated by computers and prepared into reports for use in process management and control procedures (Chapter 2). Checkweighers can also be linked by feedback controls to filling machines, which automatically adjusts the fill-weight to increase filling accuracy and reduce product give-away.

25.8 Metal detection

Details of contaminants in foods and methods of removing them before processing are described in Chapter 3. Contamination with metal fragments can also occur during processing as a result of wear or damage to equipment, and metal detection is therefore an important component of HACCP systems in all food processing plants as well as a requirement to prove due diligence (Chapter 1). The basic components of a metal detection system are:

- a detection head that is correctly matched to the product and set to its optimum sensitivity
- a handling system that conveys the product under the detection head
- a reject system that is capable of rejecting all contaminated product into a locked container
- an automatic fail-safe system if any faults arise
- staff training in procedures to carry out and record quality assurance tests (Greaves, 1997).

Excluding X-ray detectors (Chapter 3), there are two types of metal detectors: the ferrous-only type, used for products in aluminium containers which is based on alteration of a magnetic field; and detectors that are based on the ‘balanced coil system’. These latter detectors are made from a coil of wire that conducts a high voltage to produce an electrical field, and two receiver coils placed either side. The voltages induced in the receiver coils are adjusted to exactly cancel each other out. When an electrical conductor (for example a ferrous or non-ferrous metal contaminant or metal-impregnated grease) passes through the detector, it changes the amplitude and/or the phase of the electrical signal induced in the coils, depending on the type of metal (Graves et al., 1998). This change is detected by the electronic circuitry, which activates an alarm and a mechanism to reject the pack (Mayo, 1984). The detector is adjusted for each particular product to take account of differences in electrical conductivity of different foods. Various reject systems are available, including air-blast, conveyor stop, pusher arms for items up to 50 kg and a retracting section of conveyor that allows the product to fall into a collection bin underneath. Details of the operation of metal detectors are given by Anon. (1991). Recent developments include microprocessor control, which enables the characteristics of up to 100 products to be stored in the detector memory, automatic set-up to compensate for
product effects, automatic fault identification and production of printed records to show
the number of detections and when they were found.

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25.10 References


Filling and sealing of containers