Packaging Operation Technology (Max. 50 pages)

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I. Packaging machinery and line operations.

A – The typical packging line.

A typical sequence of activities of a packaging line includes 8 steps:

- Bring the packaging components from WH to packaging line.
- Place the containers onto a converyer belt which will move them in the correct orientation.
- Clean conteiners (if required)
- Fill the product into the containers.
- Close the containers
- Apply the label or a sutable identification.
- Apply any additinal packaging such as leaflet.
- Collect and arrange the primary packs into secondary packs and palletise the secondary packaging packs for transfer finished goods to WH.

For filling and labelling stations, the two most common configurations for a packaging line are straight-line or liner and rotary layours.

- Straight-line layout is applied in sequence of an intermittent operation, depending on the complexity of a particular operation. The kind of layout many have a “U” or “S” shape.

- *Pros:* Simple process and easy for maintenance, flexible for size change.
- *Cons:* Take up a lot of space, filling speed can be limited so that multi-filling heads and double belt system provided to improve smooths of filling.

- Rotary layout operate by feeding out of the main packaging line into a rotating circle (called a turret).

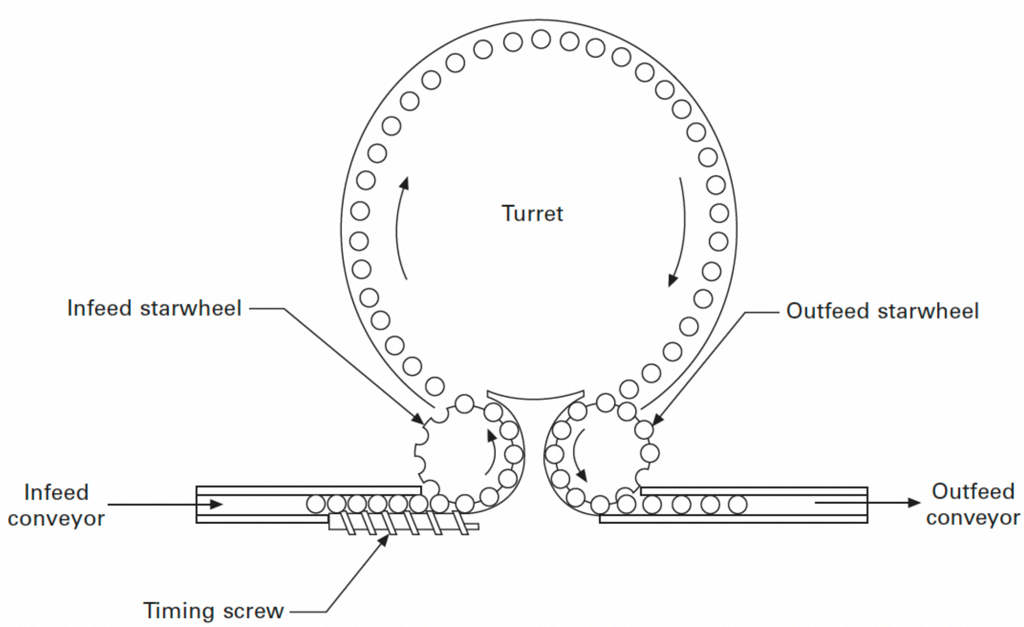


Figure 1. Rotary layout on a packaging line.

- *Pros:* More units filling at a lower speed, compatible with higher precision capping and labeling with continous flow of product.
- *Cons:* invesment cost, more difficult to maintain, suitable for high productivity lines.

1.1 Unscramblers (packaging preparation)

This stage requires to move packaging up to the packaging line and remove any items used to protect them during transport, and also to be sterilized them before filling if needed.

Metal cans for food and glass bottles for beer and spirits are usually filled on relatively high- speed lines and the containers are delivered stacked in rows on pallets. An automatic depalletiser takes an entire layer of containers from the pallet and places it on an in-feed.

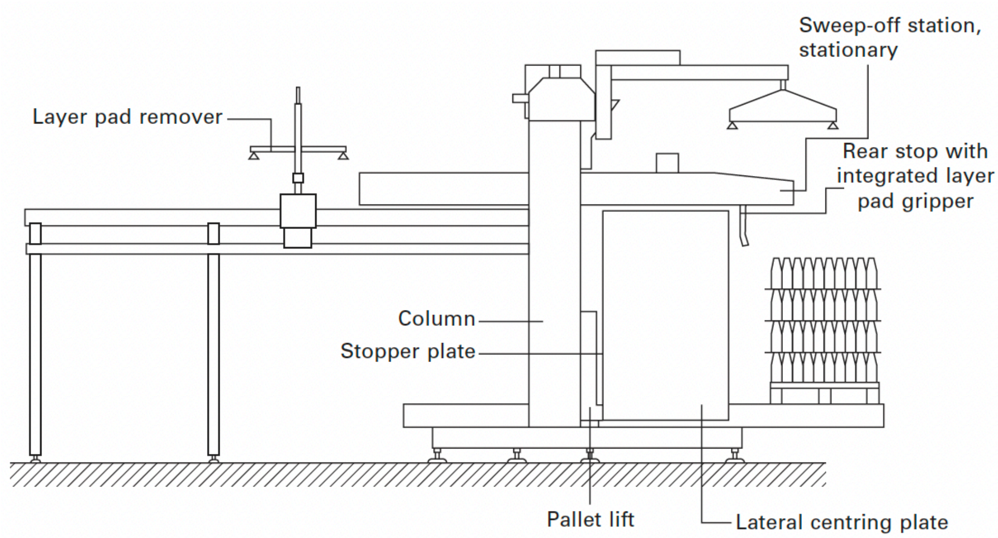


Figure 2. Automatic depalletiser with sweep-off mechanism.

The unpacked packaging will run on the conveyor in oriented rows. If cleaning is required, this may be done depending on each type of packaging:

- For cans, conveyor belt will invert each one and blowing clean air into it, to remove any loose debris, spraying with steam or hot water, and then drying them before ready for filling. Visual quality chek can be inspected by sensor or camera during this stage to reject these cans non-conformity.
- For glass bottle or jar, packagings were come into bottle washer in which they will be rinsed by hot water, detergent wash, deionized water at each zone, and then dry by air and visual check by sensors before coming into labellong zone. Note that glass packaging need to be careful thermal shocking if product is filled with hot or cold temperature.

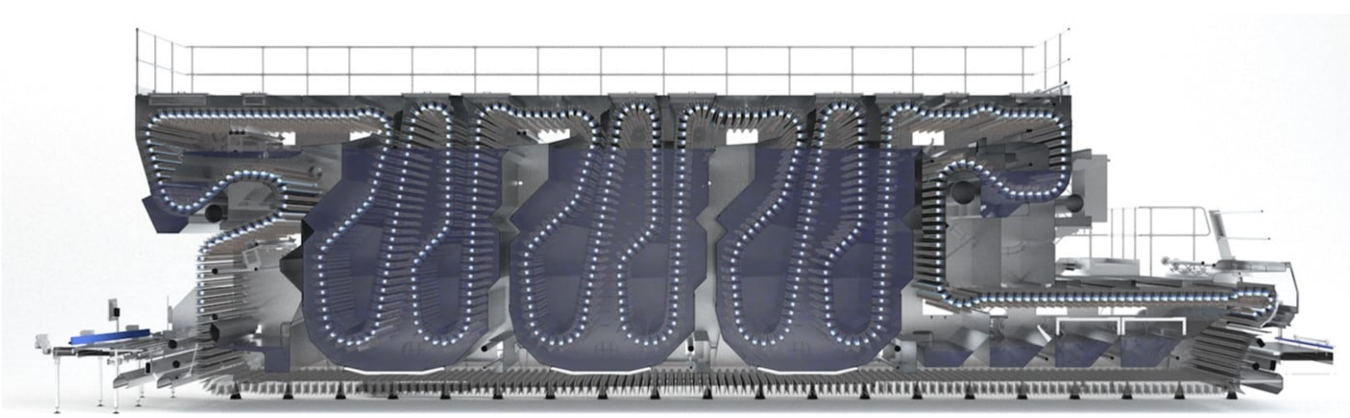


Figure 3. Cross section depicting the internal chambers of a bottle washer.

- For rigid plastic packaging, they are usually much more durable, softer and easier to dismantle, the unsorted packaging is held upright by a bounce bar on the packaging line. Cleaning may be done using dry air to blow away dust, and in some cases hydrogen peroxide can be used if the packaged product is a pharmaceutical product before coming into filling area.

However, some special packaging types such as cosmetic tubes or glass perfume bottles are packed in cartons with partitions. They must be manually fed into the packaging line.

1.2 Filler and filling.

Filling machines measure the product by weight, volume or count. To select the appropriate machine, there are several factors need to be considered include:

- Whether the product is a solid, liquid or semi-liquid.
- The precision of filling operation required:
  + Must to meet the legislation and relevant quality standards within the country such as an adequate validation of the process capability of the filling system, and adequate sampling and measurement checks to ensure that each batch is correctly filled.
  → The ingredient list on the label must show the product sold by net weight, net volume, or exact number of units per package.
  → Over-filling or high levels of wastage can be very costly if it is a pharmaceutical product or an expensive product like perfume or cosmetics.
- The type of required containers: rigid, semi-rigid or flexible packaging.
  + Rigid containers made from glass, metal or thick plastic can withstand the application of a vacuum or high-pressure during filling while semi-rigid one such as plastic bottle or yoghurt can bulge under pressure or collapse if applied vacuum.
  → potential damage for packaging, inaccurate filling, poor sealing and labelling.
  + Semi-rigid container and flexible packaging such tube, bag or sachets can require the insertion of bottom filling or application of pressure to push the product into container.
  + The required shelf-life of the product can depend largely on removal of air from the container, vacuum at head space, heat-sterilised methods and adequate sealing.

1.2.1 <u>Filling solid product</u>

Solid product can be categorised in two ways:

- Discrete solid product which are often filled by counting a given number of items per container. They may vary in handling properties due to varying shapes and sizes, fragility (e.g snack).
  → Filling by weight is more accurate than filling by level or volume.
- Powders which can be further categorised by characteristics such as particle size, moisture content and bulk density. They can be sub-divided into two types:
  + ***Free-flowing powder*** (or granules) have a consistent density, do not trap air and pour readily. As the result, they normally form a cone with a shallow angle when poured onto a level surface.
  + ***Non-free-flowing/agglomerated powders*** (e.g milk or flour powders) have characteristics such as irregular particle shape or high moisture content that cause the particles to stick together, making pouring difficult. They tend to form a steep cone or agglomerate with particles clumping together by trap air, result in variation in density in different areas of the product.
  → Filling by weight is more appropriate than other fillings.

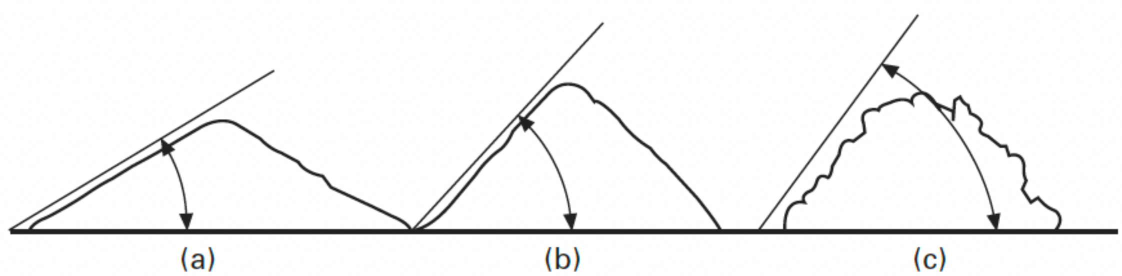
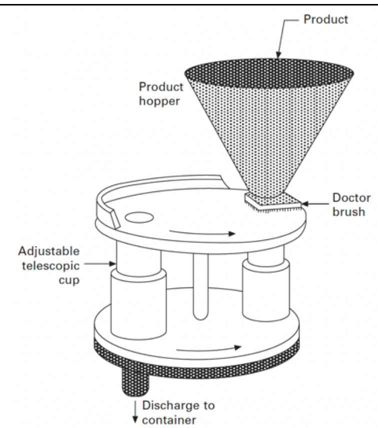
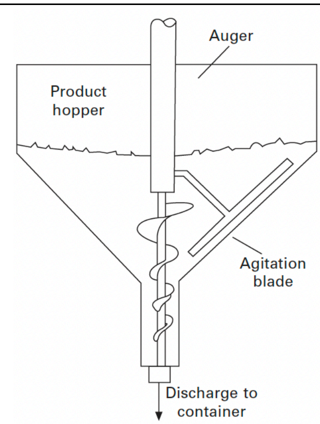
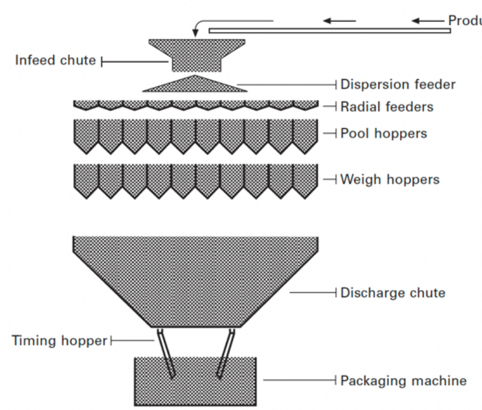
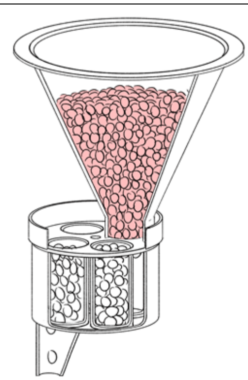
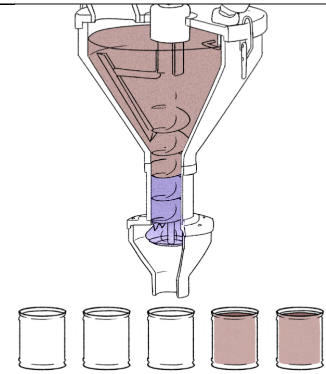
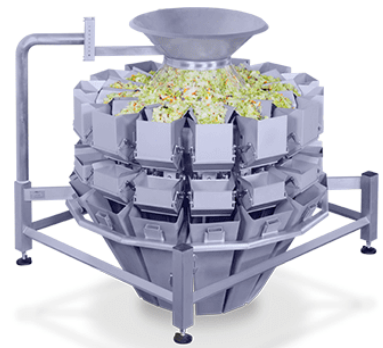


Figure 4. Angles of repose:
(a) free-flowing powder, (b) Non free-flowing powder and (c) agglomerated products

Solid products are filled into containers by:

- Volume
- Weight
- Count (for unit items).

Filling type	**Weight**		**Volume**	**Count**
Mechanism	A circular plate which revolves to present each cup under the product hopper in turn. Scrapers or brushes (called ‘doctor’ brushes) wipe over the top of the cup to level off the amount of product in the cup and then then move to a discharge point. An alternative system uses trap doors under each cup to release the product directly into the container. Some systems use adjustable telescopic cups which can be raised up to accommodate a larger volume of product in each cup.	A hopper with a funnel or tube at the bottom. An auger or screw runs through the middle of the hopper together with an agitation blade. Towards the bottom of the auger each turn of the screw (or flight) is calibrated to a precise level volume. As the auger rotates, the agitation blade rotates in the opposite direction to remove air, homogenise and then feed the powder into the flight. Tapered augers can be used to compact finer powders.	Product is fed from a hopper into the bucket. Once a certain weight is reached, the hopper is closed and the bucket tips the product into a discharge chute or directly into the container. A multi-head machine which fills products into several containers simultaneously. These systems often use several weighing stations to fill each container, selecting which stations to use to fill the container to the exact weight. Free-flowing powders can be measured by volume using a telescopic measuring section of the machine which is filled before the product is transferred to the container.	Filling machines by count normally use mechanical or photo-electronic systems. Mechanical counting systems usually place the product over a plate with an appropriate number of holes of suitable size. Once each hole is filled, the excess product is wiped off the plate. Photo-electronic counting systems usually involve tumbling or vibrating the product to create a flow of single items which move past the photocell on a conveyor belt for counting. Once the required number is reached, a gate diverts the counted items into a feed chute which fills the container.
Illustration				

	 Filling by volume using a cup filler	 Filling by volume using an auger filler	 Multi-head filling by weight	 Filling by count
Pros	These systems are suitable for free-flowing solids of consistent density.	Suitable for non-free-flowing solids, e.g moist brown sugar.	free-flowing solids like fruit	The amount of product is declared by count such as tablets or capsules.
Cons				

1.2.2 <u>Filling liquid product</u>

There are several criteria to consider in filling container with liquid, including:

- The properties of liquid such as viscosity (low or high, free-flowing, viscous or highly viscous semi-liquids); foaming capacity or surface tension which may result in frothing or foaming when agitated, particulate size in semi-liquid.
- The condition required for filling such as temperature, speed of flow, duration time, filling press, and filler technology.

Liquid filling can be done in three ways including by level, by weight or by volume. Filling can be done at the top or bottom of the container. The filling tube or container can move, lift and lower during the filling process on the packaging line.

- **Top filling** involves inserting the filling tube into the neck of the container and either allowing the liquid to drop to the bottom or directing the liquid to run down the container sides, or moving the tube itself.
- **Bottom-up filling** involves inserting the filling tube down to the bottom of the container and gradually withdrawing it as the container fills.

→ *Bottom-up filling is particularly effective in minimising air entrapment, limits frothing or vapourisation of more volatile liquids.*

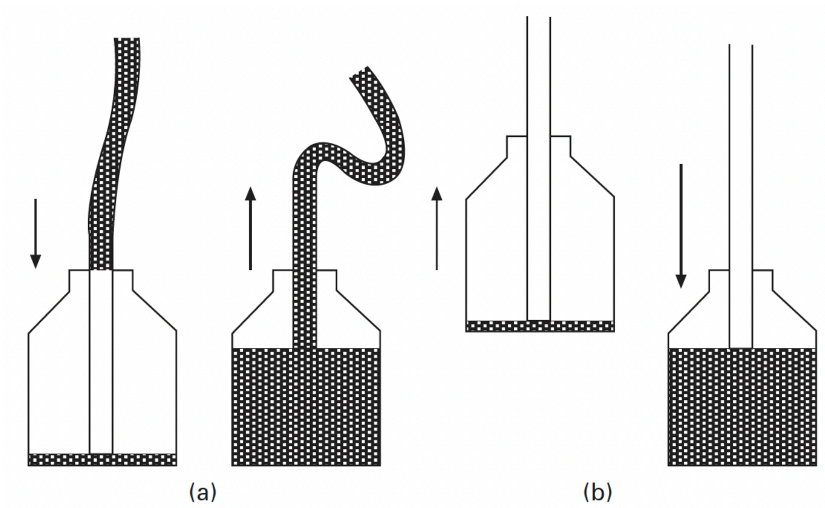
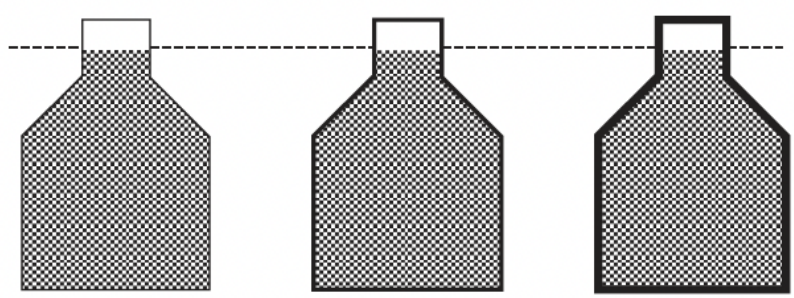


Figure 5. Filling movement: (a) Movement of filling tube; (b) Lift and lower movement of packaging.

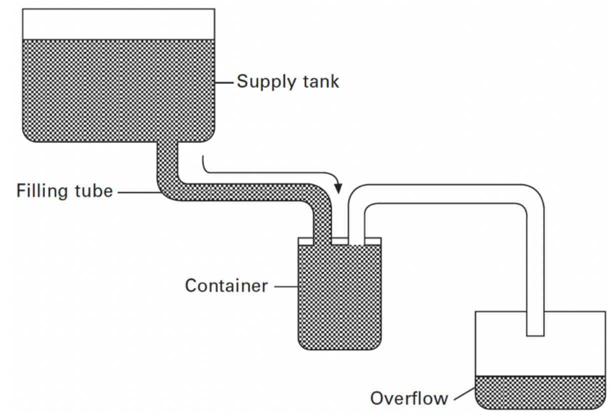
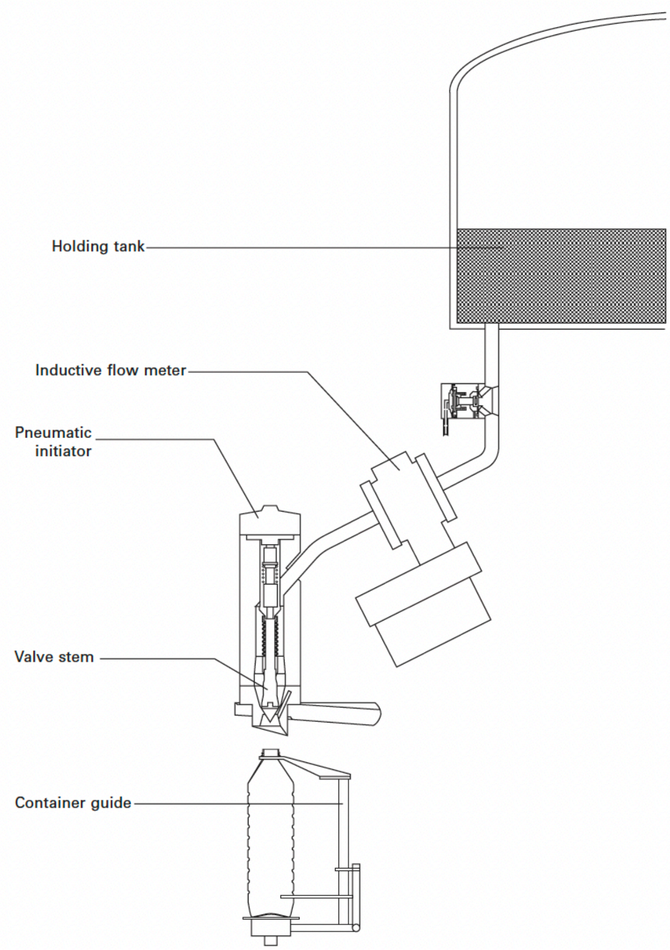
Level fillers use the container's volume to measure the amount of liquid filled. The containers are the same design will have differing volumes due to slight variations in dimensions and wall thickness. This form of filling is more accurate than volume or weight filling. Therefore, the lower cost liquid such as beer, soft drink, milk or sauces will less consider for volume than a visually constant fill level.



The target level is measured by modern level filling systems:

- Use sensor to identify the right level of liquid has been supplied.
- Pneumatic systems which use a flow of low-pressure air in a tube next to the filling tube, once reaching the correct height, back pressure in this second tube triggers a valve to close off the supply of liquid.
- More advanced sonic systems use high-frequency sound waves which reflect off the surface of the liquid when the liquid reaches the desired height to close the liquid supply valve. → Applicable when filling product into colored containers.

There are three main types of level filler including gravity fillers, vacuum fillers and pressure fillers (also known as over-pressure or counter-pressure fillers).

<table>
<tr><th>Filler types</th><th>Description</th><th>Illustration</th></tr>
<tr><td rowspan="2">By gravity</td><td>The principle of gravity filling: the liquid flow from a supply tank into the container at a flow rate is determined by the height distance between them. The computer will control the opening and closing time of the valve to deliver the target amount to the container, any excess can flow into an overflow tank.</td><td>
</td></tr>
<tr><td>A typical design involves a filling tube with a valve connected to a spring-loaded outer tube that fits over the container neck. As the container is raised, it activates the spring to open the valve to fill the container. A sensor identifies to closes the valve when the liquid has reached the top of the container.
✓ Pros:
• Cheap process but is slower than vacuum filling.
• Suited to liquids prone to foaming since there is less agitation during filling. E.g shampoo.
• Bottom-up filling can be used for very foamy products.
• Suitable for a wide range of container types.
✕ Cons:
• Less suitable for viscous, slow-flowing products or products containing large particulates.</td><td>
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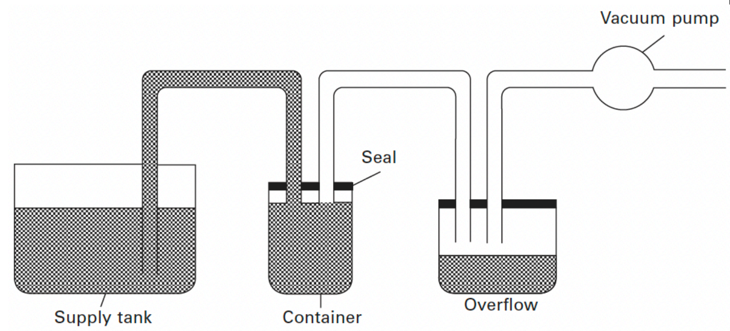
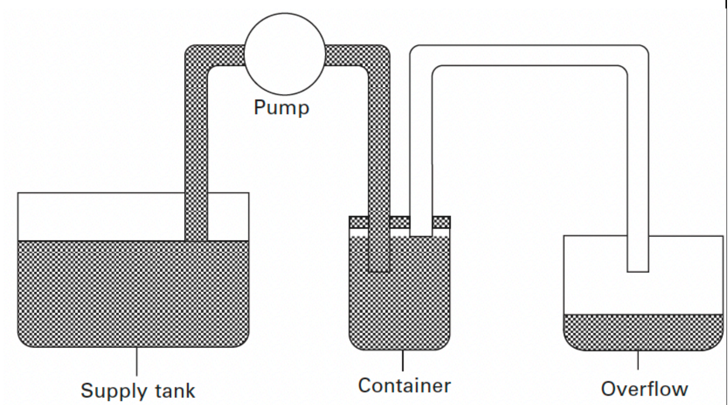
</table>

By vacuum	The principle of vacuum fillers typically works by lowering a filling tube and a vacuum line (connected to a vacuum pump) into the neck of the container and then sealing the neck. Air is drawn from the container to create a vacuum, liquid is then drawn from a supply tank trough the filling tube into the container. When the liquid reaches the vacuum line, suction draws it into an overflow tank, ensuring the desired level is not exceeded. The Surplus liquid can then be returned to the supply tank. As with other systems, vacuum fillers also use sensing devices to identify when the desired level has been reached to stop filling. ✓ **Pros:** • Vacuum fillers are fast, flexible and relatively low cost. • Suitable for liquids with little aeration. ✗ **Cons:** • Limited to rigid containers (e.g glass bottles) which are not distorted by creating vacuum conditions.	
By Pressure	Pressure filling uses a pump to transfer the liquid from a supply tank to the container. On the other hand, the supply tank is kept at high pressure by over-pressure machines, forcing the liquid through to the container. The fill level is determined by the vent tube inserted into the container. When the liquid reaches the vent tube, the supply is interrupted by the difference in pressure, surplus liquid into an overflow tank. If the product is CO_2 saturated, the container will perform isobaric Filling (Counter-Pressure Filling) to blow air out, maintaining a corresponding saturated gas inside equal the filling pressure, and then the product will gently fill into the container by the gravity. ✓ **Pros:** • Pressure filling is relatively fast and is suited to viscous products.	

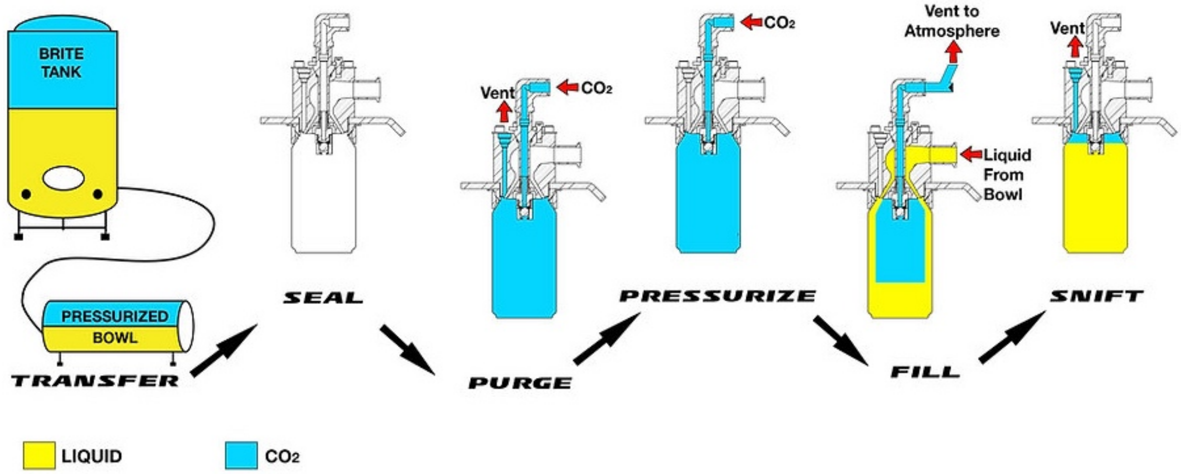


Figure 6. Isobaric Filling (Counter-Pressure Filling).
https://www.youtube.com/live/_O64N_-Wmt8?si=Do2QRmSUvpbTfd_P

Weighing fillers for liquids typically use scales which weigh the desired quantity and then open and close a valve for filling to the container.

It is suitable for filling products which require net weight in bulk quantities or smaller amounts of products with a high value and is sold by weight, liquids of varying consistencies.

✓ **Pros:**

- A high level of accuracy.

✗ **Cons:**

- The high cost per filling head
- The relatively slow rate of filling.

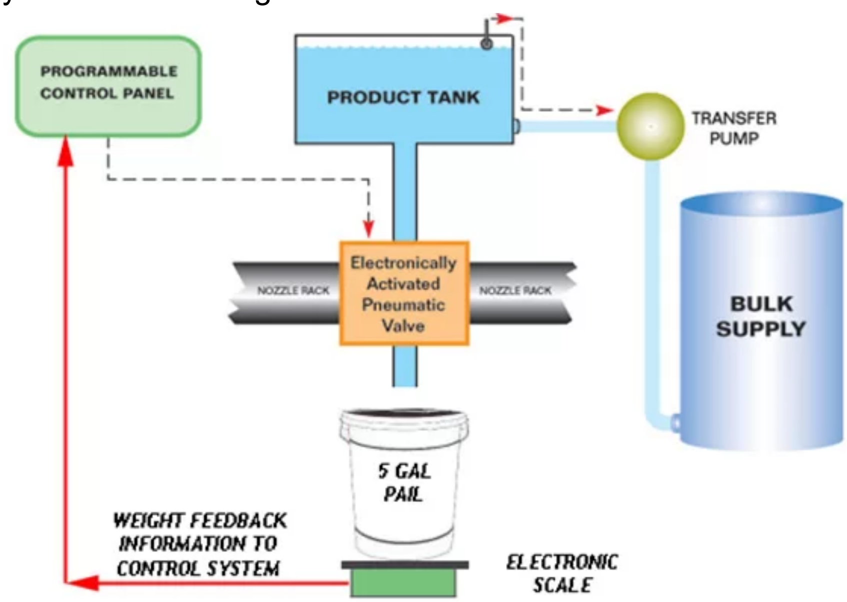
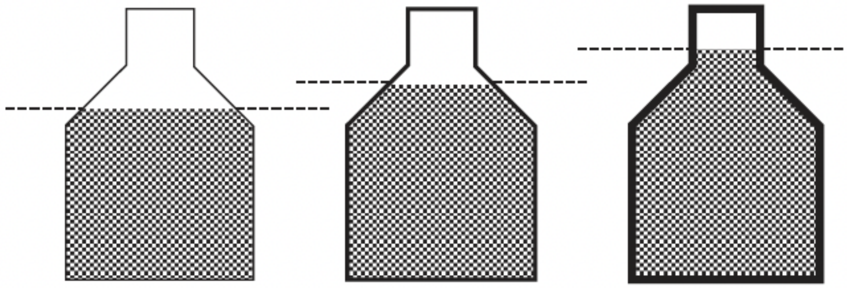


Figure 7. How net weight fillers works.

Volume filling is more accurate measuring than level filling but may result in variations in the level of a liquid in containers, depending on variations in container size.

The fill level will be easily observed by the consumer if the container is transparent, a neck label can be applied to obscure this difference.



Volume filling is used for high-value products and products sold by weight accurately or volume is important (e.g pharmaceutical products). The three main types of volume filler are: piston, cup and flow: time-pressure or flow meter.

The basic piston filler is the piston force-pump which is connected to an adjustable crank, driven by a control system similar to the wiper. When the pump is activated, the crank makes one full turn, delivering the contents of the piston to the container, and then re-filling the piston in readiness for the next container. The amount of product supplied is controlled by the size of the piston cylinder and its stroke.

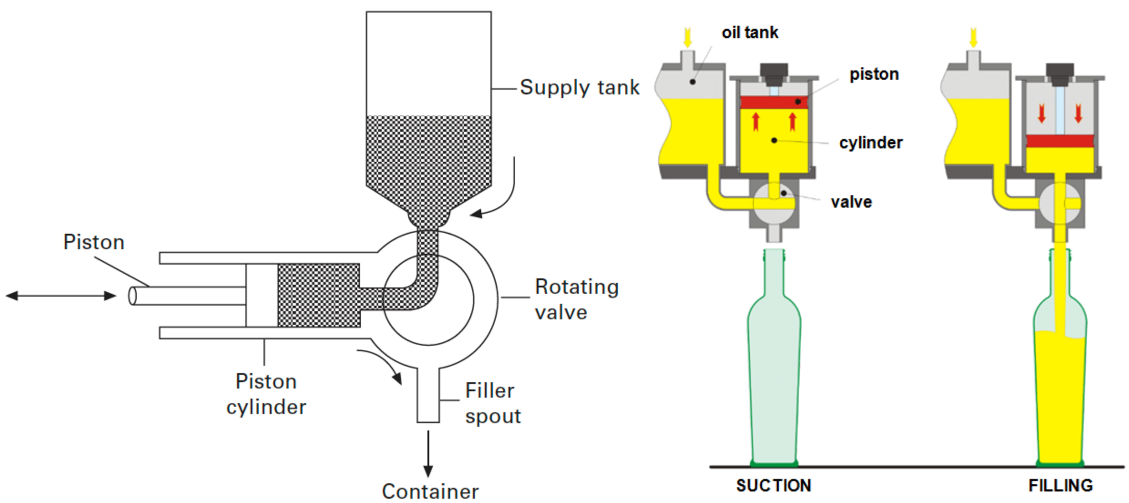


Figure 8. Filling liquid/paste products using a piston filler.

Piston fillers can be fully automated by the group of rotary pumps working in sequence, with electronically controlled drives which regulate the number of turns the pump makes to provide products to each container. A control computer will track the number of rotations of the pump and the target fill volume precisely.

✓ **Pros:**

- Suitable for low viscous liquids.
- the most cost effective, rapid and accurate way of filling viscous products.
- Can minimise the amount of air trap into the container if using inject nozzle filling directly.

✗ **Cons:**

- Leakage problems between the piston and the cylinder.

The cup fillers the liquid product flows from a supply tank into a measuring cup (similar to the cup filling of solid product). Once this is full, the measured quantity of liquid is emptied into the waiting container.

The flow control principle of the filling process is divided into two ways:

Flow control type	Time-pressure filling	Flow meter filling
Operating mechanism	Controlled fillers divide the liquid into portions using a valve which are then fed to individual containers. A constant pressure and temperature as well as consistent viscosity in the liquid should be maintained to ensure accurate measurement.	Use meters which control the opening and closing of measuring valves. Meters measure the liquid in a number of ways, including measuring its conductivity or mass.
Advantage	✓ Liquid products have a viscosity range from liquid to moderate. ✓ High-precise filling of net weight and volume is required. ✓ Ability to adapt to changes in temperature, pressure and filling speed.	✓ Low and moderate viscous liquids ✓ The precise filling of volume is not required. ✓ Prone to foaming and sensitive to air.
Suitable for	Oil, cosmetics such as serum, lotion; detergent or homecare products, solvent, and liquid medicines.	Soft drink/ carbonated liquid such as beer, beverage, sodas; sterilized milk, cosmetic such as shower gel.

1.3 Closing and sealing containers.

1.3.1 Push-fit closures.

There are two types of closure consist of the closure is pushed in the open neck of the container such as a wine cork, other is pushed on or over the outside of the top of containers such as the metal lid on a tin of can or plastic over-cap on the drum.

The application of push-fit caps is a relatively simple process on the packaging line, involving positioning the cap on the container and then moving it under an inclined conveyor to press the cap against the inside/outside of the container neck. A thin metal or plastic can be covered around to provide further protection as well as decoration.

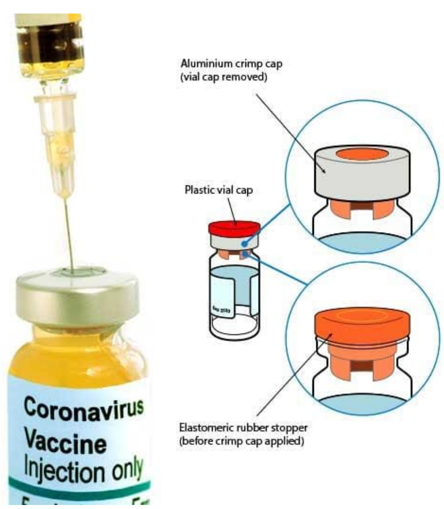
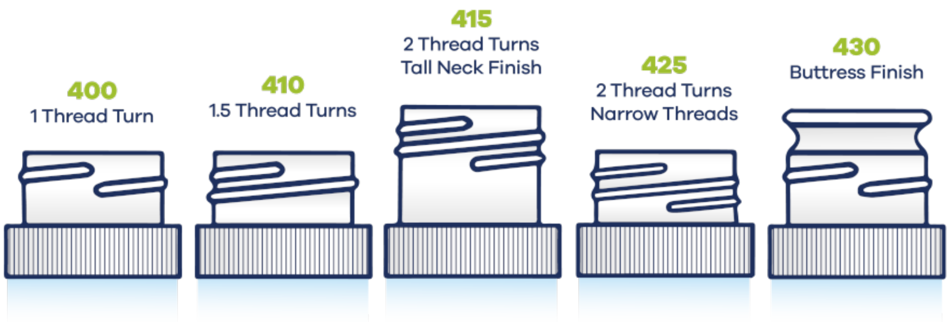


Figure 9. A rubber push-in closure using on vaccine bottle.

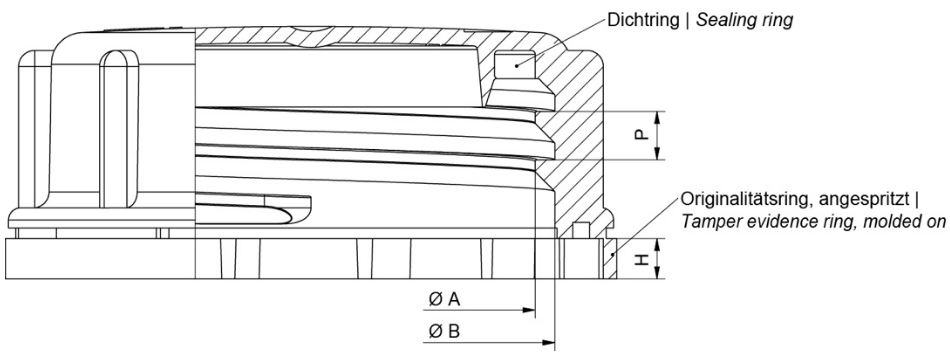
1.3.2 Screw-threaded closures

This type of closure (made of plastic or metal) has a thread on the inside which must be matched up with the thread on the neck of container. There are two factors that need to be considered when designing the neck of container and screw-thread closures:

- The number of turns



- The dimensional tolerance of the threads.



- The material used. *E.g Plastic cap is vulnerable to creep, deform under stress and lose torque.*
- That is any liner inside closure → design a safety gate to prevent over threading.

Closures are fed down via a chute to land on filled containers. A chuck will rotate the closure onto the neck of the container until a pre-programmed torque (tightness) is achieved. Some container designs include a rim which prevents the closure from being tightened beyond a certain point. The chuck then releases, allowing the sealed container.

1.3.3 Roll-on Pilfer-proof (ROPP) closures

This type of closure is typically made from soft-temper aluminium with a partially perforated ring (or skirt) at the lower edge of the closure, and is typically supplied fitted with a wad.

The closure is positioned above the neck of the container which is designed with threads at the top and at the bottom, a ridge (known as a ring grip) to take the perforated ring. A thread roller will apply force along the body of the closure to tighten it with the thread on the neck of the container. The tamper-evident feature, broken when the closure is unscrewed, is formed by a temper-evident roller which creates the perforated ring closed around the ring grip on the neck of the container.

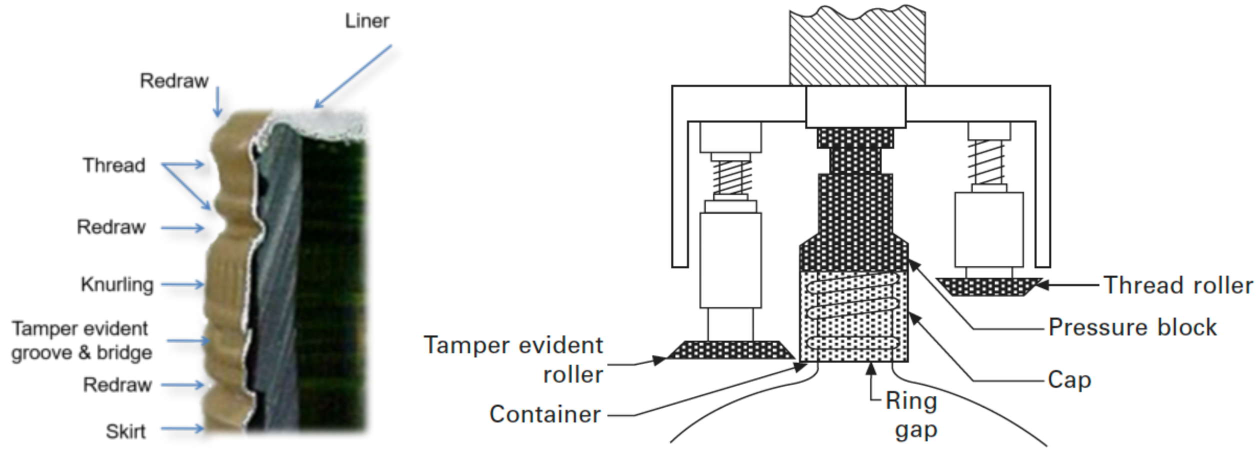


Figure 10. Application of a metal ROPP closure

1.3.4 Lug, Press-on twist-off, crimped or crown closures

Lug closures include lugs or protrusions on the inner edge, designed to engage with an interrupted thread on the container neck. They are secured by placing on the container, exerting a downward pressure and twisting so that the lugs slide under the thread to hold the cap in place. Given the stress exerted on both closure and container, this type of closure is restricted to rigid containers such as glass.

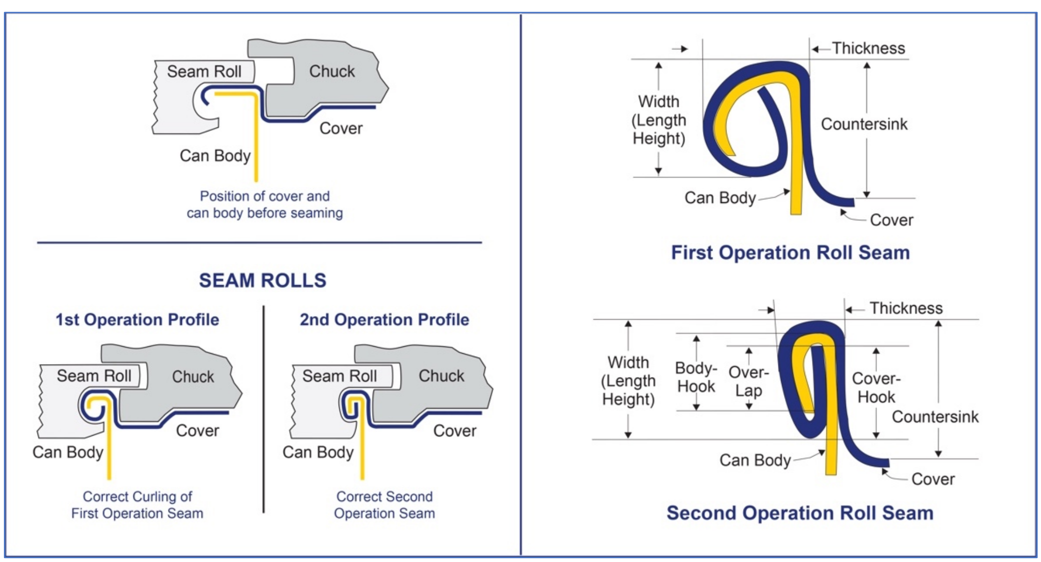
Press-on twist-off caps do not always require lugs but often include a thread, commonly include a soft thermoplastic seal and rely on a partial vacuum in the container (developed when the hot-filled product cools down) to keep the lid in place.

Crimped closures (or crown corks) widely used on bottles of beer and beverage, are made from heavy gauge metal and have a sealing material inside (commonly a soft plastic material around the inner circumference). It's applied by placing over the neck of the container, often using magnets, and the outer circumference is crimped around the lip of the bottle, to secure it in place.

1.3.5 Can closing.

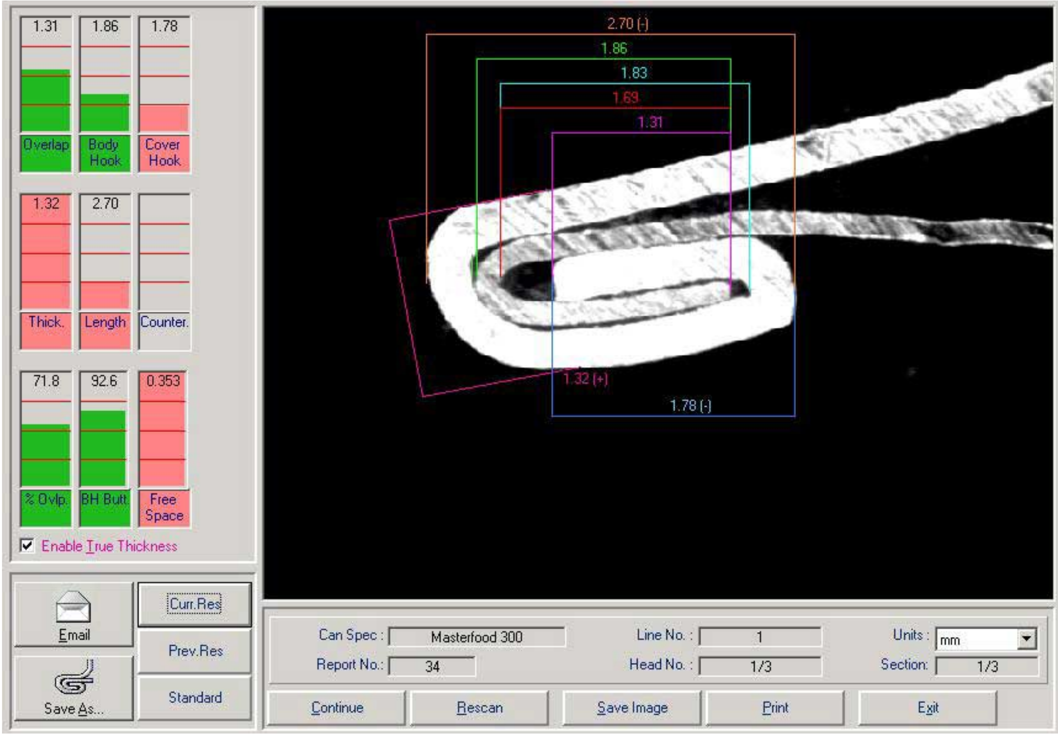
Can lids are sealed by a double seam created by two seaming rollers.

The first seaming roller bends the outer edge or hook of the lid on the can rim, and then a second seaming roller continuously presses the two hooks together to obtain an airtight double seam.



A sealing compound (typically a water-based latex emulsion or synthetic rubber compound) on the lid rim provides a hermetic seal following tightening.

Since the seam is the weakest part of the can, seams are routinely inspected, often using x-ray technology to identify defects.



1.4 Form, fill and seal (FFS) packaging operations.

FFS is described as a packaging process for flexible packaging in which the materials stock is supplied in reel form and shaped into a container for filling before being closed by heat sealing. FFS is used for a wide range of packs and products, including shampoo or sauces sachets; sterilization cartons of fruit juices or milk and bulk sacks for fertiliser and animal feed product.

The main types of FFS machines are divided into:

- Vertical (VFFS) machines, used for liquid products such as milk, fruit juices, soups, liquip cosmetics; solid products such as frozen vegetables, sugar or powder, snacks, etc.
- Horizontal (HFFS) machines used for cakes, biscuits and bars of confectionery.

1.4.1 Vertical FFS machines.

The operating principle of a VFFS machine involves several sequential steps shown *as figure 10*. First, the film is unwound from a reel and guided over a forming collar to create the shape of a bag. It is then wrapped around the vertical filling tube and sealed along its length to form the body of the bag. The film is continuously pulled downward by draw-down belts and sealed at the bottom. Next, the product is loaded through the filling tube into the formed bag. Finally, the horizontal sealing jaws close to seal the top of the bag and cut it from the film, allowing the filled bag to drop into the outfeed chute. *The finished packs can be the simple shape of pillow, rigid rectangular box small cylinder and others.*

Another type of VFFS machine uses two reels of film that are sealed together to form a vertical channel, using heated and crimping rollers. A horizontal seal is made at the bottom to form the base of the pouch, and the product is then poured into the newly formed cavity. After filling, the top of the pouch is sealed and cut to produce individual pouches. This type of machine is suitable for continuous liquid filling, as the sealing and cutting process creates packages with minimal or no trapped air; and more than one pack is produced at the same time.

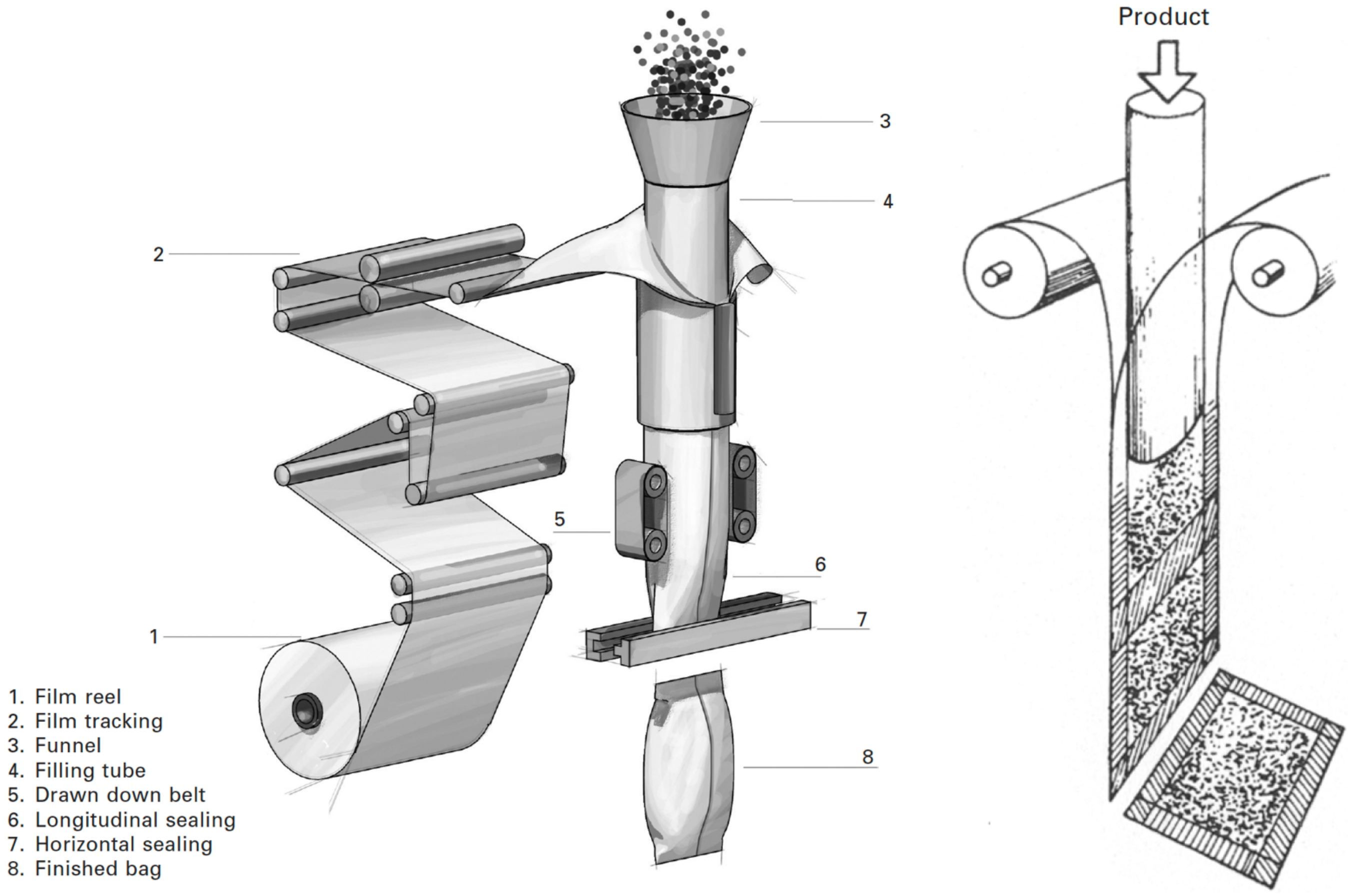


Figure 11. (a) Basic operation of a vertical form, fill and seal machine. (b) Variation of VFFS operation.

1.4.2 Horizontal FFS machine

Or “flow wrappers” are used for fragile products which cannot withstand the drop-down filling chute of a vertical machine. E.g biscuits or chocolate bars. The basic operation principles of HFFS machine involve some sequential steps shown in figure 12. First, the film is fed into a forming box where it is formed into the desired shape, continuously sealed along the sides and partially cut so that it starts to form an individual container. At this point, each product is oriented and fed into a single container from conveyor belt using push bars or “flights”. Finally, it sealed at both ends and then separated into individual packs.

Most flexible films or laminates used on VFFS or HFFS machines are heat sealable, which means heating the surface and applying pressure to fuse them. The strength of the seal is determined bt the temperature, pressure and time of sealing as well as the type of thickness of the two film and the heat-sealable coating. The sealer has a range of different type as:

- Hot-bar or jaw sealers which hold the two films between heated jaws until the seal is formed.
- Impulse sealers clamp the films between cold jaws which are then heated to create seal. It can reduce wrinkling or shrinking of films during sealing.
- The sealing head can be either rotary or band type and is used for high-speed filling operations. It works by passing the film between two heated belts, followed by cooling belts, which clamp the film together until a strong seal is formed.

- Other types of sealers include high-frequency sealers, which use an alternating electric field to induce molecular vibration in the film, generating heat to form the seal. Ultrasonic sealers, on the other hand, apply high-frequency mechanical vibrations to achieve the same effect, heating and sealing the film.
- Cold seal adhesives require only pressure to seal the film wrap, eliminating the need for heat application. This offers several advantages, such as avoiding damage to heat-sensitive products like chocolate or ice cream, enabling easy pack opening by pulling the seal open, and allowing for higher packaging speeds. However, the sealing strength of cold seals is generally not as strong as heat seals.

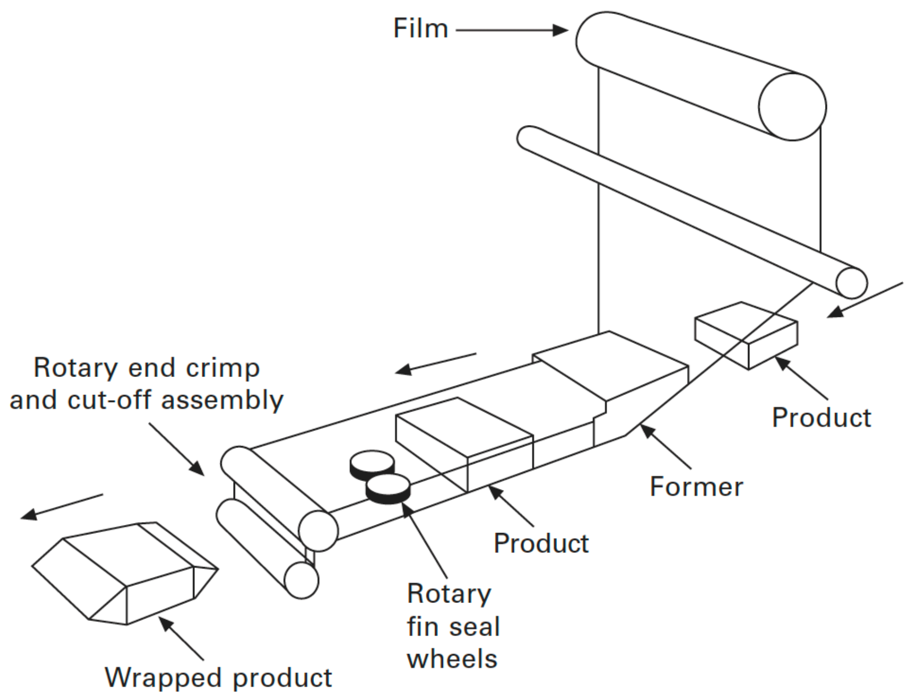
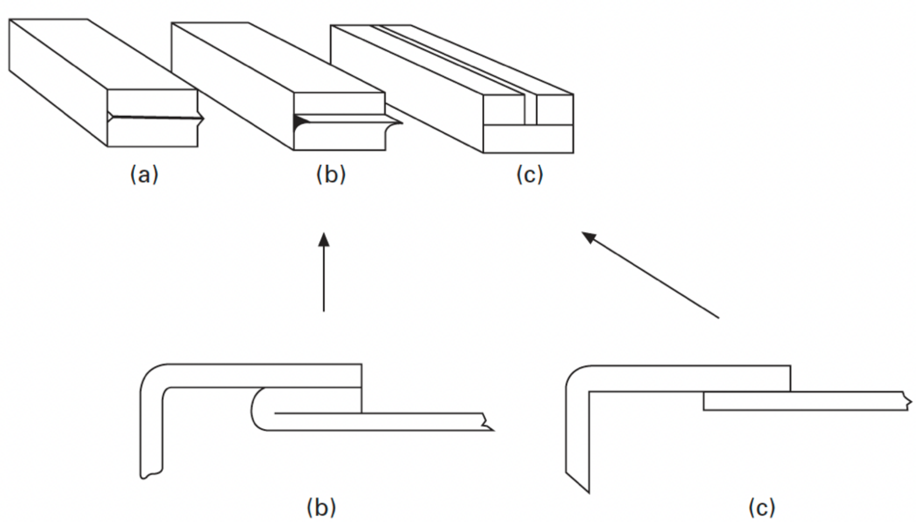


Figure 12. Basic operation of a horizontal form, fill and seal machine.

The sealing types are classified into three common styles, including:

- Bead seals **(a)** is a narrow weld joining the two edges of the film.
- Fin seals **(b)** is created by folding one edge of the film over before it is sealed to the adjacent edge to lie flat. It uses more film than others but is suitable for film that is only sealable on one side but use more film.



- Overlap seals (c) which has the front and back surfaces of the film are lapped one over the other, giving a flat seal.

1.4.3 Sachet forming and sealing machines

The printed film is unwound from the reel and folded in half along its length. The machine then uses sealing and cutting bars, guided by photoelectric sensors that detect registration marks printed on the film, to form open-ended pouches for product filling. During the filling process, two filling heads are used, one for injecting inert gas and the other for dispensing the liquid product. Once filled, the sachets are sealed at the top, cut into individual units, and transferred to a collation station for wrapping and cartoning.

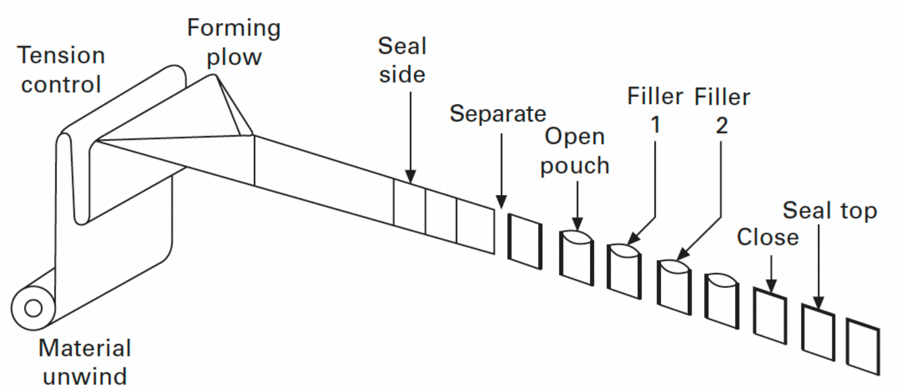


Figure 13. Basic operation of sachet forming and filling.

1.4.4 Thermoforming packaging machines

These machines typically operate on a horizontal bed. A base film is unwound and formed into the required shape through sealing. The finished packs are then cut out, while the waste skeleton or matrix is wound up and removed for disposal. This packaging method is commonly used for products such as razors, toothbrushes, frozen meat, yogurt, etc.

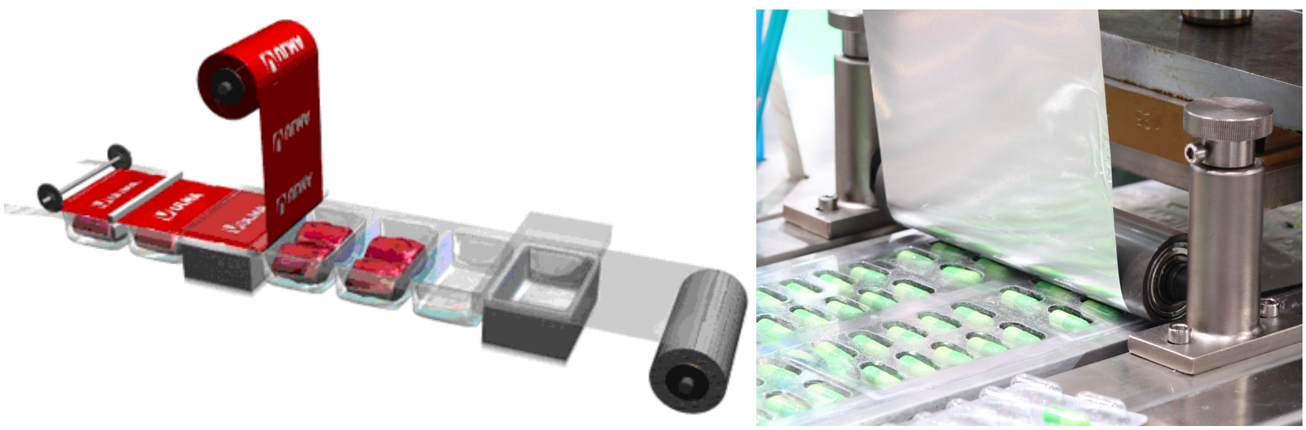


Figure 13. Basic operation of thermoforming packs.

1.4.5 Blister packaging

This type is widely used for items such as tablets, which are contained in indentations or pockets on a plastic strip and sealed with a foil layer. This sealing method is similar to that used in thermoforming packaging machines.

1.5 Labelling

1.5.1 Applying self-adhesive labels.

These label types are pre-cut and supplied on rolls with a silicone-coated backing paper or plastic liner. There are several important features determined by the labeling machine, including:

- The orientation and unwind direction of the front and back label rolls for proper labelling.
- The core diameter of the roll.
- The maximum overall diameter of the roll.

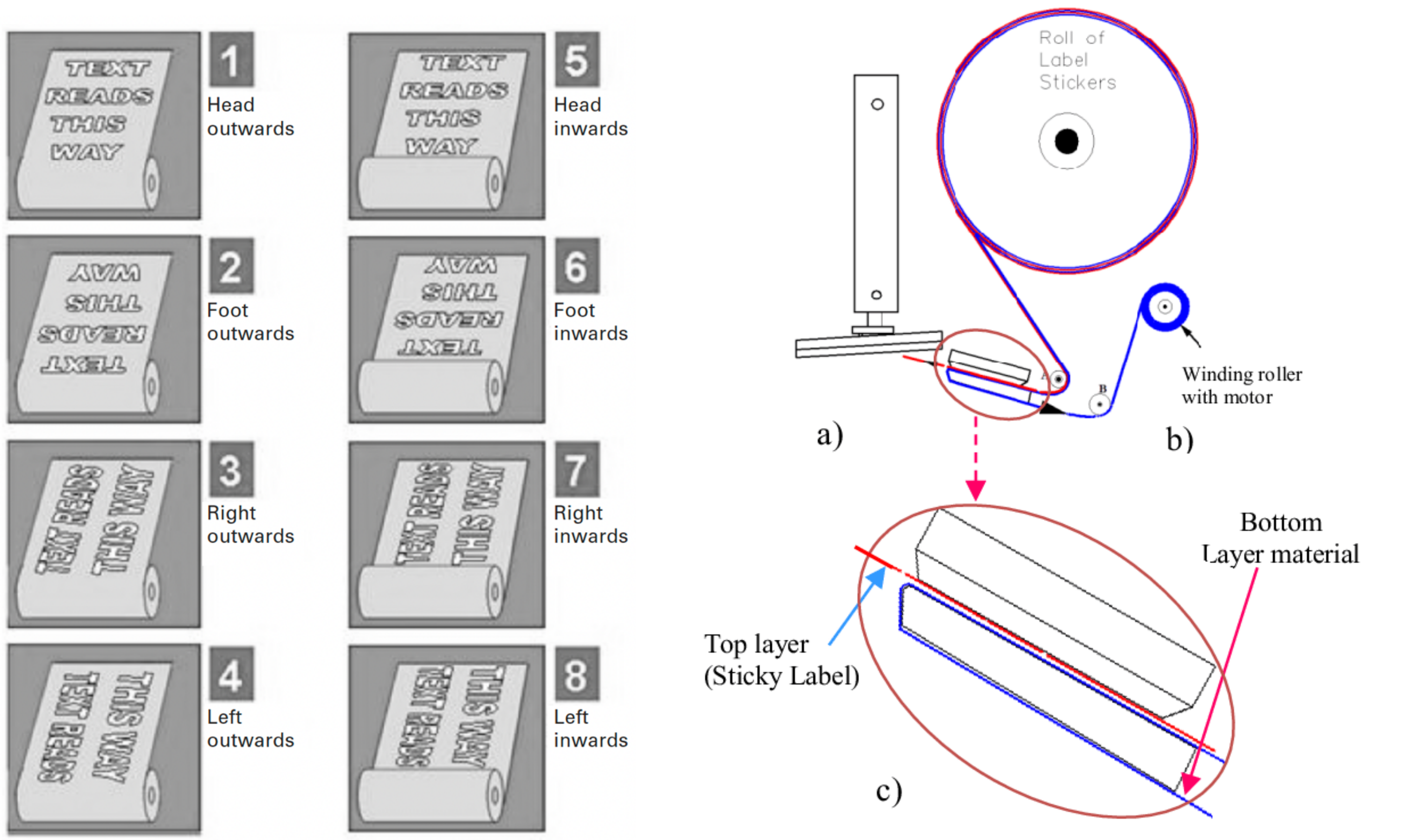


Figure 14. Layout options for self-adhesive labels and the mechanism of peel off backing liner.

A self-adhesive label applicator operates by pulling the backing liner using a rubber roller grip. When a container is detected by a photoelectric sensor, the roller begins to rotate, drawing the backing paper around a tight radius on a metal component known as the dispensing beak. The speed of the label and the speed of the container are synchronized, allowing the label to peel off the backing paper and be applied to the container. A brush is then used to press the label firmly into place.

For cylindrical containers, a wrap-around mechanism is employed. This consists of a belt running at twice the speed of the conveyor track, pressing the container against a soft, rubber-faced stationary plate to ensure full adhesion of the label.

1.5.2 Applying unglued labels

These label types are supplied in bundle packs, with each label easily separated to allow single-label picking from the stack. A precise cutting die is critical to avoid pick-up failures, edge damage, or label jams at the packer-filler.

The correct paper grade and grain direction, typically parallel to the label base, are essential. If not, adhesive moisture may cause curling strong enough to lift the label edge before the adhesive sets.

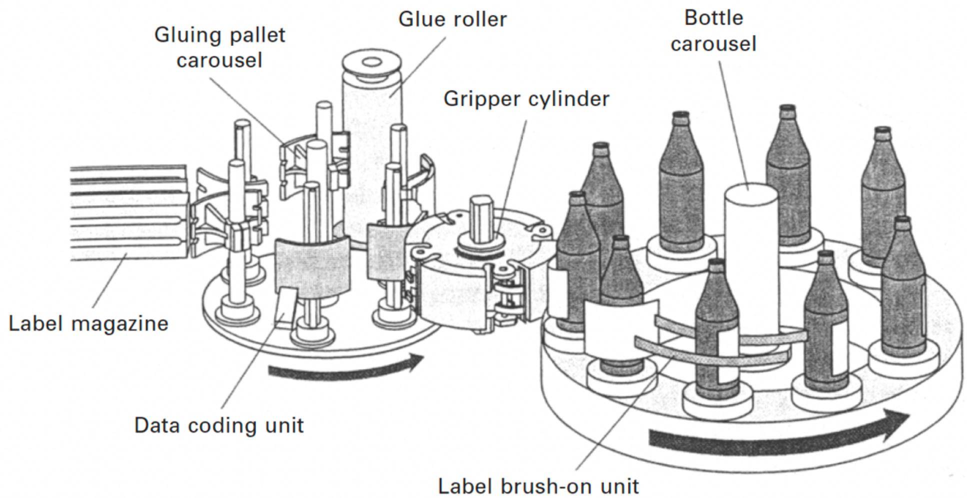


Figure 15. Automatic application of unglued label on bottle labeller.

The adhesive used for unglued labels is usually in the form of liquid polymer or water-based adhesives. The operating principle of automatic labeling with unglued labels consists of several sequential steps. First, the label which uses a rear push bar to press labels forward. The back side of the label contacts a gluing pallet unit on a rotating carousel, which collects glue from the glue roll.

Next, the label is transferred to a gripper cylinder equipped with gripper bars that rotate and apply the label onto the bottle. The label is then secured along the bottle curvature by a brush-on unit.

Data coding can be ink-jetted either before or after labeling. Front, back, and neck labels can be applied simultaneously by a bottle carousel, which not only rotates itself but also rotates each bottle to ensure precise label alignment.

1.5.3 Applying Sleeves

Shrink sleeves are typically made from heat-sensitive thermoplastic films such as PVC or PE. They are supplied either as flattened, welded tubes wound onto cardboard cores, or as film rolls, both printed on the reverse side to prevent scuffing. Key considerations include:

- A register mark printed on the film to signal the machine where to cut each sleeve.
- The correct sleeve length, which must match the container size.
- The material properties and thickness, ensuring appropriate shrinkage at the required temperature.
- Artwork design must account for distortion due to varying shrinkage rates across the container surface.

The application process involves placing the sleeve over the container, or wrapping it around and joining the ends with hot-melt adhesive. The container then passes through a heat source, such as wet steam jets or hot air, causing the sleeve to shrink tightly around the container's shape. In some cases, a **heat tunnel** is used for more consistent shrinkage and a better fit.

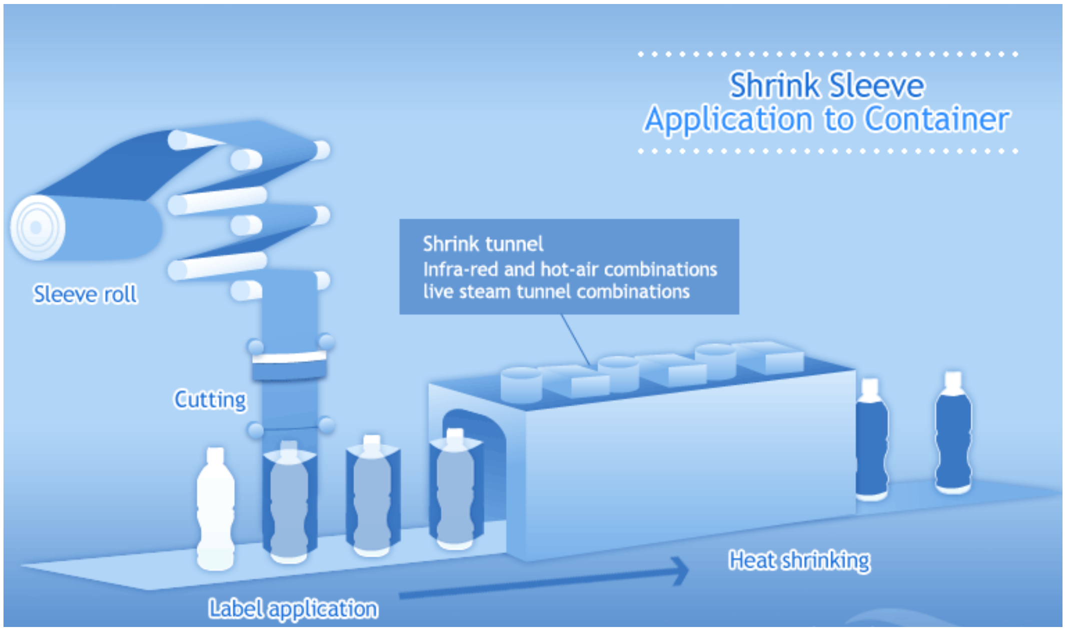


Figure 16. Sleeves application using heat tunnel for label shrinkage.

1.6 Coding systems

Coding is essential to be able to identify when a batch was made and packed, depending on a unique code, date and times information on packaging allow business can track-trace product come from batch if there is any a problem with the safety or quality. Coding can be printed on both primary and secondary packaging. The technical available for batch coding include:

Type	Operating principle	Pros	Cons
Embossing	A letter-press wheel/roller physicallyembosses (indents) the date code into the substrate; no ink is used.	• No consumables ink. • Code doesn't fade • Very low running cost at high volumes.	• Only works on rigid/semi-rigid materials (not flexible film) • Limited character set; tooling change needed to update code • May mark or weaken thin substrates
Hot foil printing	A heated metal type presses pigmented/metallic foil onto the substrate; the molten foil layer bonds to the surface.	• High print sharpness and opacity • Good adhesion on many substrates (paper, films, foils) • Durable, scuff-resistant codes	• Moderate line speed; foil indexing pauses can limit throughput • Foil is a consumable → ongoing cost & waste • Code changes require type change or image block replacement
Thermal transfer	A thermal print-head heats spots on an inked ribbon; melted wax/resin transfers to the packaging surface.	• Very clear, high-resolution text & barcodes • Variable data change is instant (electronic) • Works on labels, films, foils, papers	• Ribbon is a consumable; waste after use • Higher operating cost than embossing/laser • Print-head wear → periodic cleaning or replacement

Inkjet printing	Non-contact droplets of ink are jetted directly onto the substrate (CIJ – continuous ink-jet, or DOD – drop-on-demand).	• Extremely high speed, suitable for fast lines • Any variable data (dates, QR, logos) on-the-fly • Can mark curved or uneven surfaces	• Ink can fade or smear depending on substrate & environment • Regular maintenance / nozzle cleaning required • Solvent fumes & dust/moisture can affect quality
Laser marking	Using laser power to carve directly on surface material by change color or firing outer surface of material	• No ink or ribbon → zero consumables • Permanent, tamper-proof, high-resolution codes • High line speed, minimal maintenance	• Highest capital cost • Substrate must absorb or react to laser; reflective or clear materials may need a coating • Safety enclosure & fume extraction required

1.7 Direct product shrink-wrapping and stretch-wrapping

Flexible films such as LDPE are designed to stretch over and then shrink around an object. The degree of shrinkage is measured in two directions:

- Machine Direction (MD) – along the length of the film
- Transverse Direction (TD) – across the width of the film

Based on the shrink ratios in MD and TD, films are categorized as:

- Preferentially balanced (e.g. MD = 50%, TD = 20%)
- Fully balanced (e.g. MD = 50%, TD = 50%)
- Low shrink (e.g. MD = 10%, TD = 10%)

→ These characteristics are critical when selecting, sizing, and cutting the film to ensure proper fit and closure around the product.

There are two main methods for closing the film around products:

- Shrink-wrapping – the film is loosely applied and then heated to shrink tightly around the item.
- Stretch-wrapping – the film is stretched and wrapped tightly without heat.

1.8 Cartonning

Folding cartons, pre-glued at the side seam, are delivered flat and loaded into a magazine on the cartoning machine. Each carton is picked up using suction cups and erected into shape. One end is closed using hot-melt adhesive, sealing tape, or a tuck-in flap. The product is then inserted either vertically from above, or horizontally using a robotic pusher or manual operation. The remaining end is closed using the same method.

An alternative approach uses flat, unglued cartons stacked in piles. These are erected on the cartoning machine by wrapping them around the product before closing. In this case, products are first arranged in a pre-defined layout, inserted horizontally, then the carton is sealed at the side seam and both ends using hot-melt adhesive.

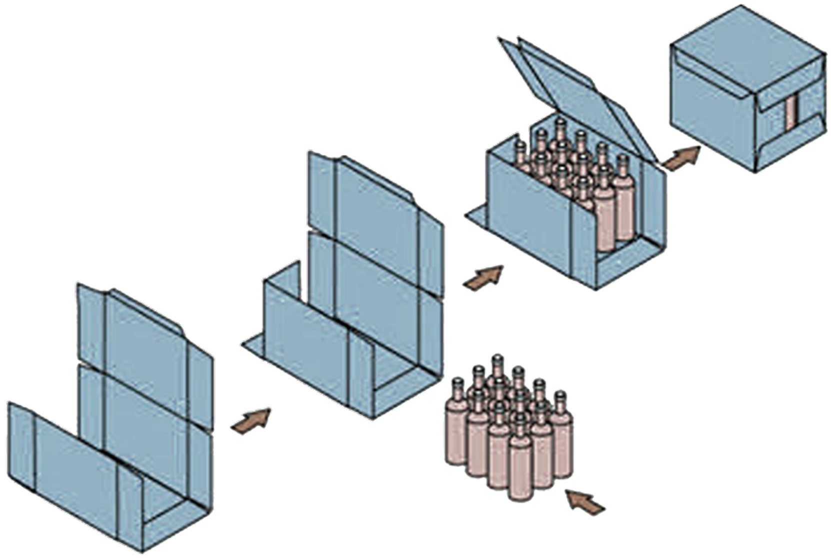


Figure 17. The operating principle of RSC wrapping-around carton machine

Shrink-wrapping can also be used as an alternative to full cartons. Products are pre-arranged in layout and placed in a case or tray, then wrapped with shrink film and passed through a heat tunnel to tightly secure the package.

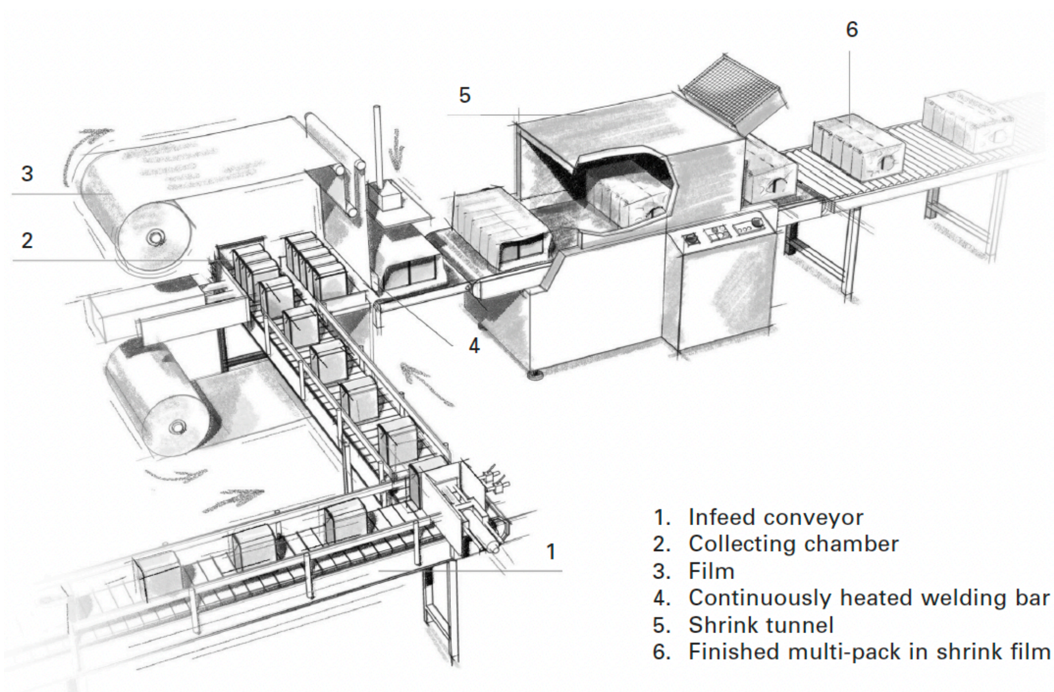


Figure 18. Shrink-wrapping process of collated primary packs

1.9 End-of-line equipment

Palletisation is the process of transporting secondary packs onto pallets. This can be done manually, with mechanical assistance, or fully automatically using robotic handling systems.

Mechanically Assisted Palletisation includes systems such as:

- Roller conveyors: to move products close to the pallet position.
- Vacuum-operated lifts: suction pads lift and place products onto the pallet in the desired arrangement.

Fully-Automated Pick-and-Place Palletisation will include some steps, including:

- The pallet layout is pre-programmed into a computer.
- The computer controls the pick-up mechanism and conveyor actuators.
- Actuators move the packs to correct positions.
- Packs are lifted and placed precisely in the next available spot.
- For uniform-shaped packs, an alternative method includes:
  - Collating packs into a full pallet layer layout.
  - Using a push-bar system to slide the entire layer onto the pallet.
  - Repositioning the system to the correct height for the next layer.

For secondary packs such as cartons with a glossy, low-friction coating, anti-slip glue needs to be applied during palletisation, especially when stacking to a high height, in order to prevent the cartons from slipping or shifting during handling and transport.

Once palletised, loads are usually stabilised using stretch-wrap film, applied either manually or by an automatic wrapping machine. Ultimately, each full pallet should be labelled for identification and tracking purposes, supporting efficient supply chain management.

B – Quality and efficiency aspects of packaging operations.

Sensors include those using light, electromagnetic waves, infrared radiation, microwave or radio frequency waves, gramma rays or ultrasound. These types of sensors may be used to monitor aspects of filling and packing sensitive items such as food and beverage products.

Excepting these types of sensors, video tracking of the components and video inspection of the lot coding process, and barcode reading are also applied.

Parameter	Sensor type	Examples of application
Bulk density *(khối lượng riêng)*	Radiowave detector	Granules, powders
Caffeine	Near light infrared detector	Coffee processing
Colour	Ultraviolet, visible, near infrared light detector	Colour sorting, optical imaging to identify foods or measure dimensions
Conductivity	Capacitance gauge	Cleaning solution strength
Counting food packs	Ultrasound, visible light	Most applications
Density	Mechanical resonance dipstick, gamma-rays	Solid or liquid foods
Dispersed droplets or bubbles	Ultrasound	Foams
Fat, protein, carbohydrate content	Near infrared, microwave detectors	Wide variety of foods
Fill level	Ultrasound, mechanical resonance, capacitance	Most processes

Flowrate (mass or volumetric)	Mechanical or electromagnetic flowmeters, magnetic vortex meter, turbine meter, ultrasound	Most processes
Foreign body detection	X-rays, imaging techniques, electromagnetic induction (for metal objects)	Most processes
Headspace volatiles	Near infrared detector	Canning, MAP
Humidity	Hygrometer, capacitance	Drying, freezing, chill storage
Interface – foam/ liquid	Ultrasound	Foams
Level	Capacitance, nucleonic, mechanical float, vibronic, strain gauge, conductivity switch, static pressure, ultrasound	Automatic filling of tanks and processing vessels
Packaging film thickness	Near infrared detector	Packaging, laminates
Particle size/ Shape	Radiowave detector	Dehydration
pH	Electrometric	Most liquid applications
Powder flow	Acoustic emission monitoring	Dehydration, blending
Pressure or vacuum	Bourdon gauge, strain gauge, diaphragm sensor	Evaporation, extrusion canning
Pump/ liquid ratio	Nuclear magnetic resonance (NMR)	In development
Solute content	Ultrasound, electrical conductivity	Liquid processing, cleaning solutions
Specific micro-organisms	Immunosensors	Pathogens in high-risk foods
Specific sugar alcohols, amines	Biosensors	Spoilage of high-risk foods
Specific toxins	Immunosensors	High-risk foods
Suspended solids	Ultrasound	Wastewater streams
Temperature	Thermocouple, resistance thermometers, near infrared detector (remote sensing and thermal imaging), fibre-optic sensor	Most heat processes and refrigeration
Turbidity	Absorption meter	Fermentations
Valve position	Proximity switch	Most processes
Viscosity	Mechanical resonance dipstick	Dairy products, blending
Water content	Near infrared detector, microwaves (for powders), radiowaves, NMR	Baking, drying, etc.
Water quality	Electrical conductivity	Beverage manufacture
Weight	Strain gauge	Weighing tank contents, check weighing.

1.10 Storage of materials

The storage of packaging materials is important both to ensure they are safe to use (e.g clean and contamination free) and that they are fit for purpose. The normal storage condition for almost packaging is flowing:

- ~ 20-25o, 45-55% relative humidity (RH)
- No double stacking of pallet → much pressure on materials at the bottom, could constitute a health and safety hazard.
- Away from direct sunlight and cool air.

Other examples of packaging materials which may be adversely affected on the packaging line, due to poor storage are:

- Not enough cold temperature for self-adhesive label which may lead to adhesive failure or bleed around the die-cut edges of the label.
- Labelling problems on glass bottle will occur if bottles are brought (e.g. Warehouse) from cold to warm, moist environment to cause water condensation on the glass surface.

→ For maximum performance, all packaging materials, especially those based on cellulose (e.g paper), should be acclimatises to the temperature and humidity of packaging line environment for at least 2hrs, or longer if the environment has high humidity, before use. This process is known as "conditioning".

1.11 Maintenance and training

It includes the correct setting up, operation and adequate maintenance of the packaging line equipment and training programme for line technicians and machine operators is essentials.

In accordance with health and safety regulations and the ISO quality standards (e.g 9001), accurate records must be maintained and reviewed to ensure that both personnel and equipment are capable of performing the processes required to manufacture the product.

1.12 Calculating line efficiency

There are some key terms and their common definition whilst define a packaging line:

- **Station** *describes each machine serving a specific function in the packaging line.*
- **Running speed:** *the time taken for a station to complete its cycle or the number of cycles the station can complete in a given time. (E.g. the number of bottle is filled in a cycle turn)*
- **Design cycle rate:** *the speed of a station running empty.*
- **Design speed:** *the theoretical running speed of a station under perfect operating conditions (slower than the design cycle rate), or defined as container per a minute (cpm)*
- **Input***: The number or volume of product enter into the station at a given time.*
- **Output***: the quantity of product leaves the station at a given time under realistic operating conditions.*
- **Efficiency***: the ratio of output over input.*

It is noticeable that the design cycle rate/ design speed is not the same as output/efficiency. No machine runs continuously at its design speed. In practice, efficiency may be affected by common operating problems such as variations in power supply, variability on supply or quality of product, container or other packaging materials required to complete its operations, blockages, component problems, the need for maintenance and cleaning as well as wear.

To set a required output, it is essential to consider the output of each station in the packaging line, as the overall output can never exceed that of the slowest station. The overall line efficiency is a cumulative result of the performance of each station, as shown in the following example:

Bottle washer		Bottle filler		Bottle labeller
Design speed: 800 cpm	→	Design speed: 1250 cpm	→	Design speed: 1000 cpm
Efficiency: 95%		Efficiency: 98%		Efficiency: 85%

Since the design speed of the bottle washer represents the bottleneck of the line, the overall efficiency is calculated as follows:

800 cpm x 95% (*washer efficiency*) x 98% (*filler efficiency*) x 85% (*labeller efficiency*) = **633 cpm**

However, if each station does not operate at its highest efficiency, it results in a loss of capacity and investment. To optimize line efficiency, one common approach is to use double stations at the bottleneck points, the stations with the lowest design speed, to increase the total input to the subsequent stations.

Alternatively, engineers can design accumulating devices between stations (e.g. longer conveyer belt), allowing temporary storage of containers and regulating the input flow to the next station. This helps balance the line and maintain steady production despite differences in station speeds.

1.13 Changeovers

Many packaging lines are typically designed to accommodate variations in products, such as filling containers of different sizes. However, this flexibility often leads to time-consuming changeovers, increased machine complexity, and the need for recalibration procedures.

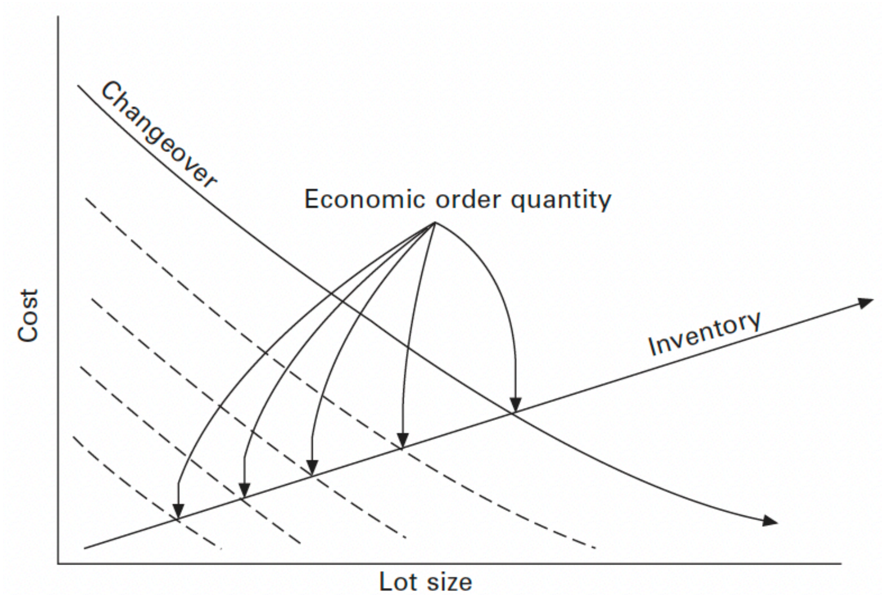
Changeover times can be significantly reduced by analyzing which actions consume the most time in practice and identifying ways to make these actions more efficient. Some effective strategies include:

- **Improving procedures:** *Simplify and standardize each step, using clearly defined and quantifiable settings.*
- **Enhancing documentation:** *Break down the changeover process into a series of simple, easy-to-follow instructions.*
- **Improving staff training:** *Ensure operators are well-trained and confident in executing quick and accurate changeovers.*
- **Managing changeovers offline where possible:** *Prepare components or adjustments while the line is still running.*
- **Minimizing tools and components required:** *Use as few parts and tools as possible to reduce complexity.*
- **Centralizing access:** *Perform changeovers from a single, convenient access point whenever feasible.*

A machine designed for changeover will require the storage of spare parts for each type of container. The changeover process can typically be divided into several key stages:

- **Preparation:** *Ensuring that appropriate procedures, components, and tools are available, along with properly trained staff who are familiar with the equipment and the steps involved.*
- **Changeover:** *Physically replacing components and recalibrating the machine as needed to accommodate the new container type.*
- **Trial Run:** *Conducting test runs, performing final adjustments, and allowing for run-in time.*

While high-volume production of standardized products helps reduce unit costs, it may also lead to increased inventory costs. On the other hand, frequent changeovers to accommodate multiple container types can increase downtime and operational complexity, impacting overall efficiency.



1.14 Other way to increase the efficiency of packaging line

There are several options for increasing production:

- Use a third party such as e.g a contract packer → Adapt to temporary fluctuations in demand or break-down machinery for maintenance.
- Increase the efficiency of the existing equipment such as discussion above.
- Expand production with additional or larger machines (either new or refurbished). → Refurbished machine can reduce the capital cost but the new technology can be limited.
- Purchasing of new packaging machinery → Increase initial investment costs, carefully consider building configurations based around a standard pack format for long-term use, and a standard framework can then be customised in a number of ways:
    - To process a range of sizes of pack
    - To achieve a certain of weight or volume of product
    - To include extra functions such as date coding, leaflet insertion, etc.
    - To be compatible with other packaging machinery in the packaging line.

Before beginning the purchasing process, Engineering should draw up a detailed specification of what is required, possibly by covering these specifications below:

- Product type, characteristics and requirements
- Product processing and hygiene requirements
- Packaging, sealing materials and requirements

- Labelling materials and requirements
- Basic pack shape and dimensions
- Range of pack weights or volumes
- Number, type and speed of changeovers required
- Output required
- Level of compatibility with other machinery in the packaging line.
- Power and installation requirements
- Maintenance, technician and training requirements.
- Legal requirement and potential hazards.

Ultimately, a formal quotation should be release, include:

- The capital investment
- The quality and availability support (e.g. service engineers, materials training for in-house technicians, project management service, etc.)
- The timescale for design, construction installation and commissioning.
- The operation validation requirements.

1.15 Installing new packaging machinery

A Packaging line consist of a series of linked machine with separate functions. Each can come from a different supplier and will have its own requirement.

Installing new machinery or packaging lines requires consideration of the services required to operate machinery, including power sources such as:

- Electricity
- Steam
- Compressed air

It also required allowing for:

- Ventilation
- Means for provision of packaging to the line
- The removal of any wrappings used to supply the packaging.
- The removal of finished product and its secure storage.

Accommodation will also be required for:

- A line technician who equipped with appropriate working clothing, including PPE if any.
- The supporting technical service require stores for equipment and change parts
- Facilities for the cleaning of machines
- The space needed to carry out quality inspection process and store any inspection equipment.
- The warehousing and materials handling facilities.

× Some factors which may contribute towards problems on a packaging line, including:

- The design and specification of the machine
- The setting adjustment of the machines
- The specification of the packaging components
- The conditions of the packaging components
- The adequacy of training given to the line personal
- The standards of quality of output required

1.16 Packaging Life – cycles in the supply chain.

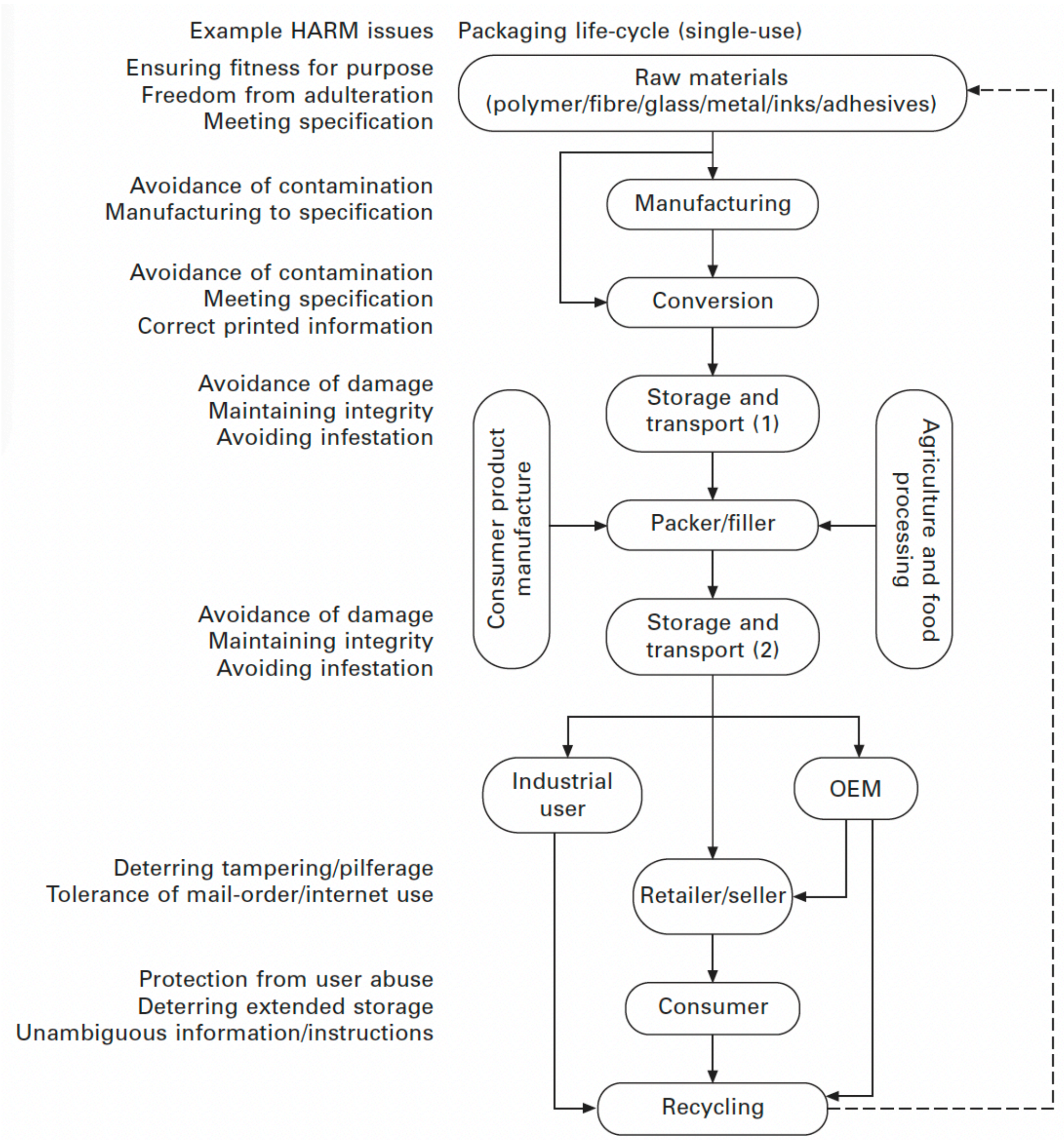


Figure 19. Example Hazard risk management (HARM) issues in the life – cycle of single – use packaging.

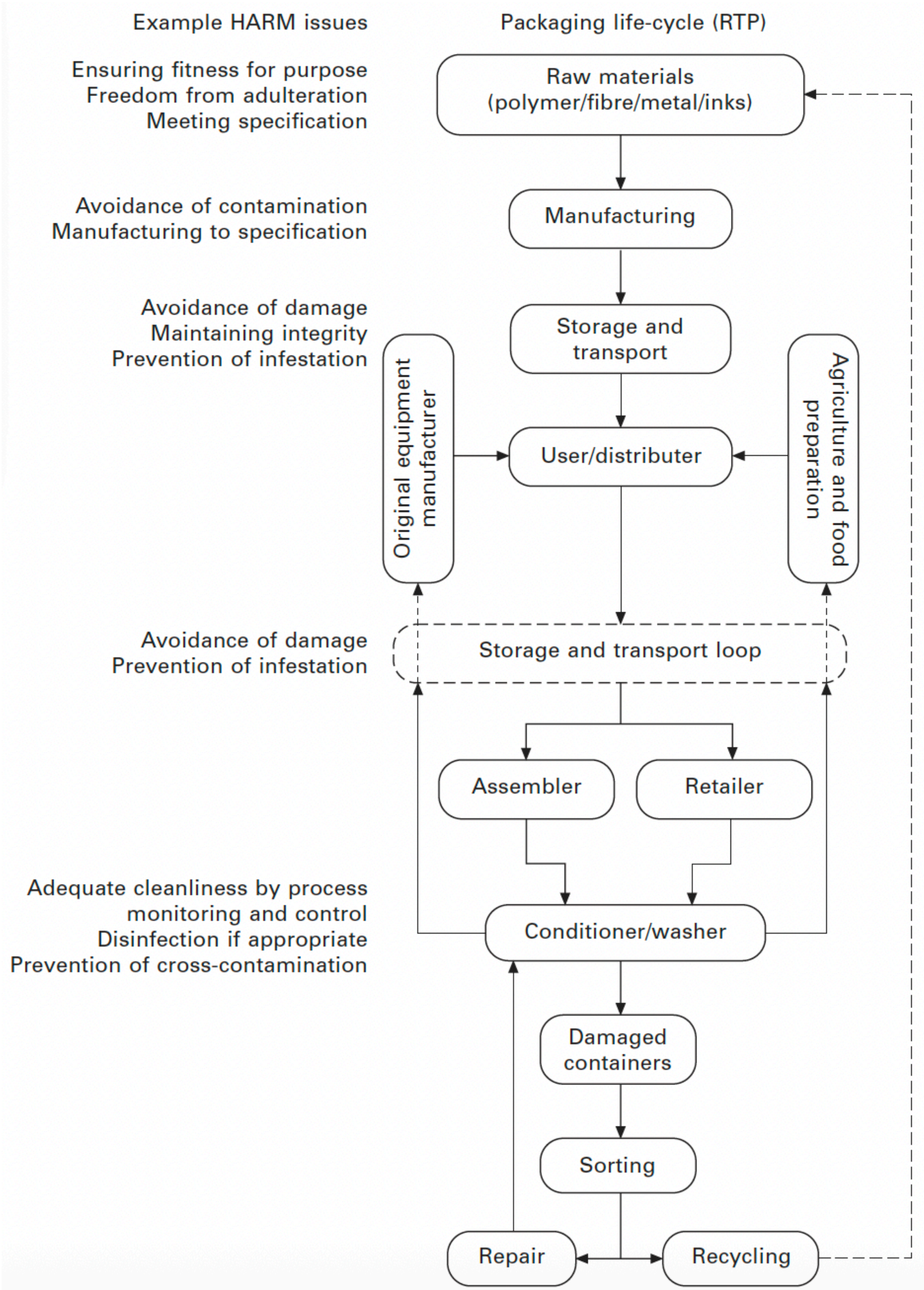


Figure 20. Example HARM issues in the life – cycle of return packaging, e.g bottle.

Table 21.2 Packaging types, example uses, hazards and consequences

Type	Use	Hazards	Example consequence(s)
Flexible polymer	Frozen food	Puncture	Contamination, freezer burn
		Seal failure	As above + product loss
	Mail order outer	Rupture	Damage to or loss of contents
		Abrasion	Weakening, loss of print/decoration
Rigid polymer	Consumer products	Weld or adhesive failure	Product damage or loss, pilferage
		Fracture	As above + fragment release
	Food and drink	As above	Product leakage and/or microbiological compromise or physical contamination
Carton board	Consumer products	Physical deformations	Loss of shelf appeal Package/product tampering
	Food	Adhesive failure	Product loss or contamination
Glass	Bottles and jars	Broken glass fragments	Consumer distress; high likelihood of claim and adverse publicity
		Closure seal failure	Product leakage or microbiological ingress post process
Metal	Cans and tins	Pinhole	Product leakage and/or pressure loss (carbonated drinks)
		Sharp edges	Consumer incident leading to claim

Table 21.3 Prerequisites to HARM

Prerequisite	Example requirements
Premises	Buildings shall be located, constructed and maintained according to appropriate design principles to assure the maintenance of standards that enable product safety and legality to be achieved
Suppliers	The company shall ensure that suppliers have in place effective quality and product safety management systems
Specifications	There shall be written specifications for all raw materials, agreed with suppliers
Equipment	Equipment shall be constructed, installed, calibrated and operated so as to ensure that product will consistently meet specification
Maintenance	Planned preventative maintenance procedures shall be in place
Cleaning	Cleaning of equipment and premises shall be the subject of written procedures, schedules and records
Personal hygiene	Employees and visitors/contractors shall follow written requirements for personal hygiene
Training	Employees shall receive documented training in all relevant aspects of their work
Receiving, storage and dispatch	Raw materials and products shall be stored under clean conditions with documented controls for location and disposition
Traceability and recall	Materials and products shall be recorded in a system which allows rapid and accurate traceability to source and recall from customers
Pest control	An effective pest control programme shall be in place

Table 21.4 Physical contaminants and procedural controls

Potential contaminant	Typical procedure
Glass (e.g. windows, lights, screens, watches)	Broken glass and brittle materials Internal hygiene inspection Personal belongings
Timber (e.g. tables, internal structures, tools, pallets)	Pallet condition Internal hygiene inspection Transport, storage and distribution
Dust and dirt (e.g. machinery, building, lint materials, carried from exterior)	Cleaning Maintenance hygiene Internal hygiene inspection
Paper, card, adhesive tape (e.g. board and tape engineering, documentation)	Maintenance hygiene Internal hygiene inspection
Blades and sharps (e.g. knives, needles)	Control of blades and sharps
Maintenance debris (e.g. wire insulation, machine parts, metal cuttings)	Cleaning Maintenance hygiene Internal hygiene inspection
Items from incoming goods (e.g. metal and plastic items)	Inspection of incoming goods
Personnel (e.g. hair, fibres from clothing, jewellery)	Personnel Personal belongings Training
Pests (e.g. rodents, flying and crawling insects, birds)	Pest control Internal hygiene inspection Inspection of incoming goods

Table 21.5 Chemical contaminants and procedural controls

Potential contaminant	Typical procedure
Cleaning chemicals (e.g. detergents, solvents)	Cleaning
Lubricants (e.g. oil, grease, aerosol sprays)	Cleaning Maintenance hygiene
Odour and taint (e.g. solvents, perfume, disinfectants, preservatives, vehicles)	Cleaning Inspection of incoming goods Personnel Personal belongings Internal hygiene inspection
Non-approved materials (e.g. agents and chemicals not on approved list)	Inspection of incoming goods Supplier assurance Product recall
Water (e.g. from roof leaks, spillages)	Internal hygiene inspections Inspection of incoming goods

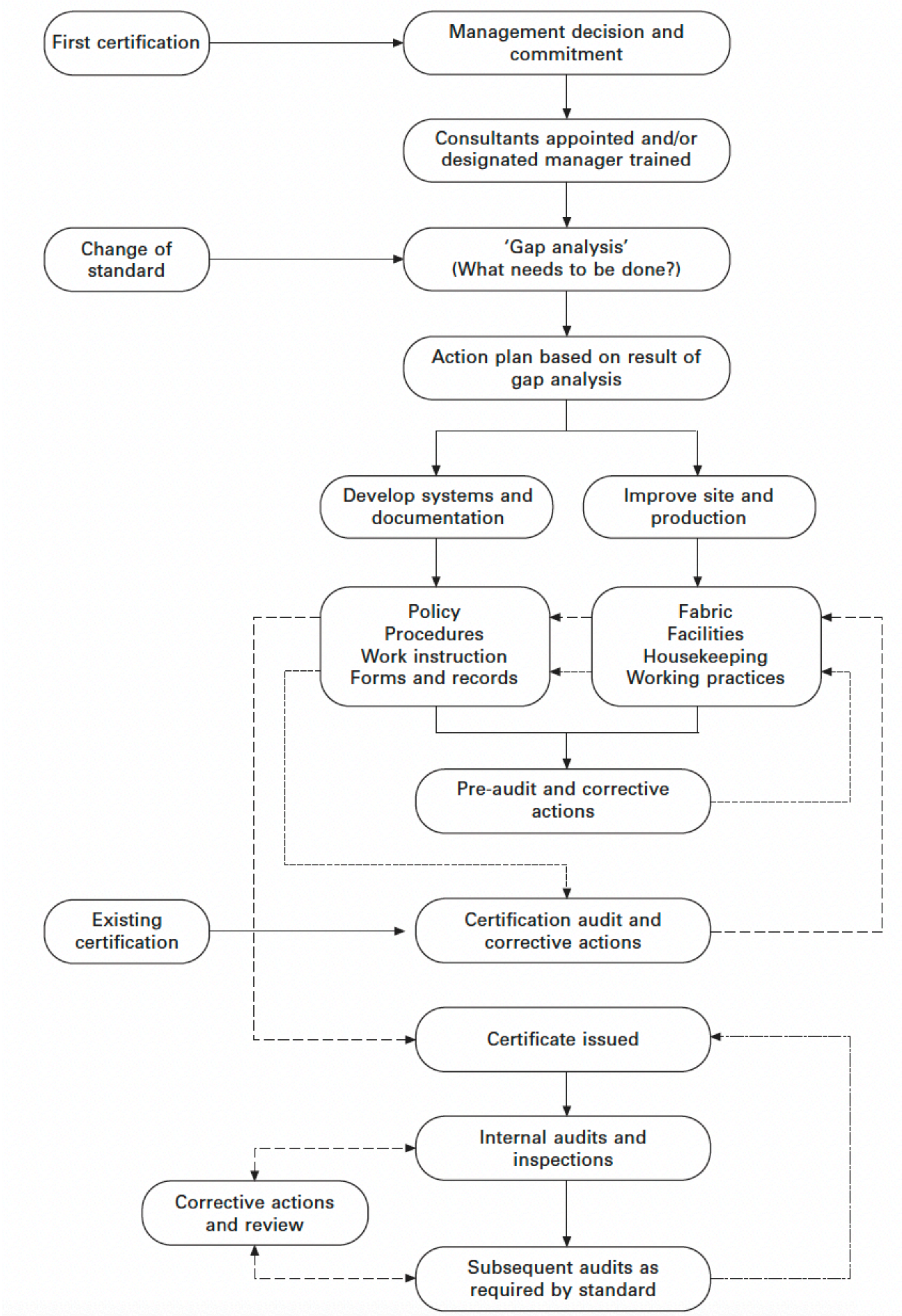
1.17 Industrial technical standards

There are three technical standards relevant to packaging manufacture, storage and distribution that requires a HARM or HACCP system as part of compliance and certification.

Table 21.9 Industry technical standards

Standard	Scope	HARM requirements
BRC/IOP *Global Standard for Packaging and Packaging Materials*, Issue 4, February 2011	Manufacture of packaging and packaging materials for food and 'hygiene sensitive' products (includes other food-contact items)	Mandatory for all categories of packaging/materials
BRC *Global Standard for Storage and Distribution*, Issue 2, September 2010	Pre-packaged and loose food products, packaging materials and consumer products (includes wholesale and contracted services such as cleaning of returnable packaging)	Mandatory with variations for consumer products Some technical guidance is appended
BS EN ISO 22000:2005, 'Food safety management systems – Requirements for any organisation in the food chain'	All organisations, regardless of size, that are involved in any aspect of the food chain	HACCP is a mandatory requirement

EU Regulations (No. 178/2002, No. 852/2004) legally oblige food storage and distribution companies to ensure systems are in place to supply safe and legal products.



Figures 11. Example of certification process

II. Food Biodeterioration and Methods of Preservation.

Factor affecting product quality and shelf life is either the basic of experience of similar products or observations of them, or from a consideration of:

❖ ***The make-up of the product (intrinsic factors):***

- water activity (Aw) (available water)
- pH/ total acidity; type of acid
- natural microflora and surviving microbiological counts in final product
- availability of oxygen
- redox potential (Eh)
- natural biochemistry/chemistry of the product
- added preservatives, e.g. salt, spices, antioxidants
- product formulation
- packaging interactions, e.g. tin pickup, migration

❖ ***The environment that it will encounter during its life (extrinsic factor):***

- time–temperature profile during processing
- temperature control during storage and distribution
- relative humidity (RH) during storage and distribution
- exposure to light (UV and IR) during storage and distribution
- composition of gas atmosphere within packaging
- consumer handling

❖ ***And the "shelf-life limiting processes" that this combination of intrinsic and extrinsic factors is likely to result in.***

A – Agents of food biodeterioration.

Biodeteriotation is defined as the breakdown of food by agents of microbiological origin, either directly or indirectly from products of their metabolism.

Contamination of packaged foods can arise form microbiological, chemical and physical sources. Microbiological sources can be present in foods prior to packing and on surfaces of packaging materials. Chemical sources usually arise form enzymes released by microorganisms in order to catalyse the breakdown of food into smaller compounds that can move through cellular walls of microorganisms. Physical contamination can on occasion introduce microorganism, but does not in itself play a role in biodeterioration.

2.1 Enzymes.

Enzymes are complex globular proteins found in living organisms, which is naturally present in foods and act as catalyst for speeding up the rate of biochemical reactions. The action of enzymes can be used to beneficial effect by the food industry to produce food products such as cheese, extraction of juice from tomatoes and apple, beverage clarification.

Enzymes associated with the deterioration of fruits and vegetables include peroxidase, lipoxygenase, chlorophyllase and catalase. They involve the action of these agents causing food spoilage. For example, during the ripening of fruit, the activity of some enzymes (e.g. pectinesterase and polygalacturanase) increase and causes a softening of the tissues as the cell wall materials are broken down.

Another problem with fruits and vegetables is enzymic browning, which results from damage or cutting of the surface and exposure to the air. This is due to the action of the polyphenol oxidase in which the present of air oxidises phenolic constituents to indole quinone polymers.

Enzymes are also produced during microbial spoilage of foods and many of these are involved in the breakdown of texture. A number of the microorganism that secrete enzymes are moulds, however, there are bacterial species (e.g. bacillus subtilis, bacillus amyloliquefaciens and Bacillus licheniformis) that produce amylase, which is a heat stable enzyme. Amylase degrades starches, particularly naturally occurring starches, with the effect that the viscosity of the food is reduced as the carbohydrates are broken down into their constituent sugars.

To inactivate enzymes presented in food and on packaging surfaces using heat or chemical means in order to preserve and extend the shelf life of foods. Blanching is intended to inactivate the majority of the enzymes without imposing excessive thermal damage to the food, it uses relatively mild temperatures (90–100◦C) and short heating times (1–10 minutes).

Yeasts and moulds are of particular concern for packaged foods because it is common for many species to produce spores as part of their reproductive cycle.

2.2 Microorganisms.

The term microorganism includes all small organisms that are not visible to the naked eye. They are found everywhere in the atmosphere, water, soil, plants and animals. Microorganisms can play a very important role in breaking down organic material, but it is very action degrading organic material that food preservation techniques aim to counteract.

Temperature is the most commonly used method to kill or control the numbers of microorganism present within foods and on packaging surfaces. Five categories of temperature sensitivity are useful in defining the preferred temperature ranges for microorganism growths:

(i) *Psychrophilic (Cold loving):* Organisms can reproduce in chilled storage condition, sometimes as low as 4^{o}C, although 12 – 20^{o}C is the preferred growth range. → Easiest to destroy by heat.

(ii) *Psychrotrophic (cold tolerant):* the optimum growth temperature is 20 – 25^{o}C but slow growth can be achieved down to 8 – 10^{o}C.

(iii) *Mesophilic (medium range):* The optimum growth temperature is 30 – 40^{o}C*. These are of greatest concern with packaged foods because many spore-forming organisms such as yeast and mould species.*

(iv) *Thermophilic (heat loving):* The organisms have an optimum growth temperature of 45 – 60^{o}C.

(v) *Thermoduric (heat enduring):* The organisms can survive above 70oC, but cannot reproduce at these temperatures.

a. <u>Bacteria</u>

Bacteria are single-celled microorganisms that normally multiply by binary fission, in which each cell divides into two cells following a period of growth. This is a level in which organoleptic spoilage of the food is apparent due to production of off-flavours, unpleasant odours and slime, or it can result in toxin release. There are four stages in bacterial growth that are important for food manufacture:

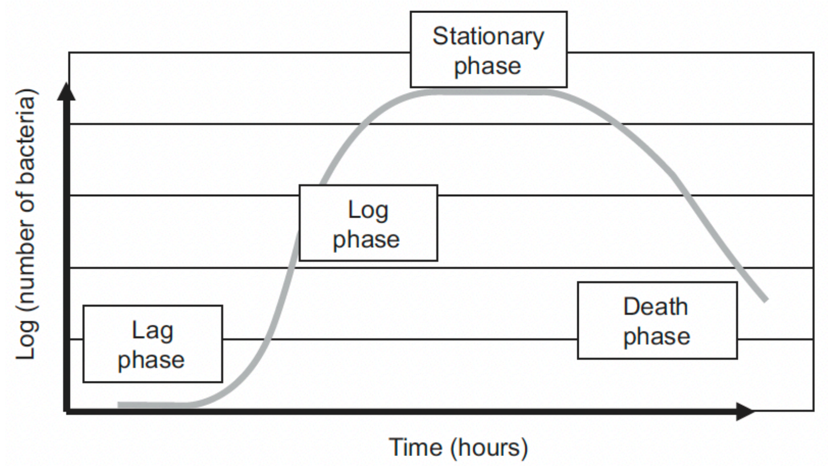


Figure 12. Typical growth curve for a bacterium.

(i) ***Lag Phase***: the bacteria are adapting to their environment, which can be several hours long.
(ii) ***Log Phase***: The reproduction occurs logarithmically for the first few hours. Conditions for growth are ideal during this period.
(iii) ***Stationary Phase:*** the bacteria's reproduction rate is cancelled by the death rate caused by the production of undesirable by-products that poison the environment surrounding the bacterium.
(iv) ***Mortality or Decline Phase:*** The exhausted nutrient levels and/or the level of toxin metabolites in the environment prevents reproduction, with the results that the bacteria gradually die off.

The simplest method of identifying bacteria is according to their appearance, which approximates to spherical (cocci), rod and spiral shape. For example, diplococci in pairs, staphylococci in clusters, and streptococci in chains. They are small and can vary in size between 0.4 and 1.5 mm, whereas the larger bacilli are between 2 and 10 mm in length.

The most widely used method of identifying bacteria was introduced by the Danish bacteriologist Gram and is called Gram dyeing. Bacteria are divided into two main groups according to their Gram stain characteristics: *Red Gram negative and blue Gram positive.*

Bacteria require water, proteins, carbohydrates and fats for growth. In addition, small quantities of vitamins and trace elements are needed to support and catalyse metabolism. Nutrients must be available in soluble form to aid transport through the cytoplasmic cell membrane.

- Water is essential for bacterial growth because it facilitates transport of small molecules through the outer cytoplasmic membrane of the bacterial cell via osmotic pressure gradients. The available water or water activity (a_w) is the amount of free water in a food and excludes moisture that is bound and unavailable to the microorganisms. *Most bacteria cannot grow below an aw of 0.91–0.94.*
- All bacteria need a supply of oxygen to oxidise their food to produce energy and for growth. Some bacteria obtain their oxygen directly from the air (aerobic bacteria), whereas others obtain oxygen from their food (anaerobic bacteria).
- Light is not an essential requirement for bacterial growth because the cells do not synthesise food using light energy. Instead, light has a destructive effect on bacteria because of the ultra violet (UV) component that causes chemical changes in the cell proteins.

Several bacteria (e.g. pathogenic bacteria) need consideration when designing a packaging and processing line. They produce toxins such as *Clostridium botulinum, Listeria monocytogenes,* *Salmonella spp., Escherichia coli, Staphylococcus aureus, Bacillus cereus and Camplylobacter.* These can be controlled by the use of sterilising solutions and/or heat, with the aim of achieving the condition of commercial sterility for the packaged food.

The most lethal of these is *C. botulinum*, which produces a toxin that attacks the nervous system. Their spores only germinate in anaerobic conditions where there is available moisture as well as nutrients and the pH over 4.5. This critical pH limit is an important determinant as to whether heat-preserved foods receive a pasteurisation or sterilisation treatment. *Sterilisation processes (typically 115–135^{o}C) using heat have greater cooking effects on product quality than the relatively mild heat treatment of pasteurisation processes (typically 75–105^{o}C).*

Growth of most strains of *C. botulinum* are inhibited at refrigeration temperatures, however, there are psychrotrophic strains that can grow at low temperatures and are increasingly giving rise for concern in foods. *Listeria* is another bacterium that can survive and grow at low temperatures, but fortunately is killed by mild temperatures. The process used to achieve a 6-log reduction in *Listeria* is 70◦C for 2 minutes, a process also applicable to Salmonella and E. coli.

Not all bacteria are pathogenic or the cause of food spoilage. Bacteria have been used to beneficial effect in fermentation and preservation processes to extend the shelf life of certain foods. One example that has been exploited for many years is the deliberate introduction of lactic acid bacteria for the fermentation of milk to produce yoghurts.

b. <u>Fungi</u>

Fungi are a group of microorganisms that are found in nature on plants, animals and human. They have a variety of species and vary in their structure and method of reproduction. Fungi may be single-celled round or oval organisms such as yeasts or threadlike multi-celled structures such as moulds. The mould threads may form a network, visible to the naked eye as seen, for example, on foods such as bread and cheese.

One of the most important medicines for treating bacterial infections, penicillin, is derived from the *Penicillium* mould. Another fungis, *Oospora lactis*, which displays characteristics of both yeasts and moulds, occurs on the surfaces of cultured milk as a white velvety coating. This is used for the ripening of soft cheeses.

Fungi have a greater resistance to osmotic pressure than bacteria and can grow in many commercial jams and marmalades. Optimum growth pH for fungi tends to be in the pH range 4.5–5.0 and can present on packaging surfaces and in food, we will be killed by the heat process applied to the packaged food, typically of the order 85◦C for 5 minutes (CAMPDEN BRI, 1992), but once the jar is opened, airborne contamination from mould ascospores can occur.

Yeast cells are facultatively anaerobic and moulds almost exclusively aerobic. In the absence of oxygen, yeast cells break down sugar to alcohol and water, while in the presence of oxygen, sugar is broken down to carbon dioxide and water. The former reaction is used in the fermentation of alcoholic drinks, but lie between anaerobic and aerobic can produce alcohol, carbon dioxide and water.

Yeasts are single-cell organisms of spherical, elliptical or cylindrical shapes. The size of them varies considerably; for example, Brewer's yeast, Saccharomyces cerevisiae, has a diameter of the order of 2–8 μm and a length of 3–15 μm. Some yeast cells of other species may be as large as 100 μm. Yeast cells normally reproduce by budding, which is an asexual process.

Moulds belong to a large category of multi-celled threadlike fungi. They attach themselves to their food, or substrate, using long threads called hyphae. Like yeasts, moulds can also multiply by sexual or asexual reproduction, and this results in the production of a large numbers of ascospores.

Conditions for the growth of yeasts and moulds are similar to those for bacteria. They are more tolerant to high acidity levels, with yeasts able to grow between pH 3.0 and 7.5, and moulds between pH 2.0 and 8.5. They can survive at lower available water levels, which is why bread is at risk to mould spoilage but not to bacteria. Typically, most yeast or mould cells are killed after only 5–10 minutes heating at 60^{o}C.

2.3 Non-enzymic biodeterioration.

An important reaction in foods that takes place between sugar constituents and amine-type compounds results in progressive browning and the development of off-flavours. The only successful way of inhibiting these reactions is by using sulphurous acid and sulphites. The levels of sulphur dioxide allowed in foods products are strictly controlled by legislation and also by the amount that can be tolerated before taste become unacceptable.

B – Food preservation methods.

The purpose of food preservation is aimed at extending the shelf life of food. In most cases, it is the growth of either spoilage or disease-causing microorganisms that limits the length of time that a food can be kept.

2.4 High temperatures

Microorganisms and enzymes are both susceptible to heat, and appropriate heating regimes can be used to reduce, inhibit or destroy their activity. The degree of heat processing required will depend on the nature of the food, its associated enzymes, the numbers and types of microorganisms, the conditions under which the processed food is stored and other preservation hurdles used.

Manufacture of a heat-preserved packaged food can be broken down into two basic processes:

(i) The food is heated to reduce the microorganism numbers to an acceptably small probability of surviving pathogenic and spoilage organisms that can grow under the intended storage conditions.

(ii) The food is sealed within a hermetic package to prevent re-infection.

Preservation methods, such as traditional canning, seal the food in its package before the application of heat to the packaged food product, whereas other operations such as aseptic, cook-chill and cook-heat the food prior to dispensing into its pack.

a. <u>Blanching.</u>

It is a process designed to inactive enzymes such as using high temperatures (e.g. thermal processing) or low temperatures (e.g. freezing), and is usually applied immediately prior to other thermal preservation processes.

Blanching is not designed to reduce the microbial population on the surface of foods but it will nevertheless reduce the numbers of organisms of lower heat resistance, such as yeasts, moulds and certain bacteria (e.g. *Listeria, Salmonella, E. coli*).

b. Batch thermal processing.

Canning is a term still widely used in the food industry to describe a range of thermal processes where the food is heated within its sealed package to achieve a commercially sterile food; in other words, no microbial growth can occur in the food under ambient storage conditions until the package is opened. Once the package is opened, the effects of canning will be lost and the food is regarded as perishable, and its shelf life will depend on the nature of the food itself.

Various packaging materials are encompassed within the phrase canning, which includes not only metal, but glass, plastic (pots, trays, bottles and pouches) and aluminium cans.

The most heat-resistant pathogen that might survive the canning process of low-acid canned foods is ***C. botulinum***. This bacterium can form heat-resistant spores under adverse conditions, which will germinate in the absence of oxygen and produce a highly potent toxin that causes a lethal condition known as botulism, which can cause death within seven days. As the canning operation generates anaerobic conditions (i.e. no oxygen), all canning processes target this organism.

In practical terms, the thermal process must *reduce the probability of a single spore surviving in a can of low-acid product* to one in one million million (i.e. 1 in 10^{12}). ***This is called a 'botulinum cook', and the standard process is 3 minutes equivalent at 121.1◦C, referred to as*** $\boldsymbol{F_0 3}$.

However, if the ambient conditions are to allow the growth of thermophilic organisms, a more severe process must be applied, of the order of 15–20 minutes at 121.1◦C. $\mathbf{F_0 3}$ is regarded as the absolute minimum, however, most canned foods receive a much higher heat treatment ($F_0 6$ or more) to deal with uncertainties over variations in product and/or thermal process control.

In the traditional canning process, the filled aluminium or metal cans are hermetically sealed with can ends via a double seaming operation, and the cans are heated in a batch steam retort and ensure that the heat penetrates to the slowest heating point in the can. After heating, the food needs to be cooled (e.g. cooling water) so that container handling must be avoided in re-contamination from water acting as a conduit for microorganisms.

Thermal processing can be achieved using either batch retorts or continuous cooker-coolers. This process operates with a variety of heating media, which includes condensing steam, mixtures of steam and air, water immersion, or water droplets that can be sprayed or rained onto the packs.

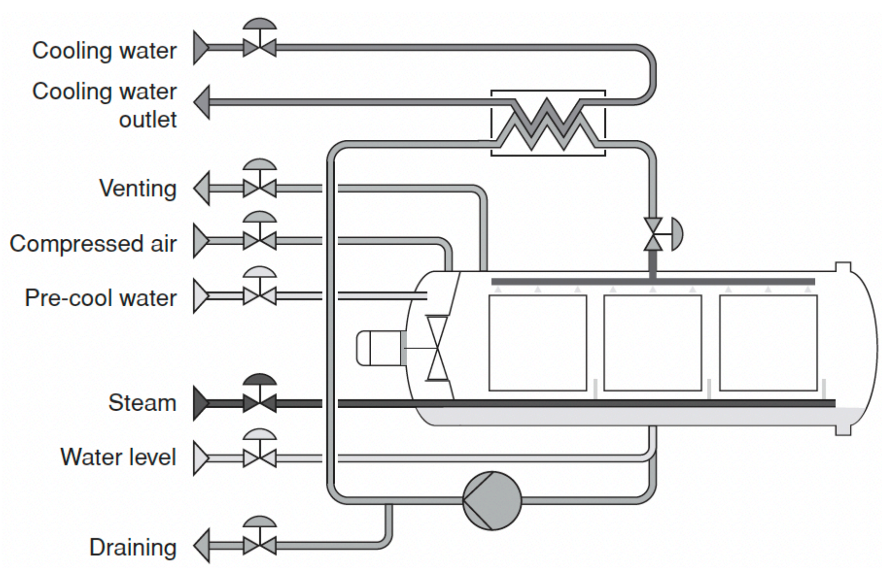


Figure 13. Example of a batch retort operating on the steam and air principle.

Overpressure profile is one of the critical control points (CCPs) in a thermal process, and must be established by viewing or measuring pack deflection inside the retort. The retort pressure is adjusted in order to maintain the original pack shape.

A defect in the sealing area, for example a seam wrinkle, need only be a few microns in size to allow a bacterium to pass through. Since most packs, particularly metal cans, are closed to form an internal vacuum, which helps to eliminate oxidative deterioration of the food and reduce internal corrosion, the external pressure acts as a driving force, moving water from outside of the sealing area to inside the pack. The first few minutes of cooling, the substantial pressure swings in the retort that arise as steam condenses to leave a vacuum.

The baskets (or crates) within a batch retort can be rotated in order to induce mixing inside the food by end-over-end agitation of the packs. This increases the rate of heat transfer to the thermal centre (i.e. slowest heating point) of the pack. Typical rotation speeds can vary between 2 and 30 rpm, depending on the strength of the pack and the convective nature of the food inside the pack. A recent addition to batch retorts is the ***Shaka retort***, which uses high frequency longitudinal agitation instead of end-over-end rotation.

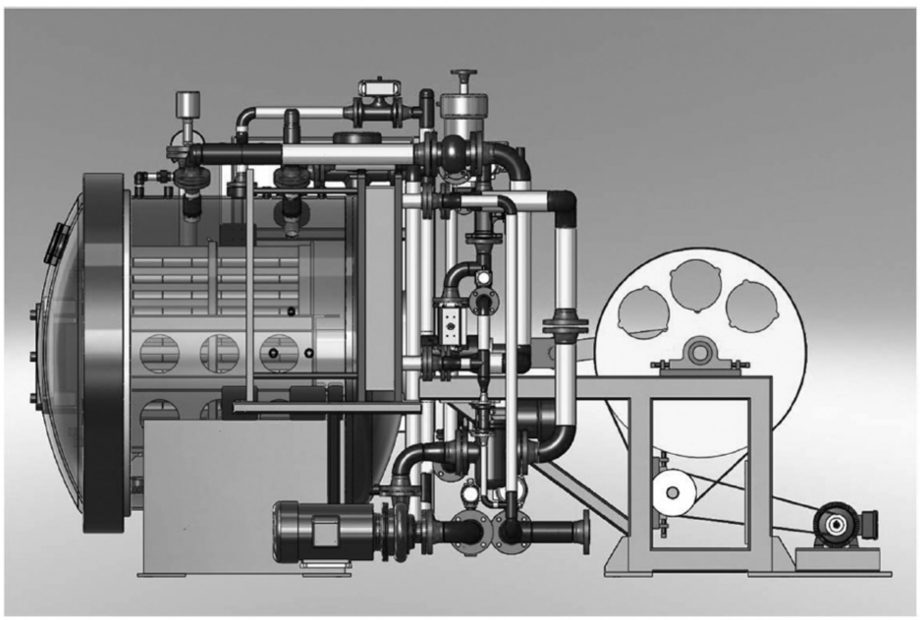


Figure 14. Shaka retort using longitudinal agitation.

Continuous cooker-coolers come in two types; reel and spiral, and hydrostatic. Both use the ability of the metal can to roll along a pathway. The process includes pre-heat at 80–90°C, sterilisation at 120–130°C, pre-cool at 80–90°C and final cooling to 40°C. The only rotation is a half-turn as the cans move between the chambers. Hydrostats are used for high viscosity foods where rotational forces cannot be utilised, *for example solid pet foods and meat products.*

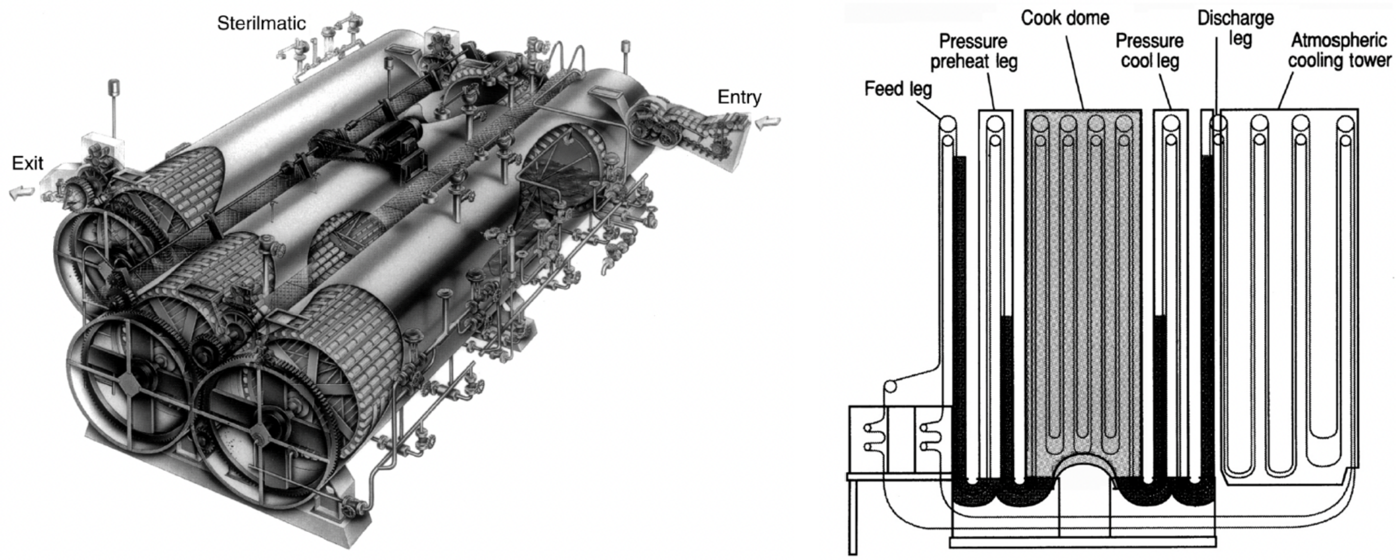


Figure 14. (Left) Reel and spiral cooker-cooler and (right) Hydrostatic cooker-cooler for processing cylindrical food cans.

Metal cans are the traditional packaging material for thermally processed foods, offering high production speeds, pack size flexibility, and high compression strength to withstand physical abuse during processing and distribution. Other media including glass bottles/jars, plastic cans/bowls/pots/trays and flexible pouches are also filled and processed in a similar way. These are increasing in popularity because they offer a lot of benefit such as the possibility of microwave re-heating, product visibility and consumer handling characteristics

c. <u>Continuous thermal processing (aseptic and hot fill)</u>

The term UHT (ultra-high temperature or ultra-heat treatment) has been used to describe food preservation by in-line continuous thermal processing. In the aseptic filling process, UHT treatment is followed by filling into sterilised packages within a sterile environment. *Examples of an aseptic package is the form, fill and seal (FFS) process in which the packaging material is supplied on a reel and is formed into the package as part of the filling operation.*

The food or beverage is sterilised or pasteurised in a continuous process in which it travels

through a heat exchanger before being filled cold into the package, suitable to liquid foods such as soups, fruit juices, milk and other liquid dairy products. Aseptic packaging is available in the formats of metal cans, plastic pots, plastic bottles, flexible packaging and foil laminated paperboard cartons.

Suitable heat exchangers for heating and cooling the foods are plate packs for thin liquids, tubular heat exchangers for medium viscosity foods and scraped surface heat exchangers for high viscosity foods that may contain particulates.

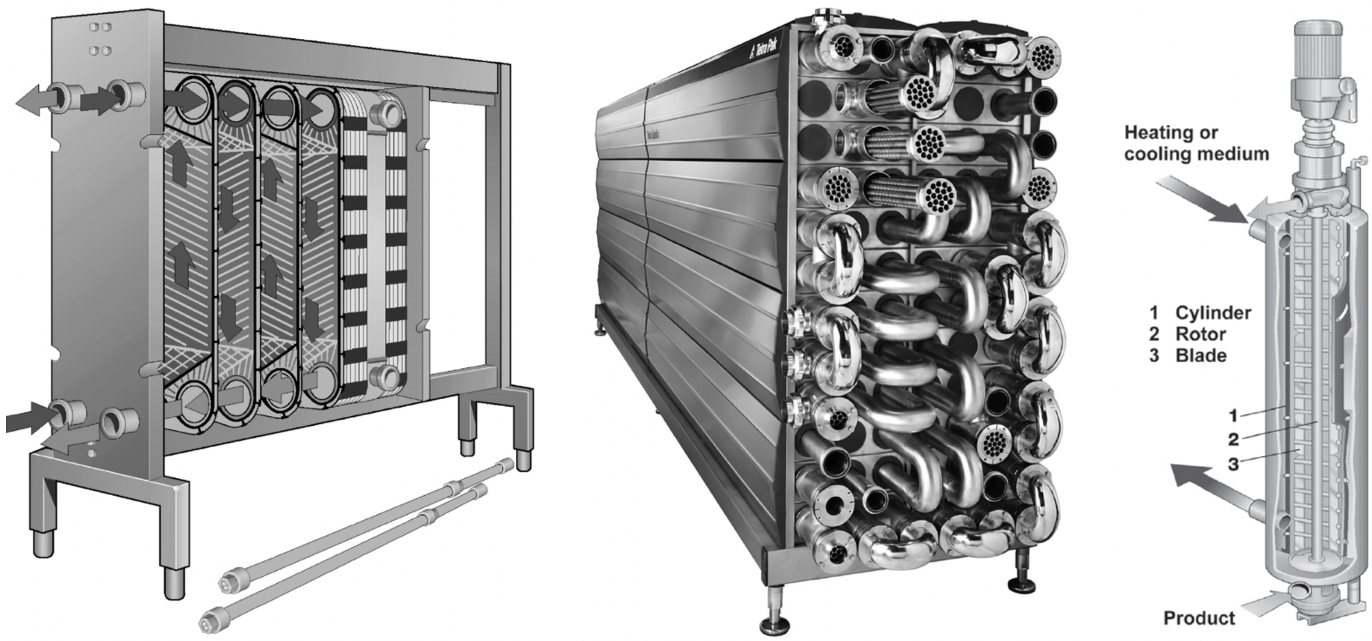


Figure 15. (left) Plate heat exchanger and (centre) Tubular heat exchanger and (right) Scraped surface heat exchanger

Sterilisation values are calculated from the holding tube outlet temperature and the residence time taken from the measured flow rate. Control of these parameters must be to very high levels of accuracy because of the high temperatures (140^{o}C) and short times (a few seconds) (HTST) used. One potential advantage of UHT processing is that of enhanced food quality, as the problem of overcooking can be reduced. This benefit is aim to sterilised milk and cream that would end up too brown (caramelised) with associated off flavours if it was processed in pack. In the case of fruit juice and fruit drinks, it is increased vitamin C retention which is a heat sensitive substance.

Aseptic filling is widely used for heat-processed foods due to its ability to run at high line speeds. Packaging, such as Tetra Brik Aseptic (TBA) cartons, is sterilised inside a controlled environment using hydrogen peroxide and heat, while liquids are pasteurised before filling. In the TBA system, sterilised carton material is formed into a continuous tube, filled with pasteurised liquid, and sealed through the liquid itself, ensuring strong seals, minimal packaging use, and typically no headspace (though this can be added, e.g., with nitrogen in chocolate milk). However, TBA is limited to liquids without particulates, since these can interfere with sealing. For products with particulates, alternatives like the SIG Combibloc system are used, which fills pre-formed cartons instead of continuous reels.

An alternative to aseptic filling is to fill the food hot and cool the filled package by immersing in water or under raining water. This is used for acid foods and some chilled soups and sauces.

d. <u>Pasteurisation</u>

Pasteurisation is a moderate heat treatment (generally below 105 °C) designed to achieve commercial sterility with the support of other preservation factors. The required heat process varies with food type, microbial load, and enzyme stability; sometimes extended pasteurisation is needed to inactivate heat-resistant enzymes.

First introduced in the UK in the 1930s (63°C for 30 min) - Tunnel Pasteurisation, modern milk pasteurisation uses 72°C for 15 seconds via heat exchangers, with products clean-filled into bottles or cartons and preserved by chilled storage.

Pasteurisation is widely applied to foods like fruit products, pickled vegetables, jams, and chilled ready meals, either in sealed containers or continuous systems similar to aseptic filling. Unlike sterilised foods, pasteurised foods are not sterile and rely on chilled storage or intrinsic factors such as salt, sugar, or acidity for stability. Shelf life is shorter than sterilised ambient-stable foods, which last 18–24 months.

2.5 Low temperatures.

a. <u>Freezing</u>

Freezing of food does not make it become sterile but this process can reduce the levels of some susceptible microorganisms. However, once the frozen food is defrosted, the viable microorganisms present will grow and multiply. At commercial freezing temperature (-18 to -24°C), all microbial activity is suspended and the the length of time for which the food can be kept is dependent on other factors.

At freezing temperatures, enzymic activity may continue, albeit at a reduced rate. *For example, the sugar in peas is rapidly converted to starch once the pods are picked, and if not addressed, will result in a very un-sweet product so that blanched before freezing to ensure that enzymes are inactivated.*

The rate of freezing is important to the quality of the food. Rapid freezing in blast freezers is to prevent the formation of large ice crystals that will tend to adversely affect the texture of the food by disrupting cell integrity in fruits and vegetables or degrading the muscle proteins of meat, fish and poultry. Additionally, Repeated freeze-thaw cycles damage the food structure around the edges and promote chemical and physical breakdown. *For example, Repeated thawing-freezing of ice cream can cause the product structure to become less smooth and more crystalline, harder.*

Packaging for frozen foods uses a variety of materials and formats, including paper, plastic and metal. Migration of gases such as oxygen through the packaging material has less effect on the food because the chemical reactions do not occur at significant rates.

b. <u>Chilling and cooling</u>

Chilling lowers food temperature to 0–5°C, slowing but not stopping microbial and chemical spoilage. Unlike frozen foods, chilled foods have limited shelf life because microbes can still grow—sometimes without visible signs, posing safety risks. Therefore, products like chilled dairy must carry a “use by” date.

Pathogenic microorganism	Minimum growth temperature (°C)
Bacillus cereus	4.0
Clostridium botulinum (psychrotrophic)	3.3
Escherichia coli O157 (and other VTEC)	7.0
Listeria monocytogenes	−0.4
Salmonella species	4.0
Staphylococcus aureus	6.7
Vibrio parahaemolyticus	5.0
Yersinia enterocolitica	−1.0

Table 1. Minimum growth temperatures for selected pathogens.

Chilled prepared foods are usually pasteurised (e.g., 70°C for 2 min) to kill pathogens and extend shelf life up to 10 days, with more severe heat treatments allowing longer storage. Chilling also slows microbial growth and biochemical changes in fruits and vegetables, though some (like bananas below 12°C) suffer chill injury. Packaging for chilled foods is simpler than for frozen or canned products since shelf life is short; packs only need to be clean, not sterile. More advanced methods, such as modified atmosphere packaging or in-pack pasteurisation, may be used to further extend shelf life.

2.6 Drying and water activity control

Microorganisms need water to grow, so lowering water activity **(a_w)** is central to preservation. Most bacteria, yeasts, and moulds stop growing below a_w 0.91, 0.85, and 0.81 respectively, while *dried foods reach $a_w \approx 0.3$*, preventing microbial and enzymic spoilage.

Drying method	Food products	Packaging format
Spray dryer	Powdered milk, coffee granules	Plastic bottles, glass jars, tinplate cans, multiwall paper sacks
Freeze dryer	Granulated coffee	Glass jars
Perforated plate	Fruit, e.g. raisins, sultanas	Plastic film, laminated board
Fluidised bed	Peas	Cartonboard
Drum dryer	Breakfast cereals, flaked products	Plastic laminated Cartonboard, cartonboard with plastic inner bag.
Sun	Tomatoes, meat	Glass jar, packed in oil to prevent contact with moisture

Table 2. Commercial drying methods with examples of food products.

Dried products like herbs, cereals, and rice can last months to years if dry, though shelf life is often limited by moisture ingress, which softens textures (e.g., breakfast cereals). Drying methods such as spray drying or sun drying achieve low a_w. Rapid drying reduces chances of spore formation while slower drying may allow spores. Sugar further preserves by binding water, giving traditional jams long room-temperature stability, whereas low-sugar versions lose this benefit and need refrigeration.

Effective packaging with strong moisture barriers (laminates, pouches, glass jars) protects stability. In jams, packaging must also withstand heat filling and allow reclosure.

2.7 Chemical preservation.

Chemical preservatives are widely used to inhibit microbial growth and chemical reactions in foods, though their use in the UK/EU is strictly limited by type and level. The most common preservatives are ***sorbic and benzoic acids, sulphur dioxide, and nitrate/nitrite salts*** (restricted to certain meat, cheese, or fish products). They are usually mixed into foods before packaging (*e.g., benzoates in soft drinks to inhibit yeasts and moulds after opening*). In meat products, nitrites or nisin allow milder heat processing while maintaining safety.

Antioxidants are also used to prevent deterioration such as fat rancidity or browning of cut produce.

a. Curing

It is a traditional preservation method that ***uses salt, nitrate, and nitrite*** to inhibit microbial growth by chemically or physically binding water, making it unavailable to microorganisms. Salt also adds flavor, while nitrite contributes preservation and characteristic color. Common cured foods include bacon, ham, gammon, fish, and some cheeses.

Cured products are typically shrink-wrapped or vacuum-packed and stored chilled, extending shelf life by reducing oxidation and microbial growth.

b. Pickling

Pickling preserves foods in **acid or vinegar**, lowering pH below 4.5 to stop growth of most harmful bacteria like *C. botulinum*. Yeasts and moulds require even lower pH (1.5–2.3) to be inhibited. Common pickled foods in the UK include beetroot, gherkins, cucumbers, onions, cabbage, walnuts, and eggs.

Some pickled foods are simply immersed in vinegar, while others require additional processing, such as blanching and pasteurisation, to ensure safety and quality (e.g., shredded beetroot).

Typical packaging includes glass jars with twist-off lids and lacquered tinplate cans. Strong seals are essential to prevent leakage and corrosion caused by acidic brines. **Hurdle technology**, combining low pH with mild heat, ensures microbial safety while producing high-quality products.

c. Smoking

It is a traditional preservation method that ***combines partial drying with chemical preservation***. Polyphenols in smoke act as antimicrobials and antioxidants while adding characteristic flavour. For example, smoked salmon, where brining, smoking, and chilling together form a “hurdle” system to limit microbial growth.

Modern practices often use **liquid smoke**, which allows faster production, better flavor control, and reduced poly-aromatic hydrocarbons. Unlike traditional smoking, liquid smoke does not dry the food, which may alter the microbial population and spoilage pattern.

Packaging is typically air-excluding, transparent shrink-wrapped film, maintaining flavor and extending chilled shelf life.

2.8 Fermentation

This is a major preservation method, contributing up to 30% of caloric intake for some diets. It works by encouraging the growth of *beneficial microorganisms*, which inhibit spoilage and pathogenic organisms and stabilize chemical composition.

Three main types of industrial fermentation are:

(i) **Bacterial fermentation of carbohydrates** (e.g., yoghurt), producing lactic acid and lowering pH to 4.0–4.3, which prevents pathogen growth.
Milk is pasteurised first to reduce natural microbes before adding cultures.

(ii) **Bacterial fermentation to acetic acid** (e.g., vinegar production).

(iii) **Yeast fermentation of carbohydrates to ethanol (e.g., beer, wine, spirits).**

In yoghurt, cold-filling into heat-sealed plastic pots is common. Low pH and short chilled shelf life reduce the need for aseptic conditions, though long-shelf-life yoghurts may use aseptic form-fill-seal systems.

2.9 Modifying the atmosphere.

Modified Atmosphere Packaging **(MAP)** extends the shelf life of fresh foods (meat, fish, cut fruit, bakery, and dried products) *by replacing air with gases* that inhibit microbial growth and slow deterioration. *For example, grated cheddar cheese may be packed in 30% CO_2 and 70% N_2.*

Food product	**Gas mixture**
Raw red meat	70% O_2; 30% CO_2
Raw offal	80% O_2; 20% CO_2
Raw, white fish and other seafood	30% O_2; 40% CO_2; 30% N_2
Raw poultry and game	30% CO_2; 70% N_2
Cooked, cured and processed meat products	30% CO_2; 70% N_2
Cooked, cured and processed fish and seafood products	30% CO_2; 70% N_2
Cooked, cured and processed poultry products	30% CO_2; 70% N_2
Ready meals and other cook- chill products	30% CO_2; 70% N_2
Fresh pasta products	50% CO_2; 50% N_2
Bakery products	50% CO_2; 50% N_2
Dairy products	100% CO_2
Dried foods	100% N_2
Liquid foods and drinks	100% N_2

Table 2. Typical gas mixtures use in MAP of retail products.

In the most high-water foods, CO_2 dissolves in surface moisture to form weak carbonic acid, preventing growth of aerobic spoilage microbes, while O_2 absence slows oxidation. MAP is usually combined with refrigeration and transparent films for retail display.

Active packaging can further control gases or moisture, while *vacuum packaging* removes all gas to retard oxidative changes. However, anaerobic pathogens like *C. botulinum* require specific pasteurisation (*psychrotrophic botulinum process*) for safety.

Sous-vide uses vacuum packaging with mild heat and chilled storage to produce high-quality meals with long shelf life (up to 42 days at <3°C). Process parameters have evolved from 70°C for 40 minutes to 90°C for 10 minutes. Clean packaging is essential for extended shelf life.

2.10 Other techniques and developments

To enhance flavour and nutritional quality, food manufacturers are exploring alternatives to traditional thermal processing. Key novel techniques include:

(i) High Pressure Processing (HPP): Foods are subjected to 500–600 MPa to kill microorganisms, though spores and enzymes may survive. Often combined with chilled storage or high acidity and used for meats, fish, sauces, juices, and smoothies, typically in transparent plastic packaging.

(ii) Ohmic Heating: Electrical current heats the food directly, enabling shorter heating times and better *retention of nutrition and flavor. Suitable for high-acid foods with particulates, e*.g., fruit preparations. Cooling is still done conventionally.

(iii) Irradiation: Effective at killing pathogens and extending shelf life of fresh produce. Limited in the UK due to public perception; licensed mainly for dried herbs, spices, and packaging decontamination. Not suitable for high-fat foods due to off-flavors.

(iv) Membrane Processing: Uses selective membranes to separate microorganisms and solids. Enables cold pasteurisation of beverages like juice, milk, or beer. Packaging must be sterilised.

(v) Microwave Processing: Thermal effects destroy microbes; rapid heating can improve quality, particularly in heat-sensitive foods. Used for chilled, ready-to-eat meals and re-heatable packages.

(vi) Pulsed Light: High-intensity visible light decontaminates surfaces such as bottle caps. Applications are still under development.

Reference materials.

[1] *Packaging technology – Fundamentals, materials and processes. 2nd edition*. Edited by Anne Emblem and Henry Emblem (2012), Woodhead Publishing.

[2] *Food and Beverage Packaging Technology 2nd edition.* Edited by Richard Coles & Mark Kirwan (2011), Blackwell Publishing.